Use and optimization of public transport vehicles

Aspects of bimodal systems in urban areas

International Management Project

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Executive summary

This project aims to describe the various aspects of bimodal public transport vehicles, primarily for operation in intermediate urban areas. These highly innovative vehicles need special system conditions to perform well and add value to urban public transport. It is shown how different barriers are still obstructing innovation in this industry. Moreover the importance of the environment for possible shifts into new vehicle solutions is described and related to specific situations.

It is the hope of the author that this work is presented in a way which will interest readers with different backgrounds, and that the various chapters can nurture the on-going discussion about efficient and sustainable public transportation systems in general, and specially to give some inputs to matters regarding optimal transport technology solutions for smaller cities and connected areas with scattered populations.

I specially thank Mr Francis Kühn at INRETS in Paris for his comprehensive support during my research, as well as Mr Fritz Schöbinger at the University of Karlsruhe for our discussions related to important aspects of the project.

Grenoble, August 2004
The author

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1. Introduction

1.1 The topic as a result of the situation of today

Among many topics concerning urban public transportation of today are the concerns related to the employment and creation of the most suitable, efficient and economically feasible service lines and total solutions. In Europe but also in several other parts of the world are special demands valid in areas with a population between 50 000 and 400 000 inhabitants, often characterized by one centre and scattered settlements/suburbs around. In those areas are more heavy investments for the establishment of conventional “big city” solutions (subways etc) neither feasible nor efficient. Conventional bus systems are on the other hand often not fulfilling the demands of efficiency and capacity for the whole area as such.

Seen in the light of the increasing urbanisation and the general needs of more efficient and sustainable public transportation systems, this project aims to give a general overview of subjects related to flexible urban transport solutions as well as a more specific description of guided/bimodal vehicle systems. Furthermore aspects regarding innovation and operation of the mentioned systems are discussed and put into a general context. Finally, constraints and knowledge about guided vehicle systems in terms of operation are treated. Through comparisons and evaluations of various systems, certain attributes and features will be established in order to identify methods for evaluation of optimal systems operation.

1.2 Matters of demand

One of the important drivers behind the search for enhancement, flexibility and a wished increased efficiency in parts of the public transportation segment is the various need of different urban areas with respect of their population density. Large concentration leads to high passenger volumes and conversely, suburbs can have a dense population, but as mentioned initially, normally a scattered pattern of population is the reality in such areas. We can divide the situation of demand into two categories:

High passenger volumes

We are speaking about bigger cities, with populations of around 500.000 and upwards. In such areas both resources and population will normally be sufficient to establish certain high capacity corridors. Economically resources are often sufficient to handle the great passenger volumes. The knowledge of the features, possibilities and constraints of relevant transportation systems for use in this segment is quite comprehensive. Solutions like subways or trains are operated quite successfully. As an example, who could imagine London without an underground transportation system?

Scattered and lower passenger volumes

It may be harder to define certain exact limits of population that fit this spectre. Roughly estimated it is about smaller cities or centres with about 50 000 inhabitants and upwards. Depending on which part of

the world we are studying, it becomes clear that the local features and (current) infrastructures are showing a tremendous variation. In smaller societies, however, the "borders" between urban and rural areas are not always distinct. We detect intermediate areas, which are areas with more scattered population but still not can be characterised as rural areas. Intermediate areas are demanding in respects of linking and connecting them to "core" areas (centres with a dense population) in an efficient and flexible way, to offer the inhabitants an efficient and convenient transportation solution. In most cases this has to happen under the dictate of limited communal/governmental economical funds, and it is obvious that scarce resources is another driver for the search of new solutions in the field of intermediate demand.
Furthermore are the issues of integration related to frequency improvement, reduced transfers and emerging forms of sustainable mobility considerations that must be included in the aspects of demand.

1.3 Methodology

The second chapter of this work is mainly written in a descriptive context whereas the other parts represent an effort to compile and systemize parameters, also by studying related transit systems, in order to see if it is possible to come up with some decision parameters for optimising and selecting bimodal public transport vehicle systems in compliance with the given local demography and infrastructure as well as financial resources. Furthermore are some considerations about innovation implemented in order to focus on the special elements of concern that characterize the development of this special type of new technology.

To begin with, however, the approach is made on a vehicle level. The view is then expanded throughout the work and in chapter 5 is focus put on whole system considerations. This is mainly made to clearly show that the issues cannot be considered isolated but rather as a comprehensive set of elements with connections that must be optimized.

Sources have been literature and Internet search, as well as interviews and visits to exhibitions, vehicle manufacturers and operators. The approach is tried kept as simple and transparent as possible. A bibliography and glossary are found at the very end of the text, which probably will serve as support by the explanation of abbreviations.

The choice of the more closely studied vehicle types is done on the basis of the current situation in western Europe today including some other parts of the world, and is not meant to discriminate other initiatives or innovations in the same segment. The selected vehicles represent furthermore a sound mix of proven and new technologies, which hopefully supply the considerations made with relevance for the future.

2. Urban public transport vehicles and their fields of application

2.1 Bus/trolleybus and tramways

As the focus will be kept on issues regarding comparisons of conventional and bimodal public transport vehicles, the choice of the vehicles studied is done on the basis of today's implemented "state of the art". The variety of solutions in the segment is already quite comprehensive and this work does not claim to view the complete picture of all types of innovation or studies. Innovation in the sector of public transportation could be claimed to be a quite slowly developing issue, perhaps mostly because of the vast investment and the high demand of success, as well as safety aspects. These topics are discussed more thoroughly in chapter 4. However, the constraints and characteristics of innovation, as well as historical and demographical aspects, are useful to keep in mind. Some parts of this chapter are following KÜHN and SOULAS (2001) as also build upon input from author's talks with vehicle manufacturer representatives.

Bus / Trolley bus

The subject is likely to be well known among the majority of readers. Buses are the most common urban public transport vehicle all over the world and outperform through several aspects of flexibility. In many countries buses are the first choice in more rural areas as well, often because of demographical and topographical reasons. Buses, self-propelled (until now dominantly by Diesel engines), trackless and automotive vehicles, adapt themselves well to the changes in the infrastructure and master easily streets with mixed traffic. Of course may bus systems also be negatively influenced by the lack of separate tracks, insufficient traffic light priority, etc.., that means that buses must have system support in terms of certain accommodations in order to serve efficiently. Also capacity issues can be raised when these kind of transportation systems are discussed. Innovations, like new types of propulsion and customized constructional changes as "low floor", have been important to maintain the bus as a modern public transport vehicle.

A trolley bus takes electricity from the catenary (=overhead wires or contact line) through the poles (=construction on the top of the bus) to feed its engine with electricity, and has advantage in its non-emission performance. It replaced the tramway because of lower infrastructure costs (no rails). The solution found many users worldwide until the end of the fifties. Especially in Russia and China as well as different places in Europe, this system is still in use. However trolley buses as such suffer limitations regarding flexibility and some higher costs related to the infrastructure. The contact lines must be kept and maintenance executed, furthermore each vehicle is normally around 50% more expensive than a conventional bus, this most likely because of small series.

Still, - buses in general are not demanding regarding specific infrastructure costs, as they do not need special lines, services or engineering resources in order to operate properly. This is an obvious generic cost advantage, which planners and politicians for decades have kept as an important argument for the employment of buses. We now also observe infrastructures in many places that are developed for this kind of public transport vehicles. Among the most frequent infrastructure features in this sense are bus terminals and separate Right of Way (RoW), which is nothing more than certain road lanes dedicated for buses.

Tramways

A great variety of urban rail bound systems exist worldwide. Many people would perhaps claim the tram to be the dominant vehicle in the segment of urban rail bound public transport. The tram (= streetcar) is a vehicle with single or multiple cars that runs on rails. It normally collects its energy (electricity) for propulsion from an overhead contact line with a pantograph. Since the end of the 19th century we find a variety of concepts that have developed locally to serve the certain purposes and topographies of different areas. Tramways (may also be called **L**ight **R**ail **T**ransit or LRT) are normally used “in the town” but we also find examples of uses to suburbs, and the notion “tram-train” is then used. One good example is the tramway of Sacramento, California, USA, where tramlines are prolonged out of the city to the suburbs. Finally are subways (another vehicle to be sorted in the group of Light Rail Vehicles, LRV) in service in several big cities worldwide. Subways are joining the features of tram systems with the more speedy and powerful characteristics of train solutions. Their tunnel lines are ensuring an exclusive RoW, which is fundamental for their efficiency.

Tramways however, are often struggling a battle regarding the issue RoW. In some areas, in a dense traffic situation, tramways are having a separate RoW, but in many areas are underperforming because of frequent involvements in traffic jams. Another issue connected to trams are concerns regarding noise emissions.

2.2 Rubber-tyred rail or trace guided vehicles

In order to lower total cost of infrastructure investment and operating costs for transportation systems, technology innovations have brought new types of flexible vehicles on the market. Through mergers and shifts in business and manufacturer constellations it is difficult to follow each product from “its very beginning”. Furthermore it is also probably too early to speak about a dominant design in the segment. It is meaningful to speak about this group as an intermediate urban transport vehicle system. With features of both tram and bus it reaches a wide range of possible employments (like the use in urban areas with scattered population) and includes many different new types of technologies. The notion “system” is in this context meant to illustrate that each vehicle has a surrounding technology throughout the line, (or built in), in order to operate according to the particular local demands. Some of the vehicles in this category, depending on the type, are also able to operate autonomously. That means an ability to leave the track mode (guidance e.g. by monorail along a line with a separate RoW) and also be independently led by an operator (driver). These vehicle types can then be considered as bimodal. This notion will also be used further on to describe the generic kind of double mode guidance functionality, not necessarily with regard to the underlying specific technology in each case.

However, J. Larmanjat made the earliest invention of monorail guidance as far back as 1867, shown at the world exposition in Paris the same year. Tramway lines following this principle were manufactured for the use in the suburb of Paris (Le Raincy / Montfermeil) in 1868, as well as a familiar system in

Portugal, under operation between 1873 and 1877. Their limited time of operation could be explained by problems related to stability of the solutions.

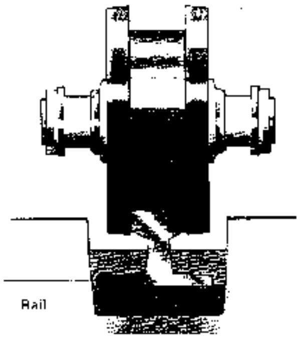
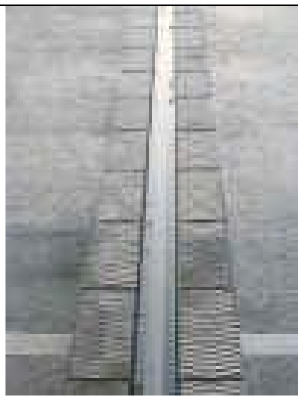
TVR ("Transport sur Voie Réservée")

As the Canadian conglomerate Bombardier Transports 1989 acquired the Ateliers du Nord la France (ANF-Industrie) and Brugeoise et Nivelle (Belgium), it was of much help to further develop the Belgian GLT (Guided Light Transit) concept from the 80ies, together with Spie-Enertrans. The system with a new name "TVR“ was presented in 1990 and wins a bid in Caen, France, in 1994 for a packaged new solution as a permanent guided system, which also was selected by the city in the same year. Nancy, France, selected the TVR of Bombardier in February 1998 to be operated on a former trolley bus platform. The TVR is a rubber-tyred rail guided vehicle equipped with pantograph or poles (like in Nancy) for the energy supply via catenaries. It is bimodal as it has the ability to leave the rail guidance and be led by an operator.

Above: TVR in Nancy (Source: www.parisceinture.com)/Below: TVR in autonomous mode (Source: www.lrta .org)

Between 1997 and 2001 the RATP was using a 1.4 km section of the Trans Val-de-Marne in southeast Paris to test first the TVR. The section includes a long ramp with a 5% gradient.

Vehicle aspects	Descriptions
Guidance Technology	Mechanical guidance. At the centre point of the underside of the vehicle a pair of in-line small double-flanged wheels are held down onto a centre slot rail (see below), by a hydraulic force.

	 
Bimodal abilities	Yes, one version in employment in Nancy.
Bidirectional abilities	No bidirectional abilities.
Propulsion	Electric traction, with electrical power supply (catenary). Auxiliary Diesel engine provides electrical power when running away from the guideway and overhead supply in driver guided mode.

The experience with TVR (in public transport employment), mainly in rail-guided mode, does now exceed 100.000 km and further aspects of the operation will be discussed in later chapters.

Translohr

Another rubber-tyred rail guided vehicle is the TRANSLOHR system developed by the Lohr Industrie. Lohr is for their public transport product segment associated to Fiat-Ferroviaria and located in Alsace, France. The Translohr is in the rubber-tyred tram range. The TRANSLOHR STE has permanent guidance and TRANSLOHR SE is a bimodal version. The bimodal version is able to leave its rail anytime and continue in driver (operator) mode, but has not been developed further from the prototype level.

TRANSLOHR from the test site of RATP (Source: www.lohr.fr)

This system has also been tested in 2001 by RATP's on the Trans Val-de-Marne site. Following the Italian city Padova, Clermont-Ferrand will be the second city to operate the system in regular use through the operator SMTC during 2006. In this city the permanent guidance system is chosen with a modular vehicle of four cars.

Vehicle aspects	Descriptions
Guidance Technology	Mechanical guidance. Centre rail has sloping railhead sides. Each vehicle wheelset is guided by two modules at the outer ends of a box frame (substituting for the axle), and each module has two wheels fixed at 45° to the rail and 90° to each other, which effectively grip the rail. Thus a module is prevented from jumping out of the guidance system. 
Bimodal abilities	The SE version (prototype) has bimodal abilities.
Bidirectional abilities	Bidirectional modes in the permanent guided version. No bidirectional mode for the bimodal version.
Propulsion	Electric traction, with electrical power supply (catenary) and batteries for distances without supply from catenary. (The bimodal prototype had a diesel electric system for permitting more extensive off- track running similar to those used in public service over the whole bus way).

To make the picture of development more complete for this segment of vehicles, it is appropriate to mention the German O-Bahn initiative from the 80ies developed by Daimler-Benz. This is a bus with side rollers for guiding the (front) axle along lateral kerbs on the roadway, which lead the vehicles in separate lines, thus the expression TRACELINE. Besides Essen, lines have been built in Adelaide, Australia and UK (Leeds and Bradford, which are the places where the system is still running). This solution can now be considered as matured and is a quite simple technology. One criticism of the system is that the guidance sides create physical barriers, which makes the solution inflexible for use in guided mode with mixed traffic.

2.3 Rubber-tyred autonomous guided vehicles

We are now tapping into the diverse segment of bimodal rubber-tyred autonomous (or immaterial) guided vehicles. The search for flexible public transportation solutions in several areas has through innovation brought this segment of solutions. ORSELLI (2004:13) claims that this innovation still does not have its own name. However, this is not strange since this category cannot be described as a vehicle segment in which we detect a dominant design. The situation right now is better described as a constellation of vehicles developed through incremental innovations, which still not have been tried out and evaluated over time. (This is the case for the Translohr system as well). More comprehensive discussions about the important aspect of innovation are found in chapter 4. However, simply speaking, we are talking about vehicles on tyres that at first look are compatible with conventional buses but with additional features concerning guidance and propulsion technology.

Civis

The CIVIS range from the bus manufacturer Irisbus implicates a promising set of vehicles in the current segment. Renault Véhicules Industriels and IVECO (Italian manufacturer) established 1999 the group Irisbus. The CIVIS solution is a bimodal vehicle with a disconnect able guidance device. The optical guidance system is developed by Matra Transport International, (a company in the Siemens Group), in cooperation with Irisbus. Since 2001 a simplified version is operating in Clermont-Ferrand, France, by SMTC.

Irisbus CIVIS THD in Rouen (Téor), France (Source: www.transbus.com)

Vehicle aspects	Descriptions
Guidance Technology	Optical guidance. A camera is detecting marked spots on the asphalt along the line and is continuously sending guiding signals to the front wheels of the vehicle for the appropriate steering. The camera is placed on the front panel (by the driver) or above the windscreen, depending on model.
Bimodal abilities	Yes.
Bidirectional abilities	No.
Propulsion	Electric traction through electrical engines on the axle. Electrical power supply through catenary. Additional diesel power pack is supplying engines with electrical power for employment without overhead line, like return to depot.

The Civis is presented as an innovation with the strength of an electrical propelled vehicle, the flexibility of a conventional bus system and finally the efficiency of a guided transportation system. According to Irisbus managers (talks with the author on 16.06.04 in Paris) represents the Civis a low risk engagement for potential customers (operators) because it is a platform of solutions with proven technologies.

Phileas

The Dutch system PHILEAS is manufactured by the Dutch company Advanced Public Transport Systems BV (APTS) in Helmond, Netherlands, with the Dutch VDL Group as the main shareholder.

The enterprise was established in 1998 after winning the contract for the development and delivery of Phileas vehicles to the city of Eindhoven, Netherlands. Its owners are keeping a wide range of capabilities in the appropriate technologies.

The Phileas vehicle is built in two different modular lengths (18 and 24 m), with an autonomous guidance system through magnets, as well as independent steer able wheel axles and advanced traction control for extensive manoeuvrability.

Phileas 18m vehicle (Source: www.apts-phileas.com)

The start-up for regular employment will be July 2004; the testing in Eindhoven has already been executed. The vehicle will in the first period of operation be lead by a driver without any automatic guidance.

Vehicle aspects	Descriptions
Guidance Technology	Magnetic guidance. Sensors placed under each wheel axle are detecting the fields of permanent magnets, placed in the asphalt layer, every 4 meters. Each axle is connected to a central computer system that calculates the optimal transport line for the vehicle. One of the results is the characteristic “snake movement” of the vehicle and also the continuous precise positioning during the employment.
Bimodal abilities	Yes.
Bidirectional abilities	No.
Propulsion	Electric traction through electrical engines on each axle (except the front axle). A modular electric-hybrid driveline provides electrical power through a Diesel, LPG or fuel cell engine. High capacity batteries are accumulating surplus energy and enable a certain time of operation only on batteries.

According to Phileas marketing chief Mr JANSEN, (in talk with the author at 16.06.04) they regard their main competitor being the Translohr. This tells something about the importance of the aspects of size and scale of this type of vehicle solution.

It is of course possible to find further various autonomous guiding solutions. Examples are the Cegelec-AEG system, which is an inductive cable guidance system (under private operation in the safety tube of the Channel link). Mainly used in logistics until now, we also see guidance through transponders, lasers and GPS / satellite systems.

3. Vehicle evaluation

Through the author's talks with different scientists in the field of public transportation and urban mobility as well as representatives of vehicle manufacturing companies and operators, a certain picture seems to emerge that concerns the technicality but also the total environment of the transportation systems. Features of vehicles as well as their total systems will be treated below, with respect to their individual capabilities, seen in the context of bimodality. Operational aspects and features are in such a context very rapidly a matter of concern as well as more human factors and perceptions. Features are sought which are not only describing the systems, but also can serve as parameters of decision for the selection of the most likely optimal solution for a given case.

Describing the systems features of the various ranges of bimodal public transport vehicles (hereafter called "**B.V.**") is in many ways a quite complex task. The pure technical approach will at this stage partly be built on content from chapter 2. In addition aspects concerning infrastructure and costs are mentioned.

3.1 Bimodal vehicle features and qualities

Table 1 on next page gathers a certain number of elements for comparison of the previous mentioned vehicles. It adds information concerning capacity and efficiency for each vehicle. The terminology understands on this place the use of the word "system" as a vehicle with its complete and necessary surrounding of technology in order to operate according to the expressed intentions.

The following text is listing core matters of concern, which can be seen as helpful elements for further consideration on a "systems level". All features cannot be considered as listed according to the degree of importance, as these together always will constitute a complex matter of concern. One approach for the discussion around vehicle solutions may be to see the issue within the methodology of RAMS (=Reliability, Availability, Maintainability and Safety), laid down in the standard EN 50126. The standard is used for railway applications and may be applied for B.V., as many aspects are similar (and generic) in the sense of importance for the two industries.

Reliability

Many would claim the reliability to be the main aspect of concern, when public transport vehicles and their systems are considered. It is no exception for bimodal vehicles ("B.V."). Mr. RAMBAUD, responsible for public transportation technology and associated services at CERTU states (in talk with the author 17.06.04): " Reliability is a very high objective for UPTS" (Urban Public Transport Systems).

Reliability can be considered from both a technical and operational/economical point of view. We are talking about the aspects related to possible failures with the system. One measure could be Mean Time Between Failures, whereas a vehicle with low frequencies of errors/failures will have a high reliability. The reliability may also be defined as risks, "implemented" in the system. Some generic aspects of risk related to innovations are further discussed in chapter 4. The main consideration of reliability connected to B.V. may be the flexibility of the system and its implementation. It is about limiting causes for failure and delay in all interfaces. Bimodality as such, because of its higher level of technology and the degree of use of "immature" technology, represents a challenge in that sense. The experience with different true bimodal systems until now is quite limited, and it is hard to consider B.V. as systems of "matured" technologies. Reports from Clermont-Ferrand have been issues concerning the Civis vehicle as such, including propulsion and different subsystems that should be corrected by Irisbus. The guidance system has shown a high degree of reliability and the system is subject to evaluation in cooperation with CERTU. The experiences with TVR have been acceptable, however it is relevant to mention the focus on reliability and some issues related to the process of connecting / disconnecting the vehicle from the rail.

Vehicle: / Feature / technicality:	**TVR Bombardier**	**TRANSLOHR Lohr Industrie**	**CIVIS Irisbus**	**PHILEAS APTS bv**	Unit:
Guidance technique	Monorail (Mechanical)	Monorail (Mechanical)	Optical (Immaterial)	Magnetic (Immaterial)	
Bimodal abilities	Yes, depending on the version	Yes, depending on the version	Yes	Yes	
Bidirectional abilities	Yes, in guided version	Yes, in guided version	No	No	
Types		4 diff. modules		2 versions	
Length(s)	24,5	18, 25, 32 and 39	12, 18 and 24,5	18 and 24,4	m
Weight (empty)	25	15, 21, 25, 29	19 (18m)	15 and 19,7	t =1000 kg
Weight pr meter	1,02	0,84	1,02	0,80	t/m
Capacity (maximal number of passengers (p) in vehicle)	200 (6 p/m2)	110, 164, 225, 298 (6 p/m2)	85, 159 and 200 (6p/m2)	140 and 188 (6 p/m2)	variable
Width (vehicle)	2,50	2,20	2,55	2,54	m
Propulsion	Electric /diesel-electric system	Electric, charge batteries for autonomy	Electric, also through Diesel or Gas	Electric, through Diesel or Gas	
Catenary / poles	Yes	Yes	Yes, depending on version	Yes, depending on version	
Manoeuvrability	Following rail or steering front wheels	Following rail or steering front wheels	Front wheel steering	Wheel steering on each axle (computerized)	

Table 1: Features overview of four bimodal public transport vehicles (B.V.)

As we see from the comparison above, the main features for both TVR and Translohr are very much the one of a tramway. Exceptions are wheel axles (and rubber tyres) instead of bogies / steel wheels and of course the track guidance system with all the technical and operational implications. Isolated seen are the reliability concerns mainly connected to these two elements. The accumulated experience until now is not so comprehensive that certain conclusions can be made. As long as the mechanical guidance system cannot be considered as matured technology, further experiences from operation are needed to make solid conclusions about its reliability. Civis and Phileas can be compared with conventional buses. Main differences are the advanced propulsion (Civis solution may be found in other trolley bus applications) with hybrid functionalities and the autonomous guidance technology. As mentioned initially are the issues of reliability for Civis and most likely also for Phileas the complete system performance related to the autonomous guidance technology and its operational aspects. However can the guidance technology of Phileas as such be considered as mature technology in generic terms, but must be tested in operation over time to see how it cooperate with other electronic systems, like the wheel control units and brakes.

Availability

Availability must be considered from several sides. The travellers as well as the operators have their own point of views and for sure different interests as they are in different parts of the value chain regarding public transportation. Other actors are the municipal and governmental transport authorities with institutions that are (partly) financing transport, depending on the levels of subsidises etc. Availability may quantitatively be understood as the ability of a product to be in a state to perform a required function.

Operators of B.V. have the mission of providing transport services within defined boundary conditions to the satisfaction of their customers (read: traveller). In this sense it is obvious that the bimodality as such does not provide or add any further generic value to the travellers. However, depending on the tender regime or the concrete contract between the principal (often a municipal representative) and the operator (may be a local company or perhaps a multinational public transport operator like Keolis or Connex) the choice of solution is leading to certain degree of availability. Applying the RAMS approach will not only imply risk considerations but also a certain total defined operational time. That means a fixed mean “uptime” and also a certain “downtime” of the system, which is used for maintenance etc. An innovative system, even after the test phase, may need more downtime. Especially if not all operational aspects and eventualities over time can be estimated at the time of contracting. However, this element can just as well be considered as a commercial matter and be regulated in the contract agreement, including how to respond on these issues.

The availability seen from the view of the travellers is including such matters as: am I able to enter the vehicle and is it arriving at the expected time etc.? The Civis vehicle is guided from the front part through the installed camera that is detecting the marks in the street in front of the vehicle. Therefore the vehicle gets a certain angle to the bus bay when stopping, getting more than 5 cm of distance from the kerbstone side to the floor-edge of the vehicle by loading passengers. This represents an object of concern as it is considered as too much for some segments of the travellers due to regulations (in France). The Phileas, with its ability of lateral movement on all axles will with great precision accommodate every demand on distances between station border and vehicle. We see that different technologies are offering different degrees of availability in unlike situations. A survey from a country with partly lower technical standard of public transport vehicles compared to France, like the study of a bus company in Campos, Brazil by DUARTE and DE SOUZA (2003:1-5) uncovers:

“*The demand rate for public transportation in Campos as well as in several of the Brazilian cities have shown a significant decrease in the last years. The major reason is the poor service quality offered by the existing bus companies*”.

One conclusion of the mentioned survey was that passenger confidence and satisfaction is heavily connected with the performance of regularity. The need of low-cost solutions was also an issue. With a high degree of availability and also reliability the operators can perform well and easily forecast and communicate “downtimes”, plan realistic timetables for peak hours and for periods with extreme climate conditions. Then we are back to issues of planning, quality of infrastructure and route operations, which are important factors for the availability but partly generic in respect of choice of technology. Out-puts of the system cannot be higher than the performance of the built-in technology.
A well functioning autonomous guidance system may lead to a better availability in areas with difficult climate conditions. The Phileas guidance system is, once established, only dependent on a certain degree of friction on the road surface to operate. Snow, icing or extreme heat will not influence the degree of availability and operator may outperform in terms of customer care through fulfilling the agreed level of availability.

Safety and maintainability

Safety will always be a main matter of concern in UPTS and constitute the “platform“ upon which availability, reliability and maintainability are established. Besides the establishment of the relevant risk parameters are safety considerations technically seen, related to the definition of the systems safety level, the ruling element on which several subsystems and their cooperation must be assessed. Using a RAMS approach supposes the need of dealing with safety integrity for the different elements of the total B.V. system, partly in numerical formats. It is obvious that the challenges of the safety considerations are in several ways more comprehensive for innovative systems.
In simple and practical terms we can mention both passive and active safety systems for B.V. A passive safety system is observed in Clermont-Ferrand. The Civis vehicle needs sets of special vertical bars to “guard” the passenger platforms in order to establish a passive safety arrangement by a camera guidance failure (and prevent accidents with passengers if the vehicle should hit the platform). During the ongoing evaluation with CERTU it is also suggested to mark the road lanes red in areas with guidance. As camera guidance until now only is used in the station areas, the red colour will be a significant mark of “attention” and communicate to all types of travellers. In Copenhagen, Denmark, several bike lanes/crossings have been coloured green with a higher degree of drivers’ attention as result. The guidance system of Phileas has different active safety routines built in. It includes speed limitation and stop/alarm if magnets are missing over a certain distance. In several situations the safety level can be improved if the driver is released from a certain number of tasks, in order to focus more on the maintaining core functions of vehicle operation. The support of the passive and active safety systems must be seen in connection with this discussion and of course be studied specifically for each case/functionality to have scientific evidence for the values of the different innovations in a safety context. It is obvious that a close cooperation with authority organisations and regulatory bodies is important to support the safety efforts by innovative vehicle manufacturers.
Maintainability or Mean Time to Repair is another issue of importance in the efforts of establishing an efficient UPTS. To perform well in operation demands, as mentioned earlier, a high level of reliability and therefore a predefined low need of maintenance and preferably no mechanical or system failures.

The experience from Nancy with the TVR shows partly a significant high wear of the guidance rail (around 2-3 mm in 3 months). This is one example of a particular need of maintenance routines that must be considered in the contracting phase to be handled efficiently by the operator. Considering the whole system, a LCC (life cycle cost) analysis could be carried out in order to make "global" long-term comparison. Such analysis comprises all technical operational aspects in monetary terms and leads to better transparency in the choice of system. The current possibilities for exercising reliability centred maintenance will most likely help the innovative initiatives that B.V. truly represents. This comprises monitoring and diagnostics systems and later perhaps satellite or other wire-less communication for the purposes of remote observation, predictive maintenance planning and logistic optimisation. In this sense "the future" is supporting the B.V. innovations. The mentioned elements lead naturally to a greater focus on the tendering work and the abilities of the operator (and the other system buyers) to set/define several measures of performance in the contract. This will lead to an important visibility of the aspects of concern and indirectly dictate the maintenance concerns. Once again we are dealing with aspects, which are generic in UPTS, but are crucial for the operational success of a B.V.

If the development in "change of roles" within the B.V. industry follows that of the rail-vehicle industry, we will observe a shift towards increased sharing of responsibilities not only for the product but also for the product development and operation process. This more open approach, including increased component reliability, longer intervals between preventive maintenance, reducing the potential for human error etc, may support the development of a B.V. system generally and contribute to lower technology risk. The employment of RAMS management will imply risk considerations that most likely will uncover the very most aspects of the innovative vehicles in situation of operation. All transparency of risk elements among technicalities may be considered as an indirect support for an innovative B.V. solution.

Finally are also insurance issues occurring within the general safety discussion. Lohr Industrie was facing the following question: What about the responsibility in the period of time when the vehicle is neither track guided nor free of track (it is in the process of connecting or disconnecting to the monorail). Which insurance shall then be applied for the vehicle, the one for a bus or the one for a track-guided vehicle? In most countries different legislations are valid for both bus and tramway circulation. These regulations are not only describing the allowed behaviour and patterns of operation, but are also giving limitations concerning vehicle lengths. The lengths of busses are in most countries limited to around 24 metres. For tramways longer cars or set of cars are allowed, which obviously gives the prospect of higher transport capacities. Besides, where are the boundaries of responsibility of the driver of a B.V.? With one (or several) functions of the vehicle automated the question may be where to put the focus of actions for the driver in a safety context. Is he/she then only in the vehicle to open/shut the doors and survey the technique, or are other aspects of "conscious operation" mandatory for certain technical elements to keep safety on a required level? These questions are naturally depending on the specific system but are relevant to mention in this context.

Flexibility and advantages of bimodality

Beyond the scope of a RAMS approach, the higher degree of flexibility is one of the most frequently mentioned advantages of a bimodal-guided vehicle. In this context it may also be an advantage to use the notion bimodality with respect of other aspects too, like i.e. hybrid propulsion, as the studied vehicles are containing several degrees of technological flexibility. The Civis and Phileas systems are showing a high flexibility, as they do not need a comprehensive support from a mechanical guidance item (rail). It is relatively easy to remark / reposition magnets along the route, without a significant high cost or impact on the existing streets or other parts of the infrastructure. Of course are some physical adjustments required, like the change of stations, adjustment of crossings and lanes, in order to have an effectively operated system. Both TVR and Translohr B.V. versions would be able to return driver led to the depot or to the appropriate place of maintenance. This would save place, infrastructure costs and enable new business models among operators and their sub suppliers. A systems breakdown on a conventional tramway normally leads to a stop or delay in the operation of the line(s). A bimodal system has a higher ability to avoid obstacles and/or planned actions like roadwork along the line. You simply disconnect from the guided line and go in driver-conducted mode around the work area. The demand of lane width can in several cases be reduced considerably. For the Phileas vehicle (18 or 24 m long) the swept path in curves constitutes only 3,8 m whereas conventional busses need up to 6,5 – 7 m, dependent of the length of the bus. The limitation of narrow curves in inner cities for conventional LRT solutions can once again be reconsidered and a bimodal system established with sufficient performance and without need of larger influence on the existent physical environment. The use of Translohr in an ancient Italian urban environment is already planned. However, the need of a durable material for the road surface will be one constraint as the choice of the right material is crucial for a good long-term performance by B.V. tyred vehicles. MEYER (1985:16-22) gives in his comparison between LRT and dual-mode bus system (O-Bahn), the following advantages of a bimodal system:

- *Considerable cost savings in the construction of the roadway infrastructure*

A simpler solution is cheaper. Included is of course also the shorter time of construction (6 to 12 months), which leads to reduced capital costs and quicker return on investment, compared with normally 3 to 9 years for building a complete tramway infrastructure. In addition we have the loss of goodwill/image during the construction time, depending on the original local infrastructure conditions. The author’s impression of the current situation in Grenoble building the tramway line 3: In spite of the municipal efforts to make the inhabitants become engaged stakeholders by supplying a comprehensive and frequent stream information, many persons are sceptic to the project as the city (still) has a large number of traffic jams related to the road work for the new line.

- *Reduced amount of wear and tear on the sidewalls of the tires when entering the bus bays and better/favourable working conditions created by the automatic track guidance*

This leads to economic and environmental advantages for this special technology. Advantages regarding working conditions are claimed to be better, and will of course be a matter of study at each chosen solution.

- *Very easy and low cost, to expand the bus system step by step, or move it*

Handling growth in an appropriate way with the least possible cost of change is one crucial parameter among city planners and political decision takers. A B.V. solution it is in most cases easier to change to a LRT solution, as the corridor is defined for several parts of the line(s). This could happen around 18 000 p/h/d (peak demand), dependent on the local situation. In the current situation of the more global business environment, the following opposite situation of an intermediate urban area may occur: One or two big companies are moving or reducing the workforce and change the demand situation radically. B.V. may add value to such movements through its flexibility.

We could add other B.V. advantages such as the ability to pick up or set down passengers while driving around in peripheral settlements (scattered populated areas) in driver lead mode, before joining or leaving guide way sections on the main line. This ability will in some situations eliminate transfer times and make the feeder – trunk system more integrated. The result is increased customer satisfaction and leads to a shift from car to public transport for some travellers.

Current information about one O-Bahn system in operation is found in Bradford, UK, where "The A641 Manchester Road Quality Bus Initiative" has been founded as a partnership between operator First, Metro and City of Bradford MDC to significantly reduce the delays to bus services on the mentioned particular road, which is very busy. It is clear that the initiative focuses on „the whole system", not only on the B.V.: It shall provide new signal controlled pedestrian crossing facilities, replace unpopular footbridges and subways and new state of the art bus shelters. The initiative includes:

* modern "low floor" buses
* improved reliability
* reduced bus journey times
* improved ride quality
* upgraded customer facilities
* new bus shelters with improved lighting and better timetable information
* signal controlled pedestrian crossings
* localised improvements for cyclists

Quality bus in Bradford, UK (Source: www.firstgroup.com)

This package includes for sure an exclusive RoW in the roadway and priority in crossings and junctions. Once again it is obvious to notice how rapidly the issues are shifting to a systems level, instead of focusing purely on the vehicle abilities. The Phileas advertisement is promoting the vehicle as an “integral part of an innovative high quality rapid public transport system”. Advantages are environmental friendliness, high average speed, frequency and flexibility as well as reliability and comfort.

Disadvantages and risks of B.V. and its systems solutions are mentioned throughout the discussion on relevant places in this work.

Environment

Finally, not to forget the environment, which in a wider ecological sense is the basis for a sound and sustainable future on earth. The use of recyclable materials, biologically disposable lubricants, propulsion solutions with non-emission performance etc. clearly shows a shift towards more focus on sustainability in the UPTS industries too. The drivers are the political regimes as well as the industry itself, which implies that the travellers (the inhabitants in most parts of the world) are inclined to support sustainable public transport offered in an efficient setting.

Focus on new and sustainable propulsion solutions is characterizing the B.V. industry. TVR, Translohr and Civis vehicles are 0-emission vehicles supplied through catenaries. Civis and Phileas (diesel-electric versions) fulfil the Euro 3 regime, and give no possible damaging wandering (“vagabond”) current through the ground that would corrode other ground installations (one solution of electric rail vehicles supplied through catenary is a current circuit with earth to ground). Phileas with a LPG-battery solution provides energy (!) by charging the batteries during braking and will in this sense represent a new step in the move towards sustainability. A step-by-step approach in the introduction of Civis in Clermont-Ferrand led to no establishment of a catenary system. The vehicle is currently diesel-electric propelled (= low degree of efficiency) which leads to energy losses and also more noise. In Nancy the TVR replaced a trolley bus system and could directly be supplied by catenaries, without significant new investments in catenary infrastructure.

Further aspects are the continuous efforts of reducing the vehicle weight and limiting noise. The weight of the B.V. is currently around 0,9 t/m (see table 1) whereas LRT in general are heavier, with around 1,2 t/m. The LRT have in several situations still a long way to go to arrive on the lower noise emission level of a B.V. Especially if we are considering structural noise, but also airborne noise (see the wheel discussion at the end of this chapter). The electric traction is normally more silent than combustion engines, but also sub systems may emit considerable noise and make a system-to-system comparison more important.

Ecology: will bimodality lead to general lower energy consumption? It is clear that a more thorough study including a life cycle assessment (LCA) could be carried through in each special case to give sufficient evidence to claim a certain preference. The standard EN ISO 14040 constitutes one of several environmental management techniques but does not address the economic or social aspect of a product as such. Furthermore may the choices and assumptions, like system boundary settings and impact categories, be subjective. The LCA is mentioned at this time to give the reader an idea about what “tools” may be appropriate to compare two (or several) systems to establish information for assessing and selecting a certain transportation system. The vehicle will then be a part of the system consideration. A LCA consideration would preferably include the advantages of bimodality, energy equations and other (relevant) system features in monetary terms. What are i.e. the savings of the implementation of a UPTS with significantly lower transfer times and increased ridership for an intermediate town with limited financial resources? Or, how much will i.e. the recyclable body of Phileas including its LPG-electric drive train (GM-Allison parallel hybrid version) count for the total system lifetime economy?

Commercial environment: the classical fight between the (traditional) merchants in the city centres, which not only have to compete with the virtual (on-line) stores, but also with the super- or hypermarkets often settled in the suburbs. A flexible B.V. system would contribute to a living and clean down town area. B.V. may be less intrusive in areas of certain cultural or heritage value, which puts constrains on the degree of possible (costly) changes in the physical environment. I.e. it is not possible to change the pavements and to establish a net of catenaries. The Translohr solution would manage both the resulting narrow curves and the operation on battery during the distances without supply from catenaries (battery operation). However, the surface material of the road along the line (roadway) must be in a special reinforced material to be able to take the certain wear and tear of the rubber tyres. Less congestion as a result of the employment of B.V. solutions would attract more people to visit the community centre using public transport.

3.2 Vehicle economy and some technical concerns

Many would argue in monetary terms by seeking pros and cons for a B.V. solution. By the choice of an optimal UPTS it obvious that both cost of investment and operation are important decision parameters. Also in an economic sense it is difficult to remain on a vehicle level during the considerations, but this fact shall not keep focus totally away from some vehicle to vehicle comparisons, as shown below. The discussions below will gradually shift into a systems approach when relevant for the general context.

Aspects of vehicle-, infrastructure- and operating costs

The vehicle cost is normally a result of corporate size, the degree of standardisation and modular production to the extent the series allows. A vehicle’s price not only covers a certain degree of R&D efforts but also give sound margins in the long run. Considering aspects of innovations (further discussed in next chapter), in the start-up phase characterised by small series and therefore a relatively higher fix production cost, will clearly hamper the B.V. initiatives with some financial disadvantages compared with modular mass-produced vehicles from a big manufacturer. The manufacturers’ corporate and pricing strategy, especially relevant for the bigger companies, is in this sense also an issue. A good example of manufacturers’ strategy is big series and modular production, which is the success of Citadis. Citadis is the brand of a tramway from the manufacturer Alstom, selected by numerous cities in France and elsewhere, many times because of a good cost/benefit ratio for the customers. During the period 1994 – 2001, there was a big hope among transport authorities, operators and manufacturers etc. in saving 30% of infrastructure’s investment and to get lower cost of rolling stocks when adopting the systems TVR or Translohr. In this sense the prospect of cost savings can be considered as a driver of innovation.

The vehicle launch in Clermont-Ferrand led to implementation of Irisbus' "Agora" (=conventional bus with diesel engine and equipped with camera for optical guidance) in May 2002 and Civis in November 2003 for the east-west line of the city. SMTC-AC did not make a full commitment to Civis in a sense of systems technology. The catenary system has not (yet) been built. This is an incremental approach, which saves cost (risk) for SMTC, but leads to a situation in which the Civis-system is not able to show all of its advantages. In 2006 opens SMTC-AC the north-south line with Translohr in operation. Mr CHARLAT, former project manager of the Civis project and now in managerial position of the Translohr project claims (in talk with the author 14.06.04): "The monorail solution is not much better than a LRT solution considering the construction costs". Establishment of the monorail track, even with its narrower profile compared with a tramway solution, demands comprehensive civil works. The total costs of the 14 km new Translohr line is stipulated to 290 Mio Euro, with around 100 Mio Euro counting for the infrastructure (7,14 Mio Euro/km), which include 2 km with exclusive RoW. Infrastructure costs are defined as all necessary works within the dedicated roadway (=GLO = "Gabarit Limite d'Obstacle"). Costs for communication, traffic control, ticketing systems etc. constitute around 10 Mio Euro. All amounts confirmed by SMTC-AC. Operational costs for the Translohr will of course depend a lot on how the system is performing over time, but will most likely not exceed the one of a conventional LRT system with similar capacity.

Civis or Phileas vehicle have both prices around 1 Mio Euro per unit, whereas Phileas price will depend on chosen technology (type of drive train and battery). Typical for all four considered vehicles are relative small series of production including (still) a partly low degree of product standardisation and that the price more or less directly will reflect "payment for innovation". Compared with a bi-articulated bus with unit cost between 420 and 500 000 Euro, it is clear that the choice of a B.V. is a more costly matter. Because of the large series, the high degree of mature technology, standardisation (modularity) and the bus producers' corporate size, the built-in R&D cost for a conventional bus is not visible to the same extent. For example, the development of low-floor solutions have continued over a longer period of time and has for sure enhanced the availability, but does not represent one special feature (or innovation) that will defend a higher product price by a certain bus manufacturer. The prime concern on a vehicles level is costs related to the degree of innovation, as well as the related technological and economical risks. These are at a systems level for sure also political risk too! One way of reducing such costs for pulling B.V. innovations will be the establishment of partnerships, as shown in next chapter by the case of APTS. However, the following table gives interesting figures for the further discussion and reveals a pattern that can be confirmed from other sources. The infrastructure costs of the Clermont-Ferrand Translohr project, around 7 Mio Euro/km, is not far away from the corresponding stipulated tramway costs in table 2 but still lower. The total infrastructure costs of the Civis project in the same city are ca 5 Mio Euro distributed on 4,2 km (=1,19 Mio Euro/km for bus lane on street). This shows clearly a competitive cost advantage if the B.V. does not demand a special durable surface (e.g. concrete roadway). Uncertainties around the local state of the current infrastructure will always be one factor of concern in these types of comparisons.

	Bus 12m	**Bus 18m**	**Trolley 18m**	**Phileas elect.**	**Tram rail**	**Metro rail**	
System							Unit:
Capacity							
Passengers/hour/direction	**2.000**						p/h/d
Average/Peak in %	60%	60%	60%	60%	60%	60%	
Number of vehicles[1]	**34**	**21**	**19**	**13**	**11**	**6**	
Service							
Commercial speed[2]	**22,0**	**22,0**	**25,0**	**25,0**	**25,0**	**30,0**	km/h
Frequency	2,4	3,9	3,8	5,5	6,5	10,0	min
Travel-distance (av.)	5,0	5,0	5,0	5,0	5,0	5,0	km
Infrastructure							
Length	**15,0**	**15,0**	**15,0**	**15,0**	**15,0**	**15,0**	km
Investment(bus lane on street)	**0,40**	**0,40**	**1,80**	**0,70**	**8,80**	**75,00**	MioE/km
Investment (bus lane new)	**4,10**	**4,10**	**5,60**	**4,30**	**9,90**	**75,00**	MioE/km
Maintenance	**0**	**0**	**30**	**5**	**150**	**325**	kE/km/y
Vehicle							
Length	**12,0**	**17,9**	**18,0**	**24,4**	**29,2**	**36,4**	m
Weight	**12,0**	**14,9**	**16,2**	**19,7**	**33,5**	**64,0**	t
Capacity 6.0 p/m2	**81**	**132**	**132**	**188**	**221**	**335**	
Price							
Price/Vehicle[3]	**180**	**300**	**510**	**1.290**	**2.000**	**4.000**	kEuro
Price/Pass (6.0 p/m2)	2,2	2,3	3,9	6,9	9,0	11,9	kEuro
Cost/km/vehicle							
Driver (1.250 h/year)	1,09	1,09	0,96	0,96	0,96	0,80	Euro/km
Depreciation (r = 6%)	0,21	0,35	0,45	0,94	1,15	1,93	Euro/km
Energy	0,23	0,31	0,38	0,44	0,45	0,66	Euro/km
Maintenance	0,16	0,24	0,50	0,65	0,80	1,00	Euro/km
Km/year/vehicle	96.000	96.000	110.000	110.000	110.000	131.000	km/year
Comparison Costs							
Vehicle							
Costs incl. driver/km vehicle	1,70	1,99	2,28	2,98	3,36	4,39	Euro/km
Costs/Passenger/Ride	0,17	0,13	0,14	0,13	0,13	0,11	E/p./Ride
Vehicle + Infrastructure							
Costs/Pass/Ride (b.l. on street)	0,19	0,14	0,20	0,16	0,43	2,70	E/p./Ride
Costs/Pass/Ride (bus lane new)	0,31	0,27	0,33	0,28	0,47	2,70	E/p./Ride
Costs/year (bus lane on street)	6.000	4.500	6.800	5.000	13.900	85.300	kEuro/y
Costs/year (bus lane new)	10.000	8.500	10.900	9.000	15.100	85.300	kEuro/y

[1] 100% up-time / [2] depends on infrastructure / [3] no project-costs (average 10%) and based on 30 vehicles

Table 2: Cost comparison of vehicles (Source: APTS)

If the Phileas vehicle were produced in a bigger scale then both fix and R&D costs could be distributed on a higher number of vehicles (or perhaps even recycled modules), resulting a reduced unit cost. From table 2 we experience that the cost pr kilo vehicle is around 60 Euro for the Phileas, tramway and metro. The future extensive use of lightweight materials makes it difficult to come up with thumb rules concerning price and weight relations for guided public transport vehicles.
Another important factor is the local demand. It is nothing new that a metro or even to a certain extent a LRT solution will be expensive by a demand around 2000 p/h/d. The Translohr of Clermont-Ferrand is expected to offer a capacity of 2500 p/h/d in an intermediate urban area (as defined in chapter 1) with a population of ca 220 000 inhabitants. The average commercial speed will be 22 km/h and this makes the project comparison with the Phileas data of performance even more relevant. Finally it is obvious that the costs of preparations made for a line of autonomous guidance will rocket if the support systems like customer information systems etc are added into the calculations. The support systems however are on the same cost level (or higher) if a LRT solution is considered.

The steel wheel / rubber tyre debate

In order to make the discussion more complete, it is relevant to mention the steel wheel / rubber tyre debate. Each technical solution has its advantages and for sure its supporters. More generic, however, it is obvious that the steel wheel gives a very low rolling resistance and a good performance on high-speed level. Rubber tyres, on the other side, have a number of features that add value to a public transport systems solution. KÜHN and SOULAS (2001:11) claim the following inherent qualities of the (rubber) tyre:

- Absence of vibration: 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 age, notably in curve where the strident grating of steel wheels on the rails becomes unpleasant for both passengers and residents.
- Manoeuvrability: a vehicle on tyre can change direction more easily. The use of tyre for tram rolling stocks allows a reduction of the curvature radius from 18 to 12 m.

Rubber tyre solutions are normally lighter than steel wheels and this is one factor of importance by the choice of technology. Furthermore, rails need comprehensive maintenance to perform well, just as the roadway of an autonomous guided bimodal vehicle must be kept in proper conditions. The economical comparisons of the long-time maintenance cost of both systems are especially related to the local topographical and climatic conditions. To deliver a bimodal performance, like defined in this work, a rubber tyre solution is obvious. However, comparisons of the different systems considerations above are useful to keep in mind.

4. Aspects of innovation and planning

Since the subjects of concern are containing important dimensions of innovation, it can be helpful to make some initial considerations about innovations in general and the special approach towards the mentioned vehicles. The innovative implications may also be useful to keep in mind during the consideration of planning aspects as we see in the third subchapter, where some focus is put on mobility mindsets and culture and how these elements are influencing the decisions of public transportation.

CHRISTENSEN (1997:69) is claiming, taking the example of the shift of the mechanical excavator industry away from cables into hydraulics from the 50ies: "*Over its history, leading firms have successfully adopted a series of sustaining innovation, both incremental and radical, in components and architecture, but almost the entire population of mechanical shovel manufacturers was wiped out by a disruptive technology - hydraulics – that the leaders' customers and their economic structure had caused them initially to ignore.*" This shows how multifaceted the whole discussion about innovation really is, and it is no doubt: more or less all companies are practicing some sort of incremental or radical innovation in order to stay competitive with their products in the market. The quotation above is not mentioned in order to initiate a general discussion about disruptive innovation, or whether some of the innovations already described may be held as being disruptive. It is rather a good example on how the employment of one innovation gave a new direction and possibility to a complete segment of machines, globally used for a special range of tasks. Furthermore, on a corporate level, CHRISTENSEN (1997:113) lists the five fundamental principles of organizational nature that managers in successful firms consistently recognized and harnessed to win the battles with disruptive technologies:

1) *Resource dependence: Customers effectively control the patterns of resource allocation in well-run companies.*
2) *Small markets don't solve the growth needs of large companies.*
3) *The ultimate uses or applications for disruptive technologies are unknown in advance. Failure is an intrinsic step toward success.*
4) *Organizations have capabilities that exist independently of the capabilities of the people who work within them. Organizations' capabilities reside in their processes and their values – and the very process and values that constitute their core capabilities within the current business model also define their disabilities when confronted with disruption.*
5) *Technology supply may not equal market demand. The attributes that make disruptive technologies unattractive in established markets often are the very ones that constitute their greatest value in emerging markets.*

Once again, not considering if we are detecting elements of disruptive innovations in our segment of vehicles, the principles above can be helpful to consider more closely. The capabilities of the B.V. manufacturer as corporate organisations may be difficult to describe but can also be seen as a mix of internal and external competencies and their ability to cooperate with external institutions with importance to their approval of new technology and systems solutions is crucial.

Only some vehicle systems have been studied in this work, mostly because of the limited extent of the research and the current situation of B.V. in operation. Furthermore it is well known that some innovations often lead to new series or modules, which serve as “platforms” for further development of more advanced vehicles. For a historical scope technical literature is probably most relevant. Interested readers will find a comprehensive overview of current innovations of transportation vehicles in Jane’s Urban Transport Systems (2001:495-508).

4.1 Innovation of bimodal public transport vehicles and market perspectives

As we see from the section above, it can be a great power in innovations regarding its impacts of future technical solutions. Caterpillar (huge manufacturer of construction machines of different types) never participated in the excavation machine market when cable actuation was the dominant design. Only much later (but successful as a follower) Caterpillar entered the hydraulic excavation equipment industry, by introducing the first model in 1972. To take a look at the industry of public transportation vehicles: Alstom has not appeared in the segment of bimodal public transport vehicles in the same way as the competitor Bombardier with their TVR. Both companies are bigger enterprises with a certain ability to take R&D risks and investments and are in that way comparable. Irisbus, a bigger actor among the bus producers, has tapped into the bimodal segment with partner Siemens (for the development of the guidance technique) by developing the Civis vehicle. The Dutch APTS, with its product Phileas, is supported with know-how from the other subsidiaries in the VDL group as well as external partners. Finally has Lohr Industrie used their know-how and for sure also financial strength of the diversified company to develop Translohr.
It is obvious that it puts demands on the alignment of strategy, corporate capabilities and market considerations to make innovations happen at B.V. manufacturers. Some of the principles mentioned in the beginning of the chapter can be especially relevant to consider by discussing the different topics of innovation in this vehicle segment:

- *Resource dependence: Customers effectively control the patterns of resource allocation in well-run companies.*

The companies mentioned above see themselves mainly not as B.V. manufacturers but as vehicle producers to the “conventional” market of public transports. This is an obvious result of the research and gives some signals about the considered corporate (and market) importance the B.V. segment has for the time being. One exception is the subsidiary of Dutch VDL Group (with its slogan: “Strength through co-operation”). APTS (producing the Phileas) is a company with a high degree of innovation and has the will to tap into a new segment of vehicle technology without the support of dozens of customers or comprehensive international governmental approvals. However, a close cooperation with the relevant governmental departments for the establishment of standards and procedures for new B.V. is inevitable, but also fruitful in the sense that it opens for a dialogue that gives new solutions. The same situation is valid for the customers. These again may have affinities, special demands or financial dictates to follow. In some situations we are talking about subsidies in the choice of certain solutions, as in Italy, where the national government is funding 70% of the investment of a new public transport system if it is zero-emission (speak: has electric propulsion, until now normally supplied from catenary). Of course such financial incentives will be important for the local Italian communities in the choice of vehicles! Incentives and support of great varieties are generally applied by different governments to better the local situation of public transports. The political instruments and their (indirect) impacts on innovation in this context are therefore important to keep in mind. It is at least clearly shown how the market of public transport vehicle producers has some special affinities that may lead to a situation in which innovation generally seen implies a higher risk than in other parts of the vehicle/machine manufacturing industry.

- *Failure is an intrinsic step toward success and small markets don't solve the growth needs of large companies*

The very high demand for reliability (see chapter 3) is another aspect that practically is influencing the degree of innovation. There are only few areas in the society where errors are so little accepted as in public transportation. This has a primarily to do with the built-in high demand of expected systems reliability, but is also of course a matter of safety and the consequences of an insufficiently functioning system. This superior demand is for sure a barrier to innovation. The introduction of the TVR in Nancy was followed by situations of disorders in connecting the vehicle to the rail, going from driver led mode into rail-guided mode. The system (through its technical solution) showed a reduced reliability, even though it was the driver (!) who some times caused the failure by over-riding the automated procedure. Problems with TVR in Nancy lead to a changed approach for the next tryouts with bimodality for Translohr. The initiative of bimodality is for the time being buried at Lohr Industrie (!). Referring to Mr KÖRBER from the commercial department of Lohr (in talk with the author 15.07.04): "The Translohr Tram-on-Tyre fulfils every demand of a rail bound public transport vehicle and add value through it's capability to pass narrow curves and climb steep hills". The discussion about bimodality is not any longer an issue, even though the technicality of a possible bimodal solution remains existent. The only visible sign of the effort is now the prepared place for the registration number on both ends of the prototype vehicle. By marketing the Translohr in the tram segment the customers and authorities are facing a familiar vehicle within a set of proven technologies. It can even be claimed that the vehicle has a higher safety concerning derailing compared with a conventional tram, as the guiding wheels are not transmitting vertical forces. (The guiding wheels are additionally covered with synthetic material in order to lower or even eliminate wear on guidance rail to give the connection "eternal life"(!)).

As the Phileas has not yet been tired out in bimodal employment it is too early to say how the complete environment, stake holders included, will respond to the initiative in Eindhoven. The operation is in the early beginning and a delivery to Italy will also give further experience with the system.

Perhaps is the small potential market size one aspect that leads Irisbus to present Civis with a certain carefulness and focusing that the vehicle is build on a platform with only few new implemented innovations (camera guidance and electro engines on the axles) in order to minimize the technology risk and to work with a limited set of innovations, and as such be able to communicate their prospective (still few) customers an image of limited risks, both commercial and technological. In Clermont-Ferrand Irisbus must pay penalties if the Civis system is not performing according to contract. It is obvious that this is an increased parameter of concern when Irisbus is considering the product with its financial and technical risks, which are increased mainly because of the innovations built in the solution. The higher degrees of risk must on a corporate level be considered in light of the corporate value of the innovation and the achievable margins of the products. Or, perhaps will the solution for Irisbus be to market the camera technique for installation in vehicles, without the Civis concept? For sure it is also about hindering brand dilution and market attitudes that can harm the other product segments. It is not known if there is or have been a discussion at Bombardier regarding the TVR vehicles' impact on the company's other tram segments. Issues could be brand dilution by scandals and/or cannibalisation of existing tram segments.

Finally it is clear that all innovation costs money and especially innovation in the mentioned segment! To have the right financial strength and endurance is dependent on the corporate size but also on the total environment including the customers, the political conditions and the whole establishment's ability and will to take risks. One way of gaining new knowledge is of course to invest and to go for innovations!

- *Organizations' capabilities reside in their processes and their values.*
- *The attributes that make (disruptive) technologies unattractive in established markets often are the very ones that constitute their greatest value in emerging markets.*

Considering the fact that APTS is a <u>project with a portfolio of special dedicated number of development partners</u>, could be a setting in which enhanced organisational capability of mastering innovation is established. "The APTS has no own R&D department but is organized as a project to supply the city of Eindhoven with public transport vehicles according to contract", stated Mr JANSEN at APTS (in talk with author at 13.07.04). The market success is still the core parameter of assessing the ongoing initiative, however the APTS marketing approach, towards connecting Phileas to Bus Rapid Transit (notion explained in next chapter) is a clever move to anchor the product in a known and more common context. It is a fact that just in China there are around 300 cities with more than 2 million inhabitants, and of course a <u>huge number of intermediate cities</u>. This implies a vast market for new and flexible public transport solutions that the existent environment has not discovered. The response of the vehicle producers to these market demands will be important for the further innovations of B.V.

4.2 Some technicalities within the different concerns of innovations

Safety and redundant technology

We have seen how both systems experiences and manufacturers affinities may guide and also decide innovations. Furthermore, certain market expectations and mindsets (see below) are giving direction and leading to certain choices. All the four mentioned vehicles are no exception in that sense. They seek all to perform “at least” on the same level of comfort as a modern tramway solution. Through their electric engines they do all have strong acceleration and ability to climb tougher gradients through the use of rubber wheels.

Further issues may be the discussion of redundant technologies. Leaving the segment of bimodality, Lohr Manager Mr KÖRBER stated (in talk with the author 15.07.04) that the driver as such is redundant in a bimodal vehicle, when he is supposed to have the responsibility for the safety and keeping the speed etc., EXCEPT steering the vehicle. APTS however is working with a transport solution in which it will be possible to choose both semi of full automatic mode for the Phileas vehicle. Semi-automatic means automatic vehicle guidance and full-automatic mode implies that the system takes over guidance, braking and speed control.

Redundant technology may also be imposed from the legislation as shown in the example below from Civis in Clermont-Ferrand. The French legislation impose both mirror and camera surveillance equipment for using the Civis solution. This leads of course to a more comprehensive and expensive solution compared with a conventional bus.

Redundant technology on Civis operating in Clermont-Ferrand? (Source: author)

Increasing the costs is also the compulsory safety "shield" of bars on the corners of each bus stop as mentioned in Chapter 3. Besides, could signalling requirements lead into a similar situation as bidirectional track bound vehicles in several countries are to be equipped with both white and red light as well as certain other attributes, depending on the local regulations. Some technology redundancies are of course required to meet high availability demands on a systems level, like integrated vehicle on-board control systems. Are then bimodal systems implying technologically overloaded vehicles with corresponding higher costs and even more sources of errors and failures in operation? In this matter will the development of the governmental (and operator) acceptance of the innovations most likely "trim" the solutions over time to meet a certain degree of technological efficiency. Some readers may remember reading about one of the first newspaper statements from those days of the newly invented car. The US newspaper claimed "*a horse should continuously pull this vehicle in order to give the vehicle approval"*. This statement seems nowadays funny but shows clearly the human approach to a new innovative way of transportation.

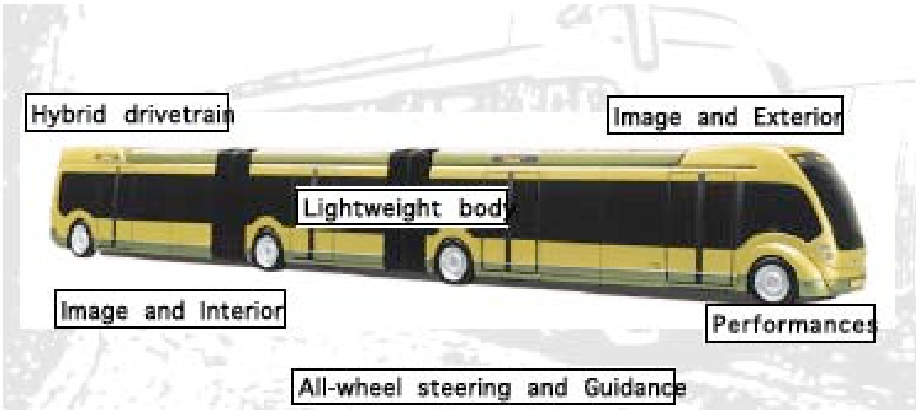
Material and propulsion technology with a move towards sustainability

The general shift in the paradigm towards a sustainable future development has also relevance in the segment of public transportation. Manufacturers strive to reduce the weight of vehicles, try out new materials and experiment with new types of propulsion as well as systems solutions are certain indications of this trend. The conventional tram has a weight of around 1,3 t/m and the Phileas system is offering a weight close to 0,8 t/m with about the similar performance in a certain spectre of demand. Other comparisons are telling the same language of innovation towards sustainability. HALL and VREDENBURG (fall 2003:61 in MIT Sloan Management Review) are claiming: "*A strategy that integrates the goals of innovation and sustainable development is needed. In contrast to conventional, market-driven innovation, sustainable development innovation (SDI) must incorporate the added constraints of social and environmental pressures as well as consider future generations. SDI is therefore usually more complex (because there is typically a wider range of stakeholders) and more ambiguous (as many of the parties have contradictory demands*". The development and innovation of B.V. may partly fit into this description, and just as well make the view more complete and "normal" concerning detected barriers on the way to realize innovative intermediate systems in operation. With this in mind will e.g. fuel cell, hybrid or different gas propulsions be a part of the future, perhaps together with ultra-low sulphur diesel (ULSD) and of course electricity, supplied via catenaries or by ground arrangements along the line. New possibilities to store electricity may also lead to a shift in the technology of vehicles equipped with electro engines. The development of different composite materials (like the use of polyester sandwich panels in Phileas) and extensive employment of aluminium alloy frames will represent another part of the outlook.

Continuing to site HALL and VREDENBURG (fall 2003:62 in MIT Sloan Management Review): *".., competency-enhancing incremental innovation is insufficient to meet sustainable development pressures. Instead competency-destroying radical innovation is needed, and will ultimately challenge current business practices*." This statement seen together with the common acknowledged importance of having or acquiring the appropriate set of corporate capabilities, gives a natural approach to the next paragraph. It shows how APTS have been capable to gain a set of capabilities by connecting the right development partners as well as keeping a clear strategy through a systems approach.

Getting into a systems approach

APTS, the manufacturer of the vehicle Phileas in Dutch Helmond, close to Eindhoven, has taken a systems approach to the product development, production and also operation (!), as we will see in chapter 5. Each area of technology has got a certain focus, a certain partner of development -in order to hold the sufficient sets of capabilities- and therefore special attention towards improvement as shown on the picture below.



Phileas innovations to meet Rapid Transit system requirements (Source: APTS)

The R&D risks are shared in his corporate constellation and the contractual and commercial links between the partners must therefore be paid special attention in order or have a fruitful synergy of cooperation.

However, there is no doubt that e.g. the cooperation with Fokker in matters of body and structural works brings a totally new approach to the work out of innovative frame and flange materials. The “everlasting” and very robust lightweight sandwich panel in Polyester-Vinylester-Carbon-Al speaks its own language. Of special interest to the discussion of B.V. will be the guidance technology, where Frog is the technology partner. The magnetic guidance system of Frog can be considered as matured technology for speeds up to 25 km/h, as it has been in operation in the so-called automated peoplemovers (APM) at Schiphol airport of Amsterdam (NL) with reliable performance over a longer period of time. The speed will now become significantly higher as a commercial speed of 30 km/h is aimed for Phileas. But because of the systems ability to “look” 20 m ahead the result will still be a smooth and comfortable voyage, even at a speed of 80 km/h. The computer registration of both wheel turns (distance) and location implies also a safety aspect if i.e. the vehicle should not detect magnets every 4 m (it will stop after having signalled the driver). This technology makes the vehicle easy to drive in operator mode, as it will have a kind of a “snake movement” because the steering abilities of each axle. This may imply an easier training and approach for prospective drivers, for sure compared

with the first (now abandoned) technical solution of i.e. Translohr. According to H. HONDIUS (2004:16 in Stadtverkehr N°6): “The drivers are evidently enthusiastic about Phileas”.
The autonomous magnetic guidance system of Phileas also gives extended possibilities of operation as it allows platooning, which means the possibility to link two or more (!) vehicles together. This may of course be a “big deal” for the authorities concerning the appropriate approvals etc., but shows the possibilities with this kind of innovation. It also implies Phileas as a part of an Intelligent Transport System (ITS). (Interested readers will find more about ITS in science literature and on Internet). Furthermore is it easy to regulate the lateral position of the vehicle in the roadway. An uncomplicated adjustment via computer will give a different wheel position along the line and thus contribute to a reduced long time wear of the roadway/line. The rubber wheels will then not have the exactly same route (position) all the time, as it is the case with a TVR or Translohr solution. Globally considered represents Phileas some kind of a “best of all” solution which will be interesting to follow in the future, whereas the operation over time in guided mode will be the final test this solution needs to perform to gain acceptance within a bigger market, and so to speak to leave the “prototype” segment.

4.3 Additional effects of urban planning, culture and mindsets

Public transport concepts as a result of urban planning and culture

A regions’ culture of transportation and mobility is without doubt an important element in ruling the choices and decisions for its public transport systems. If we consider the matters of transportation as a part of the urban planning, it is obvious that the local specific history and traditions linked to urbanism are of importance. Even if we are focusing on intermediate communities that can be considered as urban spread, the issues are based on the same generic needs of routine, occasional and exceptional mobility. Several places the establishment of tramway lines and other public transport efforts are a political instrument in urban planning. The fact that the average level of subsidies of light rail and bus in Western Europe is around 50%, according to HASS-KLAU, CRAMTON, WEIDAUER and DEUTSCH (2000:71-73), gives further support to this view. City planning and tramway development in many places go hand-in-hand. To upgrade a residential area, a tramline can contribute to a structural solution. It can also be considered as an instrument of social and economic upgrading. A successful project will give local politicians support and a kind of a “sustainable” image, especially just in front of a new 4 or 5 years election period...
On the other hand detects KAUFMANN (2003:5 in Transports Urbains N°104) an absence of issues in the general discussion today, such as concerns about the bike, the pedestrians (“the walkers”), <u>the inter-modality</u> (!) as well as the connections between urbanism and transport. According to the survey, the most frequent mentioned adjective for describing both the public transport as well as cars is “practical”, whereas the word “rapid” is given as the third respective, as the second priority. For sure is also an increased number of inter modal stations already established. These are stations or terminals where tramway, bus, trains and metro lines meet in a limited geographic area and develop certain <u>hubs</u>. Mobility hubs already exist i.e. in means of a national connection net for the US airports and in this text used for describing multifunctional transit centres in cities. Urban mobility hubs will most likely

gain flexibility by adding the qualities of a B.V. solution and as such imply a further contribution to the sustainable mobility concept.

The car will still be the future main competitor to public transport in most part of the world. This has for sure an effect on urban planning in general and puts high demands on transport management in intermediate areas, where issues such as transfers and efficient hubs are crucial. How can B.V. be considered in such a constellation? The flexibility of the B.V. should on first look be a valuable argument. KAUFMANN (2002:66) states from survey results: "*Although there is a link between comparisons of journey times by car and public transport and modal practice it by no means constitutes an automatic causal relationship, as the non-symmetrical nature of the relationship between modal practice and time comparison suggests and several results obtained from other sources confirm*". This means among several things that a portion of the respondents tends to use the car regardless of the quality of the available public transport! In this sense it would be tempting to argue for B.V. solutions that not only have a "high quality" (see more about this aspect at the very end of this chapter) but also enable car users to use the transport by establishing sufficient park and ride solutions. Another idea could be to use minibuses as feeder vehicles to a certain extent, to impose a bit of the obviously needed "sense of intimacy" among several car users. However, the easiest political action for enhancing the UPTS and environment profile has in many countries been to reduce the car parking capacities in the inner city areas and to dedicate bus lanes! These solutions are normally not that costly, but will automatically put higher demands on the efficiency and the flexibility of the transfer solutions by any UPTS. Moreover, one problem of practical concern is to dedicate bus lanes. Particular in with-flow bus lanes, the lanes are often abused by private motorists. In countries where the general attitude of respecting dedicated bus lanes are low, and other legislative mechanisms do not prevent this attitude, guide ways (= roadways) are to a certain extent self-enforcing. Also street trading alongside the road kerb may be hindered, as it is unlikely to occur on guide ways in the case of a high capacity two-way system. These are not arguments for a certain B.V. solution, but give support to the establishment of a corridor strategy.

If we continue on urban level by considering Clermont-Ferrand (C-F) and Eindhoven: What do the cities of C-F and Eindhoven have in common, and may these features give any explanation to their choice of public transport solutions? Both cities have old traditions within technology, in both manufacturing and promoting means. It is easiest to list some features:

Clermont-Ferrand (F):

- 220 000 inhabitants (342 000 whole surrounding areas included)
- Strong industrial traditions with companies like Michelin (big producer of tyres), Limagrain, Volvic
- Blaise Pascal, born in C-F, invented the first public transport vehicle of Paris
- The fist electric tramway of France began to operate in C-F in 1890
- The (former) mayor was a technician that was interested in the technicalities of both Civis and Translohr solutions. Politicians in the city are technology minded.

Eindhoven (NL):

- 200 000 inhabitants (700 000 whole region included)
- Strong industrial traditions, with focus on high-tech and automotive industry like DAF
- In 1891 Gerard Philips started to produce light bulbs in the city and the company became one of the world's biggest electronics companies with a huge portfolio of electrical products
- The politicians of the city are fund of technology. The slogan: Eindhoven leading in technology!

In addition to the same size, it is easy to notice similarities of the two European cities both historically and politically. But, are these similarities a coincidence in this context or are they describing an environment of willingness and interest to take some risks in sense of being innovative regarding public transport and go for B.V. systems solution? On basis of the findings it may not be a coincidence.

Mindsets and opinions

Mindsets, images and opinions are also important issues when describing passengers' affinities towards certain transportation systems or vehicles. A study in Phoenix, Arizona was designed to quantify the effect of the so-called "soft variables" on personal preferences and behavioural response. It contained a: "*comparison between heavy rail, light rail and conventional bus/busway system in the stated preference experimental design. The analysis confirmed a significant effect attributable to vehicle type – a surrogate for image*". This study, according to SMYTH (1994:157), may confirm a certain "vehicle affinity" among some travellers. However, no bimodal vehicle was under operation in Phoenix as the survey was carried out. Referring to another study from the same paper, executed in Essen and including a bimodal vehicle, the O-Bahn, states: "*It would appear on the basis of this survey that the citizens of Essen attribute little or no enhanced "image" to the guided busway. In other words the O-Bahn vehicles intrinsically do not produce a significantly higher level of preference to that attributable to a conventional bus. Similarly the Essen sample also suggests that the same applies to Light Rail Vehicles or tramways*". The authors own experience from the visit in Clermont-Ferrand, a city without tram but with the Civis system implemented, is that the aspect of the vehicle type as such should not be given superior attention. The accessibility and the performance of passenger information systems will support the traveller to accomplish an efficient transport. One anecdote from Clermont-Ferrand riding Civis: the passengers who entered the Civis and wanted to buy tickets, without knowing that the ticket automat was placed on the station platform, in order to buy the ticket at the bus bay (and

not from the driver). These passengers first perception of the vehicle was most likely secondary at that moment.
KAUFMANN (2003:5 in Transports Urbains N°104) claims that newer surveys, mainly made in France, show that the opinions about public transport in general are alleviating, except in some cities like Nantes and Strasbourg where we experience the positive "tramway-effect", combined with a well functioning offer of public transports in total. The tramway-effect is possible to detect in other literature, like in KÜHN (2002: ch.4.6, CODATU) where the LRT is claimed to benefit from a better image than public transport generally: "*Image is a difficult characteristic to define, but it includes shiny, modern vehicles bearing a special livery (swallows on Montpellier's LRV's), a simple route structure with clearly identified stops, readily available information, penetration of shopping centres, dedicated marketing, and many other factors*". A crucial question will then be: is it possible to transfer the "tramway-effect" to a B.V. in general and what must be done on a systems level in order to gain such positive effect for these kind of vehicles?

Furthermore we observe how the notion "car" has changed from the fifties, as it was rather an object of property, whereas now it seems to be more a consumer good for executing transportation. It can be owned, leased, hired or borrowed/shared. The focus is kept on the individual transportation as such, with the remaining facilities to accommodate an easy, flexible and efficient transport at a fair price. Aspect of feelings seems to have transformed. Seen together with the evidence that LRT attracts car users, what kind of services may then B.V. systems be obliged to deliver in order to add value to former car drivers? Considering the discussions from the first part of this chapter it seems very obvious that B.V. systems are capable to deliver image of high standard both linked to "soft" and more "hard" elements of the public transportation service. As we will see in next chapter it is crucial to choose a B.V system that fits to local capabilities and possibilities. The change in mindset will then follow the success of the operation of the new systems, as they outperform in e.g. flexibility and cost advantage.

5. Systems considerations and conclusions

Since the operation and study of bimodal public transport systems have not (yet) been carried out in large scale in different parts of the world, one approach for comparison will be first to have a closer look at Bus Rapid Transit (or Transfer) systems, abbreviated BRT as well as some comparison towards tramways (read: LRT) systems when appropriate. The study of BRT and the comparison of BRT and LRT is a deductive approach, which will give a well-documented opportunity to advance and consider elements that also are valid for a B.V. system. BRT can in several ways be quite close to a B.V. system, e.g. related to factors like the offered simplicity in infrastructure, the degree of necessity of RoW as well as certain aspects of flexibility.

5.1 Different sides of bus rapid transit systems

The history of BRT' operation

Among several experts BRT already enjoys promising support. HOFFMAN (2004:1) claims that "*Bus Rapid Transit is not a transit mode per se; rather, it is a collection of techniques and treatments by which rubber-tired transit vehicles may be deployed in a variety of services. At one extreme, BRT can describe efforts meant to help improve the operating speed and reliability of "city buses"; at the other extreme, BRT can describe "rail emulation systems" in which train-like vehicles, operating in grade-separated infrastructure ("busways" or "transitways"), provide a "rapid transit" service much like any high end rail-system*". The origins of Bus Rapid Transit are found in Latin America, where planners and officials searched for cost-effective solutions to the demands of the rapid urban growth. The heavy growth of urban Latin America since the 1970ies combined with limited financial resources to develop car based infrastructure implied that: "Latin American municipal planners were challenged <u>to create a new transport paradigm</u>"(!), according to WRIGHT (2003:1). Please note the relevance to urban planning and mindsets as discussed in chapter 4 when reading the notion "paradigm".

The main characteristics of BRT systems, following WRIGHT (2003:1-2), as we also partly find included in the B.V. initiatives are listed below:

- *Segregated busways (normally with a high degree of RoW)*
- *Rapid boarding and alighting (large and systemized bus bays acquired to serve the passenger flows)*
- *Clean, secure and comfortable stations and terminals (the aspect of safety in several concerns (!)*
- *Effective pre-board fare collection (no ticketing inside the vehicles to avoid loss of time for vehicle)*
- *Clean and prominent passenger information systems in real-time (and forecasts)*
- *Transit prioritisation at intersections (will automatically decide the degree of RoW and efficiency)*
- *Modal integration at stations and terminals*
- *Clean bus technologies (: further innovation is the situation by B.V.)*
- *Sophisticated marketing identity (for both attracting customers and creating new (?) mindsets)*
- *Excellence in customer service*

It is obvious that BRT not only is a matter of changing and prepare new transit corridors for high capacity buses. The whole system around the solution must be considered and altered (innovated) in order to work in compliance with the intensions. The complex planning situation of a BRT system is in that sense quite similar with the planning of a B.V. system.

Ten barriers to effective BRT Planning with built-in possibilities

Regional corridor studies, which attempt to compare BRT with LRT alternatives, need to be careful in describing and costing the BRT alternatives. HOFFMAN (2004:1) states: "*The goal in any such study should be to compare and contrast the best possible operating plan for each alternative within the constraints of public costs and timeframe; that is, for a given capital and operating budget (i.e. subsidy level),* what *can each mode best produce, in terms of ridership and community impacts and by* when *can their impacts be produced*?" This kind of "apples with apples" approach must be kept in order not to ignore real differences in operating characteristics by comparing "identical" operating plans for BRT and LRT. Many cities as well as smaller urban areas with suburbs are experiencing a huge difference in practical operating plans, even with similar levels of population. Focusing on the planning aspects of the launch and employment of a BRT system, the planning may suffer several barriers. Rendering *(quoting)* HOFFMAN (2004:1-6) the following aspects are to consider, implemented some possible additional implications relevant for B.V. systems:

1. Overestimating the operating costs of BRT

In e.g. USA transit agency cost allocation models are consistently overestimating the costs of faster bus services because they don't distinguish between kilometres driven in stop-and-go traffic and kilometres driven in limited-stop, high-speed operations. The slower kilometres generate considerable wear-and-tear on the vehicles, and they are notoriously fuel inefficient, especially with alternative fuel vehicles. Faster services, in comparison, generate far lower fuel and maintenance costs. Thus, beginning BRT studies with transit agency cost data for express routes might therefore significantly overstate the real costs of operating BRT vehicles in a high-speed environment. This result not merely hurts the economic performance of BRT, but makes the cost of increasing frequencies or adding express services appear prohibitive when in fact they may be very cost competitive and even cost saving. To conclude with it is important to adjust the operation cost models to reflect the lower per-kilometre cost of faster bus service.

2. Double-counting operating costs

Studies that further fail to differentiate fixed costs from marginal (or variable) costs will double-count those costs. One recent study attempted to account for all possible costs of a busway operation, including station maintenance and security, but then divided these costs among a relatively low-frequency BRT plan, resulting in a high per-hour cost per vehicle. This cost figure was then used for any additional increases in service frequency, even though the fixed costs had already been paid for by the base service. This "double-counting" of operating costs made the costs of operating a high-frequency BRT system seem prohibitive, distorting the true picture of what BRT could have produced.

The danger of double-counting operating costs for a B.V. initiative in Europe is perhaps less obvious if the currently used cost-models are applied. But, at least must the fixed busway operating costs be separated form the marginal costs of adding additional vehicles to a service plan.

3. Underestimating the operating costs of light rail

Corridor studies that compare BRT with LRT alternatives often claim that simply adding additional cars "at minimal cost" may increase the capacity of an LRT vehicle. In fact, "adding another car" is not free; the costs are generally much higher than assumed, due to a common misunderstanding about the performance of LRT systems – namely, that as labour costs are the largest source of costs in transit systems, and since light rail trains need only one driver, then adding a car must be virtually "free". It is true that transit costs are labour-driven, but it turns out that drivers represent only a small fraction of the cost of operating a train – perhaps 10-15% (of course also dependent on the local level of wages, which are much higher in many European countries). Most labour costs are actually generated by maintenance, which in the case of LRT is primarily kilometre-driven. Thus in many cases, LRT plans that use average light rail costs but then rely on additional cars to create capacity will underestimate the costs of providing that capacity with perhaps 25-30 %. Considering LRT options it is therefore important that the project operation costs reflect any increase in train size that the capacity calculations rely on. The prospect of platooning (as mentioned in chapter 4.2 about the Phileas vehicle) is in this context interesting, as the <u>driver costs are constant</u> without regard to the increase in number of vehicles. Besides, with this solution one vehicle may continue individually from the end station (of the guided line) and serve as a feeder route without any special decoupling works or additional costs.

4. Confusing the infrastructure with the "route"

With most light rail systems, the "line", the "route" and the "track" are all but synonymous; when a line is extended, it will likely serve a single route which will typically stop at all stations. Mature BRT systems, like those in Brisbane, Ottawa and Bogotá operate in a different way. The underlying transitway infrastructure will typically support a variety of routes, ranging from all-stops to express. Bogotá (see also below) is an especially interesting example, because it operates transitways in urban corridors, which tend to require much tighter station spacing (average 500 metres) than non-urban corridors. Bogotá operates several all-stops services, each of which deviates at some point from the transitway to serve stations located on branching transitways; it then layers on a series of express (connecting a smaller set of stations) and super express (bypassing large groups of stations to connect one end of the city with the other) services, <u>offering a comprehensive mix of services with a single infrastructure</u>. It is easy to understand that the BRT approach is no LRT "substitute" which offers only a single all-route stop along the proposed infrastructure. Studies of potential ridership demand on single lines, however, will often show that the market exists for a range of services in many corridors, which if provided will likely generate additional ridership. The same is valid for a B.V. solution whereas such system could add additional value by serving as both trunk and feeder line in a more sophisticated net. In all cases the design phase of both BRT and B.V. lines must consider how the underlying infrastructure can be used to support a range of services.

5. Forcing transfers to existing rail systems

Some regional transit studies have seen an opportunity to create BRT lines as "extensions" of existing (heavy or light) rail systems and not as a trunk system (or with additional allocated feeder capabilities like a B.V. system). The idea is that riders would take BRT to the nearest rail station and then transfer. Not denying the important role of transferability in an effective transit system, it is counterproductive to build a system around forced transfers to any mode. Most transit ridership studies have found a significant penalty associated with transfers; while it is possible to design transfers to minimize the negative attributes people assign to transferring, it will always be better to provide single-seat rides where it is feasible to do so. Smart BRT plans look for opportunities to bring people directly to major employment sites, minimizing the need to transfer. Such plans are likely to generate higher ridership than forced-transfer plans, and the costs of doing so may be more competitive than most studies assume. A good example of minimizing transfers is the Phileas launch in Eindhoven; the line will pass the old Philips site planned to contain business areas including start-up localities and residents. For this solution, as wisely for other lines, it is about searching for transfer opportunities within the larger transit system but not cutting lines of infrastructure short just because there is a train station nearby.

6. Not matching capacity (frequencies) to demand

A more basic issue common to some BRT studies are their failure early on, to adjust frequencies to projected demand. BRT vehicles are lower-capacity vehicles than trains; their lower capacity is offset by lower unit operating costs, which permit increases in frequency (generating additional ridership) and the development of express lines (since the threshold at which express services become viable is so much lower with BRT). Still, even assuming a vehicle capacity of 90 people in a 18m articulated vehicle, a BRT route will only be able to provide capacity for 540 p/h/l on a ten minutes frequency service. If initial ridership projections show a peak location flow of 1200 p/h/l, then the service plan needs to be adjusted in one of two ways: either by increased frequencies, or by the overlaying of express services among key ridership stations. However, the underlying economic performance of the system may be strengthened, not stretched, by such increases in service: express operations permit routes to be served by fewer vehicles in service at any one time leading to more productive use of resources. Ottawa has learned this lesson with its Transitway: though Ottawa's bus fleet today is similar in size to its fleet of twenty years ago, ridership on that fleet is significantly higher; what has increased is the system's productivity. It is obvious that demand (ridership) projections must be used strategically to develop a service plan that matches demand to capacity in the most efficient manner.

7. Underestimating BRT infrastructure capacity

Some BRT studies have expressed concern that BRT is unable to provide the capacity of LRT systems. Such claims are based on a misunderstanding of BRT operating characteristics, as well as a lack of knowledge about real-world experience with transitways. The capacity figures from Bogotá mentioned below will definitely prove BRT as a high performance urban transport system. Moreover, for a situation in an intermediate area, as relevant in the context of this work, the issue of capacity will not by any means be a limiting crucial factor of concern, as the demand level will be much lower than every high performance BRT solution may offer. (Point 7 is mentioned as it represents one generic barrier, generally seen).

How is capacity gained on BRT systems? The answer lies in the use of express vehicles, but it is also found in the use of operating nature of BRT; headways of 15 or 20 seconds are feasible with BRT (Brisbane ‘s Cultural Centre station is currently operating at 23 second peak headways without a passing facility), but light rail facilities, due to signalling and electrical systems, can rarely support headways better than 2-3 minutes. So, it is important not to underestimate the capacity of BRT systems only because of a certain vehicle segment’s relatively low capacity. Often enough, the cost of providing high capacity is still competitive with other modal operations, especially if it pulls in additional riders (and as such leads to increased revenue).

8. Ignoring the revenue side of the equation

Operating costs are only one side of the financial picture: revenue is the other side. BRT studies that begin by assuming a specific farebox recovery ratio do themselves a disservice; the revenue potential of carefully considered BRT systems can often produce better financial returns than expected. Vancouver, i.e., has found its B-Line services much more financially productive than traditional bus services, due to the combination of lower operation costs per seat kilometre and the higher demand the service creates for that seat kilometre. This advantage may not be clear in all comparisons, e.g. related to local operation characteristics. An increase in “attractiveness” can in addition be tapped by BRT systems if the shift in mindsets is attained, as discussed in Chapter 4. This “attractive power” can be realised by BRT systems through careful design and local adjustment of the system components (vehicle interiors & exteriors, stations, RoW, process (fare payment, vehicle boarding, use and quality of information, route structure, etc).

Capital costs are also relevant to mention in this place. The total revenue will for sure be strengthened by the “lean” approach of a BRT system. According to a study done by the U.S. General Accounting Office (GAO, Nov/Dec 2001 ref. in metro-magazine.com), BRT systems generally had lower capital costs per mile than LRT. “Capital costs for BRT ranged from $ 200 000 per mile for an arterial street-based system to $ 55 Mio per mile (27 Mio Euro/km) for a dedicated busway system. LRT systems had capital costs that ranged from $ 12,4 Mio to $ 118,8 Mio per mile (60 Mio Euro/km, perhaps including tunnel infrastructure costs)”. Table 2 in Chapter 3 can to a certain extent confirm these figures; the infrastructure costs for a rubber tyred vehicle (within a BRT or B.V. solution) in new lanes are around 5 Mio Euro/km, and 10 Mio Euro/km for a LRT solution. As we see, the amounts for a LRT system count about the double of a BRT solution! Other issues influencing the total financial performance may be subsidy levels and special opportunities where small investments can produce ongoing revenue streams.

9. Ignoring market research

The transit industry in many parts of the world has rarely incorporated market research as one of its core functions for the simple reason that it has been too preoccupied with serving the needs of captive riders in a cost-efficient manner; BRT systems, however, if conceived with the idea of attracting choice riders, must be planned with a careful eye to market perceptions and needs. To illustrate, a number of regional decision-makers may not believe that BRT systems can attract as many riders as LRT systems, that buses are “bad” and tramways are “good”. We are back to the mindset-discussions as presented in chapter 4. Market research has a lot to say about waiting times (particularly for the work trip, frequency trumps mode) walk times (people are willing to walk longer distances to transit from their destinations, and for the non-work trip; that final walk distances are critical), reliability, in-vehicle time, station design characteristics, transferring, and every other dimension of service. Smart BRT planning begins with an understanding of these “divers of choice” so that the resulting plans actually create value for the intended users. These elements can be directly transformed to a B.V. systems consideration and displays the value of appropriate market research efforts for the product.

10. Thinking “thin” corridors

Most traditional infrastructures, such as heavy or light rail lines, create what may be called “thin” corridors – the walking influence of the stations along such lines is generally limited to a rather small radius surrounding the station (perhaps 400-800 metres at the residential end and 250 metres at the work-trip end). Such systems imply a higher dependence on different feeder systems or “drive-up” solutions to gain access.

BRT systems (and B.V. solutions as well), by creating a core infrastructure that may be used by many distinct services, allow for the development of “thick” corridors, in which stations may be located off the alignment itself, with one or more services leaving the transitway to reach the satellite station(s), particularly if a variety of bus priority measures are employed to ensure that the vehicle can break free of traffic. Such a “branching” network structure is characteristic of transit–based BRT systems or certain B.V. solutions; BRT vehicles can pick people up closer to their homes, use the transitway as an expressway to get to key destinations, and even exit the transitway to reach important destinations not actually on the alignment. It is obvious that the whole “balance” between the conventional trunk and feeder systems must be reengineered to fit the performance of a more flexible BRT or B.V. system. Corridor plans that look at BRT alternatives but fail to develop full “thick” corridor options (as distinct from merely allowing “city buses” to use parts of the RoW) will lose out on the opportunity to create more “one-seat rides” among key origins and destinations, and hence will lose out on the opportunity to really push readership above what “thin” corridor systems can achieve.

The BRT launch in Bogotá and some additional numbers of concern

To make the overview more compete for all readers it can be interesting to mention the BRT system in Bogotá, Colombia, called “Transmilenio” (=articulated bus). This city of 6,5 Mio inhabitants has with the implementation of a BRT system in 1998 shown how it is possible to establish an efficient and reliable high capacity public transport system at reasonable cost. The total net of urban transportation is including 48 km roadway exclusive RoW operated by 470 articulated Volvo buses (18 m) and 310 km lanes with separate RoW /mixed traffic operated by 253 standard buses. In total 784 000 persons are transported every day at a price of $ 0,36 (= 0,30 Euro) per fare! The old vehicles have been gradually phased out and a rather new fleet is the result from a certain political “pressure” on the private operators to reinvest in newer vehicles, resulting in environmental enhancements due to lower emissions. With an average commercial speed of 26 km/h the system is circulating 18 hours a day with a frequency between 2 and 6 minutes moving more than 26 000 p/h/d (direction) at peak levels. The buses are spotted by satellite and around 100 persons are engaged in a control centre to control and adjust the performance of the service according to demand and circulation conditions. This advanced traffic control has strongly contributed to the 89% reduction of the death accidents along the line as well as a general decrease of air pollution by 40%, since the operation start-up in December 2000. For 2005 further 40 km roadway, 60 stations and 3 terminals will be in operation, yielding the transportation of 1,3 Mio passengers per day.

Four-lane roadway. Inner lanes dedicated to station enables high-speed bypass (Source: Transmilenio S.A.)

The following future strategic actions will give the transportation system a further strengthened performance, according to the general director of Transmilenio S.A., Mr HIDALGO, interviewed by C. CABIRON (2004:32-33 in Transport public – janvier 2004):

- Prohibition of all use of cars the first Thursday of each month until 2015
- Rapid increase of (car) parking fees
- Dedicate public space solely reserved pedestrians
- Construction of 200 km cycle paths

It is possible to observe how a mix of different system parameters is implemented to obtain a gradually complete system performance. This mix can to a certain extent be claimed, on the basis of the global discussions above, to be generic disregarding the geographical area studied. The four main geographical areas of public transportation systems: Europe (the old cities) /in USA / in South America / in south East Asia do all have their local constraints and capabilities, but for the implementation of a BRT- or a B.V.- system it is about finding the right mix of system parameters.

5.2 Elements of concern transferred to a bimodal system

BRT is mainly described as a solution for larger urban communities, some would say as the "subway" for poor and crowded cities. However, for use in intermediate areas the demand situation will be of some volume only in the urban centre. In high demand areas a BRT system represents an excellent option according to what is mentioned above. In more scarce populated urban structures the needs or resources for the establishment of comprehensive corridors are not existent and the attributes of a bimodal system will cover these needs. With the "10 barriers" in mind, the aspects of commercial operation concerns become an issue. These are linked to local infrastructural constraints as well as to risk considerations, related to the degree of innovation integrated in the system. The vehicles are in this context seen as a part of the system.

The 11th barrier of planning for a B.V. system: *Overestimating the costs of innovation*

It is inevitable not to mention the barrier of risks that are strongly linked to the innovative B.V. vehicles and their system solutions. Higher risks connected to innovations are pulling the vehicle and the system price upwards. Generally the risk can be expressed in both technological and industrial risks, which both correspond to certain additional costs. As all mature technology normally is cheaper than advanced new (unproven) technology it is obvious that the employment of new technology does not have a generic cost advantage as a part of an innovative system. In the early stage of the implementation of a new system like we observe for the project in Eindhoven, which includes an innovative vehicle, unit costs are higher than a "conventional" bus system due to the higher level of technology, small series, less standardisation with high R&D share and system uncertainties. System uncertainties may be generic technology or operating concerns or linked to issues of authority approval. Lohr Industrie has reduced both technological and industrial risk by solely offering the Translohr as a permanently monorail-guided vehicle. The technicality of bimodality is as mentioned given, but the environment is neither prepared for nor asking for a bimodal solution. P. VENTÉJOL and L. DAUBY (2004:24-25 in Public Transport International N°1) claim, by considering the experiences so far with the TVR in Nancy and Caen, including events which illustrate how difficult it is to manage innovation sufficiently well: "*TVR has now provided a wealth of experience regarding difficulties with its commissioning and, more generally, the technological and industrial risks associated with innovation*". They state furthermore that an innovative system will have to be the subject of redoubled attention. Increased staffing and efforts of TVR manufacturer Bombardier led of course to additional costs, but are necessary to carry out adjustments to ensure the TVR's reliability and availability.

However, costs of future B.V. may be reduced through a comprehensive cooperation between manufacturers, approval bodies and future operators. This reduction will especially follow as a result of an enhanced risk transparency, which such cooperation will imply. Risk transparency enhances the efforts in lowering and isolating the total risks. Furthermore, the use of partnerships and/or alliances may strengthen the financial platform and reduce the R&D risks, which will influence the result in a positive way. The idea is that a shift in environment mindset will lead to a big leap towards a sound pricing of innovations in public transport in general and especially for B.V., as innovations then will be managed in a more proper way.

Core system parameters for the choice of bimodal systems

To put direct focus on decision parameters for the choice of an optimal B.V. system, many factors must generally be considered. On basis of the earlier discussions it is possible to point out three special systems planning aspects of concern upon which a decision of system selection can be taken.
If we are able to establish appropriate transit corridors and harmonize these with the different local (intermediate) passenger volumes as well as detecting the certain needs of flexibility, a basis for the systems decision may be established. There can be other important local elements of consideration too of course, but in a generic sense it is claimed that the three mentioned aspects would be sufficient.
Figure 1 below shows the three parameters, with the "Area of optimal decision parameters". This area is nothing else than the right local mix of the three mentioned parameters, on which a bimodal transport system for an intermediate area may be selected. To call the parameters "demand elements" will be just as correct, as it is all about covering the existing needs within the local capabilities and possibilities.

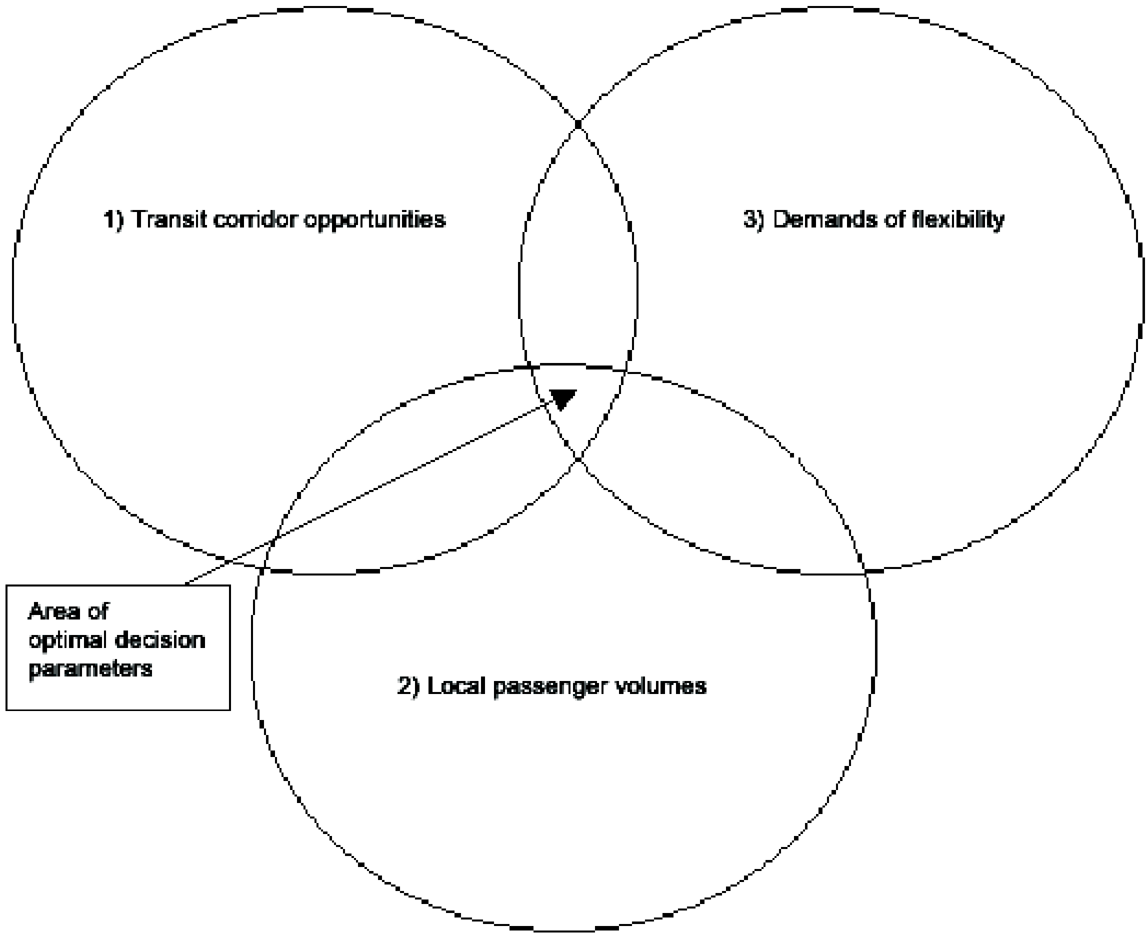


Figure 1: Core system parameters of decision for the selection of a bimodal transport solution

1) Transit corridor opportunities

To establish an effective public transportation system is, as we already have seen, primarily dependent on opportunities of establishing the appropriate transit corridors. It is not enough to have a high-density city centre alone. This is also valid for intermediate cities or smaller urban communities. The appropriate transit corridors (as documented in the relevant local transit plan), will give the B.V. the necessary commercial speed to be competitive and efficient. (Commercial speed of the tramway in Grenoble is 11 km/h in the inner city). The feasibility of corridor establishment with a sufficient RoW will thus be crucial for the success of the B.V. employment!

Establishment of transit corridors may implicate further investment in the existing infrastructure as perhaps the building of new road lanes or in some special cases tunnels or integration into commercial centres and should be kept in mind already on a strategic level.

2) Local passenger volumes

The aspect of adequate adjustment of the transport system to the local passenger volumes is obvious according to earlier considerations. The organisation of the passenger flows is, as mentioned above, crucial to the final situation of demand. For intermediate areas the passenger flow is depending on whether measurements are done in the (urban) core of the society or in the scattered populated surrounding areas. The ability to efficiently handle a large fluctuation in the ridership is a quality of the B.V. solution. Dimensioning a system for the peak hours, with a forecasted average of 60 or 80% of maximum capacity is normally sufficient, as the hourly theoretic capacity of the line must be much bigger than the real volume of passengers. This is especially the fact for demands above 10 000 p/h/d.

Vehicles (L = length)	**Total number of places**	**Theoretical capacity (p/h/d)**
Articulated bus (18 m)	97 - 187	1 949 – 5 820
Bi articulated bus (25 m)	140 - 267	2 800 – 8 400
Civis (18 m)	110 - 197	2 000 – 6 000
TVR bimodal (25 m)	151 - 270	3 020 – 9 060
(Translohr S bimodal (25 m))	146 - 262	2 900 – 8 700
Translohr ST (30 m)	150 - 275	3 000 – 9 000
Citadis TGA 202 L (22 m)	142 - 261	2 840 – 8 520
Citadis TGA 302 L (31m)	204 - 365	4 080 – 12 240
TFS (Fr. Std.) Alstom,Grenoble (29m)	174 - 312	3 500 – 10 500

Table 3: Theoretical vehicle capacities at 3 min. interval (Source: KÜHN (1998) CODATU conference Tab. 1.)

Like Table 3 shows, none of the considered bimodal vehicles will have any problem fulfilling a shifting intermediate demand around 500 to 2500 p/h/d. It will only be a matter of adjusting the frequencies and modal operations (influencing the commercial speed) according to the local demands. It is important to stress that it is a significant difference between the system theoretic capacity and the real number of persons transported per hour during a day. I.e. a bus will be most optimal exploited at around 200 to 600 passengers per hour. Table 3 also displays that the B.V. vehicles are capable to offer the same higher capacity as a LRT solution if needed by i.e. urban growth through concentration over time.

3) Demands of flexibility

The real demand of flexibility for the system will be the third major concern. It is within the issue of flexibility that the B.V. can add most value to an operator or a city, compared with conventional transport solutions. B.V. transfers competitive advantage through its higher degree of flexibility. It is about reducing or in several cases eliminating the transfer time and in that way get people quick out of the system. Who will wait 20 min. for a transfer when perhaps the total tour from the residence to work would cost 15 min. by car? Through fewer transfers the safety is automatically enhanced and a degree of uncertainty is removed from the planning process.

In addition of course, to the three mentioned parameters above, the net present value of the investment to society should be positive, according to a cost-benefit analysis completed before selecting the system. These (theoretical) calculations represent a certain “benchmarking” of system proposals in monetary terms.

Finally, it is crucial to stress the importance of the alignment between the overall (generic) strategic transport planning included its objectives and the system planning. The generic framework in Figure 2 below shows the connections in a lucid manner.

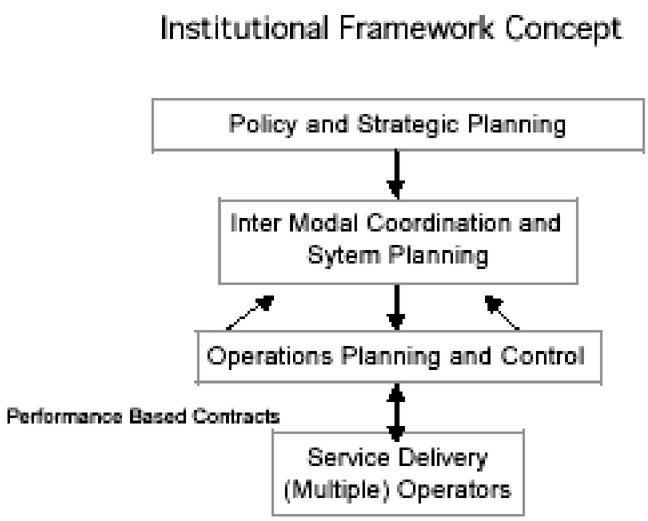


Figure 2: Institutional framework concept for BRT network (Source: HIDALGO (2004) SUTP-Asia)

Inter modal coordination is placed on the same “level” as the system planning and will for the employment of a B.V. solution need special attention. All three earlier mentioned core system parameters are in this hierarchic system concerns with a tight connection to the strategic planning.

5.3 Final thoughts and conclusions

Concluding from the discussions above it is obvious that the thorough implementation of a B.V. system in intermediate areas represents one good solution for transportation. Some B.V. may be used as in a BRT system and/or add value in terms of operation in flexible extensions or in special transfer situation, perhaps taking over a part of a feeder network. Operation cycles, manners and routines must still be studied more thoroughly with an innovative touch in order to find intelligent solutions of application to add value for the UPTS chain. In this context further shifts in paradigms or mindsets will also be needed to nurture the environment for future innovative employments of B.V. systems. The total performances offered by B.V. systems will hopefully give incentives for transport authorities to invite to tenders and establish contracts based on performance and total systems solutions before selecting a specific vehicle/transportation system.
Is the true comprehensive employment of bimodal public transport vehicles only a "hit in the air" or a part of a serious efficient public transport system of the future? Keeping in mind the experiences so far and considering the solutions for possible systems and technology barriers, it is possible to claim the latter. Each specific B.V. system represents, in general, one sustainable way for mobility in the future. Much will, as mentioned in this work, depend on the systems conditions as well as the ability of alignment of governmental objectives (finally ruled by legislation), the corporate strategies of vehicle manufactures and the future needs of the travellers around the world.

It is suitable to close with the statement of VENTÉJOL and DAUBY (2004:25 in Public Transport International N°1), discussing lessons learned from the service entry of TVR in Nancy and Caen: "*The benefit of the process has been to draw lessons from the mishaps that have affected the two networks in order to reiterate a few basic principles as regards demonstrating innovative material and contribute to introducing a regulatory and technical environment more conducive to the innovation that our sector cannot afford to do without*".

6. Glossary and references

Glossary:

CERTU: Centre d'Études sur les Réseaux, les Transports, l'Urbanisme et les constructions publiques (Lyon, Fr.)
INRETS: Institut National de Recherche sur les Transports et leur Sécurité (Paris, France)
RATP: Régie Autonome des Transports Parisiens (Paris, France)
SMTC-AC: Syndicat Mixte des Transports en Commun de l'agglomération clermontoise (Clermont-Ferrand, Fr.)
UPTS: Urban Public Transport Systems
B.V.: Bimodal public transport Vehicle(s)
RoW: Right of Way

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