The Blueprint for Chain Mobility

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Abstract

Door-to-door travel using public transport is still much of an illusion these days. It even seems to be increasingly impossible by car. Is Chain Mobility the answer? Is there a vehicular blueprint for such Chain Mobility?

Chain Mobility means gearing transport systems to each other in such a way that virtually no time is lost in changing from one to the next. This requires a flexible and better manageable transport system that is profitable in time and kind to operator and passenger alike. Automated people movers by design would fit well in a chain mobility approach. There are over a hundred applications, however relatively few in public transport.

Three complementary people mover systems require no physical guidance. There is a main line (Phileas) with a high frequency, supplemented by a demand-dependent system (ParkShuttle & CyberCab) to serve the capillaries of the network, thus guaranteeing optimal connections within a network. They make use of FROG navigations systems and the FROG Supervisory software, allowing a good platform for system integration. The more vehicles become automated, the easier it is to gear them to each other and achieve a higher level of Chain Mobility.

With this, one could argue that a blueprint for Chain Mobility is available today! What is needed is a chance to test this blueprint in reality.

Keywords: Public Transport, Electric Vehicle, City Traffic, Battery Electric Vehilce, Hybrid Electric Vehicle.

1 Mobility

1.1 Mobility Growth

Mobility contributes to economic growth and social interaction. In Europe, the transport sector represents around 10% of the community's GDP and 10% of EU employment. Over the past 25 years, goods traffic has increased by 75% and passenger movements by 110% [European Commission, 2003] .
With the enormous growth in mobility, one can also witness the negative impact on the environment and well-being trough increases in traffic congestion, air and noise pollution, land use for infrastructure and traffic casualties. Governments face the task to allow an increase in mobility for the sake of economic growth whilst keeping the negative effects of that growth in check.

In most countries mobility has increased far beyond the normal population growth. In the Netherlands, a 21% increase in traveler kilometers was registered from 1985 to 1999, whilst the population growth was only 9% [Bockstael-Blok, 2001]. The extra growth must be attributed to changes in social and economic activity patterns as well as in changes in the composition of the population.

Dutch public transport mobility in passenger kilometers has increased with 55% within the period of 1985 to 1999. The modal share however has declined since 1960 with a 34% share in 1964, to a share of about 12% currently. Although there was a larger growth rate in the public transport, the modal share remains limited compared to the automobile. The car with a modal share of 74 % (1999) is apparently still the preferred choice.

Better than public transport, the automobile is well suited to counter the ever-changing mobility patterns of today. Public transport does not have the flexibility and refined distributed access like the automobile has. Although with the high car ownership in many countries, parking difficulties and traffic congestion start to erode the true and fast door-to-door convenience that the automobile once ensured.

1.2 Mobility as a Problem

Mobility is rapidly becoming one of the biggest problems in modern day societies. Traffic over land, water and in the air increases to an extend that exceeds the capacity of the infrastructure. For land transport capacity problems are foreseen for all modalities. It leads to congestion in city centres and on highways, while railway connections also reaching maximum capacity. The arteries of the transporation network are being blocked for an increasing number of hours per day and days per year.

Congestion becomes a risk to economic growth and, very important to make it the social issue that it is, affects the freedom of people. Personal mobility is related to a feeling of freedom and is such an essential human need, that in spite of traffic jams and high fuel prices people persist in their right to move – the right to move where they want and when they want!

The mobility problem calls for new solutions. New policies or new means of transportation to relief the transporation network from its stress. Throughout history mankind has shown creativity time-after-time by improving mobility through innovations in the triangular relationship between humans, 'transportation devices' and infrastructure. Improving mobility by either adapting policies and introducing 'traffic rules' and regulations or by introducing new means of transportation. This relationship hasn't changed, but the environment of the relationship has changed dramatically, influencing the relationship itself.

Where in early days innovation in a single aspect created a dramatic improvement, such as the introduction of roads to reduce travel time in Roman ages, this is nowadays more difficult. The introduction of new roads, if at all possible with limited space available, increases capacity temporarily and at specific locations only. Bottlenecks are shifted to another location and the additional capacity leads to more traffic and thus to the same situation as before the addition of the road – at the expense of more exhaust.

New policies are usually considered first as they do not require any changes to the existing transporation network. In ongoing discussions mobility trends become apparent – the trends in their turn influence the developments started. Innovations are often a result of the mobility trends at time of their origination. Mobility trends in the past led to the development of the carriage, boats, bikes, trains, cars and in the end planes. What are the current mobility trends and where will they lead to ?

1.3 Mobility Trends

1.3.1 Closing of City Centres

More and more local autohorities develop policies to discourage people to enter a city by car. Hourly rates for parking are increased in the city center to persuade people to park away from the center and use public transporatation towards the city centre. The congestion charging of London is another example of measures taken to persuade car drivers to avoid the city centre. Some cities even develop plans to entirely ban cars from city centres. A book (Carfree Cities) and website (carfree.com) have been dedicated to this subject. On the website the problem and solution are stated as:

> ***The problem***
> *The industrialized nations made a terrible mistake when they turned to the automobile as an instrument of improved urban mobility. The car brought with it major unanticipated consequences for urban life and has become a serious cause of environmental, social, and aesthetic problems in cities. The urban automobile:*
> - *Kills street life*
> - *Damages the social fabric of communities*
> - *Isolates people*
> - *Fosters suburban sprawl*
> - *Endangers other street users*
> - *Blots the city's beauty*
> - *Disturbs people with its noise*
> - *Causes air pollution*
> - *Slaughters thousands every year*
> - *Exacerbates global warming*
> - *Wastes energy and natural resources*
> - *Impoverishes nations*
>
> *The challenge is to remove cars and trucks from cities while at the same time improving mobility and reducing its total costs.*
>
> ***The Solution***
> *The urban automobile can only be supplanted if a better alternative is available. What would happen if we designed a city to work without any cars? Would anyone want to live in such a city? Does it make social, economic, and esthetic sense? Is it possible to be free of the automobile while keeping the rapid and convenient mobility it once offered?*
>
> *Public transport is typically a disagreeable and slow substitute for the car. It needs to become a pleasant experience and should attain the average speed of a car in light city traffic. This can be achieved using proven technology, but densely-populated neighborhoods are a prerequisite for rapid mobility and economical public transport. Fortunately, dense cities can also offer a superior quality of life.*
>
> *We should build more carfree cities. Venice, the largest existing example, is loved by almost everyone and is an oasis of peace despite being one of the densest urban areas on earth. We can also convert existing cities to the carfree model over a period of decades.*

It is obvious that policies alone do not suffice to create the carfree city described. Innovations of transportation devices in combination with infrastructure and humans will be required.

1.3.2 Reduction of …

…Urban Pollution

Urban pollution is a major concern in (especially) larger cities. The pollution caused by traffic and congestion directly harms the quality of living. World wide there are several cities that are faced with smog alerts on sunny days. The most well known example being Mexico City, but other countries are faced with the same problem. 'Drastic' measures include prohibiting drivers the use of their car on certain days and additional taxes to make automobiles less attractive.

…Space Wasted for Parking

Both in city centres and at business parks policies are implemented to limit the number of parking places. In cities the number of parking permits are often limited, thus providing another incentive for people to refrain from buying a car. If parking places are created in city centres new garages are often created underground – getting the cars of the street to establish a better looking street. Although this policy is only cosmetic, the consequences are felt in terms of costs! The costs of underground parking are high and as a result automated, cheaper alternatives to manual parking are now being developed and implemented for underground garages.

At business parks the number of parking spaces are also being limited to persuade employees to travel to work by means of public transportation. The number of spaces per company is based on the number of m2 rented or owned. The result is that only 1 in 5 employees has a parking space available. The goal is to provide an incentive for companies to actively get involved in the mobility of their employees and start with mobility management. Mobility management also means the companies are getting involved in the public transportation connection provided to their premises. Often enough companies look for other alternatives, such as remote parking – thus avoiding the intention of the local authorities.

1.3.3 Chain Mobility

As inner cities and highways experience more congestion, government and local authorities develop policies stimulating the use of public transportation. To improve the service of busses and trams over the comfort delivered by the personal car, dedicated bus lanes are realised at the expense of car lanes. Simultanously there is a general quest for quality improvement – e.g. better connections and more service. The challenge is to persuade people to change their transport habits.

Using public transport often requires using different means of transportation. Because of this the weakest link determines the attractiveness of the complete transportation chain. The weak spots of the transportation chain are at transfer points (waiting times between different connections) and the feeder transport towards the first stop and from the last stop to the final destination. Often the first and/or last link in the transportation chain prove to be the weakest link. The popular statement is that public transpartation takes you from a place you are not, to a place you need not be, at the time and in company of people you don't want, for a price that is too high compared to the service offered! Optimization of the transporation chain, with minimal waiting times at transfer points and door-to-door transportation is required to make public transporation (more) competitive and a real alternative to the individual car.

1.4 Future Mobility

From the different mobility trends it becomes apparent that door-to-door transportation by means of a single mode of transportation will become more rare in the future. Even when travelling by car a door-to-door journey will no longer be guaranteed. The concept of chain mobility will become increasingly important. For chain mobility to work optimally, the different modes would need to be tuned to eachother. In an ideal world and theoretically this is possible, in the real world tuning remains difficult because most transporation systems never run exactly on schedule – being either ahead but more often behind planned times.

The optimum form of chain mobility is achieved when services are either very frequent or flexible (on-demand). Both forms ensure the waiting times at transfer points are minimized. Now the need is a transportation policy or transportation system that can meet these requirements.

2 Improving the Transportation Chain by Automation

The transporation chain can be improved by using automated systems. Automated system can be available at a higher frequency or at-demand with increasing the operational costs. Thus service is increased while the fares can remain affordable. To establish where the transportation chain can be improved by automation, it is important to know which types of systems are available on the market, which type of applications they are suited for and what achievements have been reached to date.

2.1 Innovative Transportation Systems

Many companies have seen the opportunity of improving the transportation chain and have started with the development of new transportation systems. Some examples of new transportation system have al ready become well known, while there are still many other systems that are still being developed. In 2000 there were 73 different concepts in operation at 106 locations – while in 1985 there were a mere 36 applications. The number of applications will continue to grow rapidly the next years, as the problems with the current transportation network become even more severe.

However, there is no system that is the remedy for all current transport problems! Even now we have different means of (public) transportation within cities, so why should an automated system be expected to replace all these different modes? The characteristics of automated systems are different, thus making them suitable for certain applications. Five characteristics can be used to establish a distinction:

- Transportation concept
- Type of guidance
- Suspended or Supported (and the typical level of implementation)
- Development stage
- System capacity

The transportation concept relates to the number of passengers per transportation unit which establishes the nature of the transporaton service. A distinction is made between:

- Personal Rapid Transit (PRT): typically 4 to 6 passengers per unit
- Group Rapid Transit (GRT): between 8 and 30 passengers per unit
- Mass Rapid Transit (MRT): over 30 passengers per unit

Most of the manually operated transport systems currently operational are mass transport systems (e.g. train and bus). It is only logical that through developments, automated versions of the systems become available. In direct contrast is PRT: Personal Rapid Transit. Although no real PRT application has been installed to date, the concept is not new. In the '50s the concept was al ready conceived and through the years many people have adopted it. Where a PRT vehicle could be compared to an automated taxi, a GRT vehicle resembles an automated mini bus. Group Rapid Transit systems have been installed at various locations.

Another distinction that can be made is the type of guidance used – a distinction from a technical perspective, but with a big impact on its environment however. The type of guidance heavily influences the infrastructure which, in its turn, has a big impact on the surroundings. Four main categories of guidance are currently applied:

- Rail guidance: vehicles are guided by a single or multiple rails
- Infrastructure/Cable guidance: vehicles are guided by infrastructural elements (e.g. walls) or a cable.
- Free ranging: vehicles guide themselves while reference points are used for position verification.

As soon as guidance is embedded in the infrastructure or forms an integral part of the infrastructure, it requires higher investment and maintenance costs.

For the level of implementation (at grade, elevated or underground) it is also important to distinguish if it concerns a supported or suspended transporation system. Suspended systems are always created elevated as at grade is not possible and underground is unlogical and would lead to very high costs. Supported systems, however, are not all limited to a single level of implementation. Systems that are typically implemented at grade, can also be elevated by simply raising its' infrastructure. This flexibility is required at times as at grade operations is not always possible in more densily build areas. The possibility to operate at grade however, means the costs of the infrastructure are minimized.

The development of automated transportation systems can be in different stages. Some systems have been implemented and are operational at multiple locations al ready, while others only exist on paper awaiting further research or funding. Three stages of development are distinguished: operational, testing, conceptual.

A final distinction between systems can be made on the basis of system capacity. System capacity determines in which situation a concept is applicable as both under- and over capacity should be avoided. The system capacity is determined by the capacity of a single unit, operational speed and minimum headway between vehicles, number of stops and delays at these stops, accelaration and deceleration.

The table below provides an overview of the systems developed or being developed, distigiuished by their characteristics, by the year 2000.
From this table it can be concluded that:

- Most systems are operational on an elevated (+1) level;
- Most systems focus on mass transportation;
- Most systems use physical guidance (rail);
- Most systems are in the conceptual stage.

			PRT			GRT			MRT			
			free ranging	rail guided	infrastructure / cable guided	free ranging	rail guided	infrastructure / cable guided	free ranging	rail guided	infrastructure / cable guided	Totaal
Supported	Suspended +1	Conceptual		11			2			12		25
		Testing		2	2		3			1	2	10
		Operational					5	5		14		24
	0	Conceptual		1			3					4
		Testing										0
		Operational	1			1		1	1	1	1	6
	-1	Conceptual		2						1		3
		Testing										0
		Operational								1		1
		Total	1	16	2	1	13	6	1	30	3	73

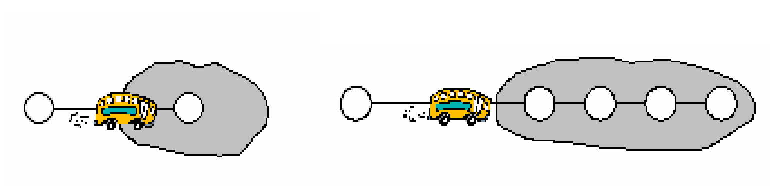
Since 2000, some of the existing concepts have taken a next step and some new concepts have been introduced. The table above thus might look differently now, but most likely the distribtution of activities will be the same. Most systems focus on mass transportation, using physical guidance. These innovative systems continue on the legacy of 150 years of public (mass) transportation. From this point of view it is only logical that MRT has the most operational and conceptual systems, since development was based on current systems.

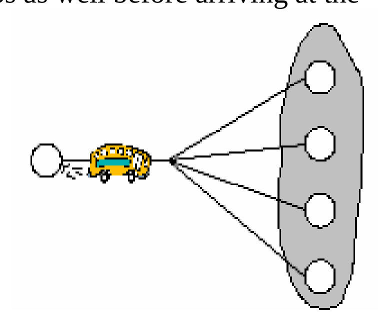
Striking is the large number of conceptual PRT systems while no systems have been implemented thus far. Especially regarding the fact that the idea for PRT is almost 50 years old. Several transportation professionals claim that PRT is the future of public transportation: fulfilling every need of today's demanding customers. This explains the large number of companies involved in PRT.

2.2 Demand Characteristics

An application and it's characteristics determine which type of system is suited. The demand characteristics for an application can be divided into the following three categories:

- *Spreading in time:*
  Indicates whether or not people arrive together on a certain node. For example there is no matter of spreading in time when a train arrives at a station and the travellers have to be transported further by means of an automated transportation system.
- *Spreading in space:*
  Indicates whether it is possible to travel to different nodes / destinations with the same mode. When there is spreading in space this does not necessarly mean that there is a connection without intermediate stops. It is possible that the system will stop at other stops as well before arriving at the destinated stop of the traveller.





- *Activity density:*
  The activity density indicates how many people want to travel to a certain spot. So the activity density is high in the city centre, because a lot of people want to travel to it (for example for shopping or working reasons).

As Mass Rapid Transit system is especially suited when there is high activity density, but the spreading (both in time and space) is small. Although PRT and GRT systems able to handle a high activity density exist, they are not capable of offering the same capacity as a mass transit system. However, when multiple nodes need to be connected, a PRT or GRT system might be just as attractive as a mass transit system.

A Group Rapid Transit system is especially attractive when there is little spreading in time. As people arrive in groups, a PRT system is less suited. The spreading in space and the activity density are preferably moderate, but some GRT systems are able to handle low and/or high spreading in space and/or acitivity density as well. Hence the GRT system will in some cases compete with both PRT and MRT systems.

The PRT – Personal Rapid Transit – system is suited for applications with a high spreading in time as it can deliver tue on-demand service. Multiple destinations, spreading in space, should not be an issue but does require the infrastructure to those destinations – which in most applications can become a problem. PRT system are known to be able to handle a relatively large number of people per hour (high activity density), but when there is little spreading in time a GRT or MRT system will quickly become a more valid alternative.

2.3 Achievements

It is not easy to determine the success of automated people mover systems. If one takes the research efforts by General Motors in the late fifties as a starting point, then just more than a hundred operational applications may not sound like a runaway success. Say 2.5 applications per year over the last 40 odd years. Some very successful in terms of passengers flows and revenues, others turned out to white elephants, costing the taxpayer dearly.

Most of the applications around can be found in the USA and Asia. However in terms of financial investments, Asia and Europe lead the pack. This can be explained by the fact that more heavy duty public transport systems were built here [de Bruijn, 2002]. In the USA, the systems are smaller and often applied in entertainment parks, at large institutions and airports. These applications often involve only one or two parties and require no connection to existing networks, which makes is easier and faster to implement. In total, only 25 percent of the applications serve in the public transport sector. Why not more? A few reasons can be formulated:

- Only but a handful of tested and proven systems are available in the market.
- Unfamiliarity of national and local governments, as well as public transport operators
- Initial investments required for dedicated infrastructure may put politicians off.
- Unclear or insufficient financial gains in operation of the driverless systems.
- Limited effect on travel time reduction for travelers.
- General inflexibility of re-routing due to often elevated and dedicated infrastructure.

Fact remains, that car use and ownership continues to grow, congestion will be hard to control, fuel prices stand to increase and more so, public transport operators in developed countries see the average age of their workforce increase and salary levels rise. Advances in technology will make automation more affordable, reliable and efficient. This is bound to have a positive effect on the development of automated people mover systems.

So far the development of the automated people mover systems has been little coordinated. It was GM that started research in how to automate the automobile. Eventually the first people mover, a monorail, was built in 1960 near an American Entertainment park. Only in 1972 a first people mover was put in operation at an airport. No single person or company can be accredited with having ‘invented’ the automated people mover.

Companies, mostly already involved in building people movers, started working on the development of their own systems independently. Not much of standardization in systems and technical specifications can be noticed. 40 years onwards from the introduction of the first people mover, the market has not yet matured. Companies with roots in rail-industry, lift- and ski lift industry were well placed to built automatic people mover systems. Companies active in the entertainment industry also play a part. The car-industry takes the automobile as transport unit, working on guidance systems and anti-collision systems. It is not far fetched to expect a convergence of both approaches in the near future.

3 The Blueprint – Integrating Technology

If Chain Mobility is the solution to make public transportation more attractive and a more valid alternative to the personal car, the integration of the different links of the chain is key. This integration between the different links is most easily achieved by automation. A human will never be as accurate as a computer – both in driving as in timing. Integration between different automated systems is possible, but integration using the same technology in different concepts is rather easy in comparison.

In the Netherlands three concepts using the same basic technology have been developed: Phileas (MRT), the ParkShuttle (GRT) and the CyberCab (PRT). In comparison to other automated transportation concepts, there are distinctively different for several reasons:

- The concepts are electronically controlled, not guided by rail or other infrastructre elements.
- The concepts are complementary to each other – each specifically suited for a different link of the chain.
- The concepts use the same vehicle software and can be controlled by the same supervisory control system.
- The supervisory control system can communicate with any other information system to import/export data 'real-time'.

The three concepts have 'Frog Inside' – the navigation technology first developed nearly 20 years ago by Frog Navigation Systems and applied in many industrial indoor and outdoor applications since. With 'Frog Inside' the vehicles navigate and by means of the supervisory control system SuperFROG the different systems can be synchronized amongst each other.

3.1 Technology

3.1.1 FROG Vehicle Navigation

The operation and navigation system of a vehicle consists of three elements : route planning, odometry and calibration.

Route planning is done in the supervisory control system. Through a CAD-like program the routes can be drawn, with elements (e.g. stopping points) and profiles (e.g. speed) being attached to the different sections of the route. Additional elements such as action points can be added to optimize the operations of the vehicles. At the start up of the system all vehicles check if their on-board map is the same as the map used by the supervisory system – if not the new map is downloaded immediately. This map is the basis of the operations of the vehicles: route planning.

Inside the vehicles, passengers can indicate their destination by means of a simple push button – the operations resemble those of a horizontal elevator. The destination is a transport assignment for the vehicle. Based on the on board map the vehicles themselves will plan the shortest route from their origin to the indicated destination. During travel, the vehicle keeps track of the distance and direction traveled by measuring the number of wheel revolutions and change of orientation (encoders and gyro) : odometry.

Through odometry a calculated position on the on board map is established. However, different loads influence the accuracy of the calculation as with larger loads the wheel diameter becomes smaller, increasing the number of wheel revolutions. To increase accuracy the calculated position is checked against the actual position of an external reference point. The position of these external reference points, magnets embedded in the road surface, are added to the map of the vehicles. When a difference between the calculated and actual position is detected, only half this difference will be corrected to avoid nervous, jerky driving behaviour. Thus the vehicels return to their planned route fluently.

It is essential to realize that the magnets are for reference only. The magnets are completely passive and can be installed in any road surface very quickly – as demonstrated during several demonstrations. The vehicles are electronically guided and plan their own routes independent of the supervisory system.

3.1.2 Supervisory Control System SuperFROG

The supervisory control system, SuperFROG, is fully customised for People Mover requirements. SuperFROG's main tasks are traffic control, lay-out management, communication, and job generation and assignment. The system can be visualized on multiple locations, and operated from where it is convenient.

Work scheduling, the assignment of transport requests to vehicles, is based on a customized set of rules (framework of conditions). The rules incorporate elements such as vehicle availability, distances, layout and transport requirements. Generation of transport request is done by push-buttons at the stations of the system or generated automatically based on logged patterns of transportation requests and/or synchronization with the arrival/departure of other modes of transportation.

As a traffic cop, SuperFROG directs traffic based on well-defined traffic rules. At crossings the supervisory systems decides which vehicle has the right-of-way based on the priority of the vehicle. It also controls interaction between the vehicles and automatic doors, elevators and signaling. The traffic cop function optimizes the total system, as vehicles do not have to wait for each other to pass.
SuperFROG is also in control of fleet management. This means a.o. ensuring timely recharging of the batteries and keeping log files of all system events and transportation requests. The log files can be retrieved for statistical processing at any time.

The necessary communication to and from vehicles is done via a Radio Frequency (RF) wireless link. Vehicles are in frequent contact to update the information. SuperFROG operates on a Linux-platform. With SuperFROG the vehicle fleet is easily expandable, requiring only the updating of SuperFROG as to how many additional vehicles are active in the system, requiring no costly software alterations. The SuperFROG system is equipped with standardised interfaces to traffic lights, traffic beams etc.

SuperFROG is capable of supporting traffic and/or bus schedules. Different schedules can be supported throughout the day, optimising the system to the needs at any particular time. Main features and functions of SuperFROG:

- Main control of vehicle systems: multisite, scalable, up to 100+ vehicles;
- A graphical user interface, at multiple locations, if necessary;
- Lay-out definition and management;
- Changes in the lay-out can be made, and updated into the vehicles during normal operation;
- Integration with other systems;
- Real-time communication with vehicles and other systems;
- Display system messages and errors, per vehicle;
- Job management and assignment. Jobs are managed from a central queue, and can be assigned to vehicles using different priorities;
- Load balancing of jobs to the vehicle, nearest, best suited vehicle, or alternative definition
- Automatic tracking & tracing of all transports, optionally with feedback to a host computer;
- Traffic control using rules and zones;
- Continuous logging and registration of all vehicle and SuperFROG data;
- Remote diagnose and support via modem or VPN connection (via internet);
- A statistics module is incorporated, data can be exported to Excel, ODBC link can also be established;
- Access control through username/password functionality, 3 user levels, maximum 100 users.

3.2 Product Range

3.2.1 ParkShuttle – a Group Rapid Transit concept

The 2nd generation ParkShuttle vehicle can be compared to a (mini-) bus. It operates on pre-defined routes in the network, stopping only at those stations where people request to be picked up. The rights to the ParkShuttle are owned by 2getthere – a wholy owned subsidiary of Frog Navigation Systems. 2getthere is actively marketing the ParkShuttle concept.

The ParkShuttle in its standard interior configuration accommodates 12-seated passenger and an additional 8 standing passengers. Other interior configurations are available, increasing the capacity per vehicle by reducing seating and increasing the number of standing passengers that can be transported. Seating is comfortable with personal space exceeding normal public transport standards. All seats are supplied with headrests for additional safety. Standing passengers use supports during travel.

The maximum speed of the ParkShuttle is 40 km/h. The system environment will determine the actual operational speed of the vehicles. As an example, it is advisable to avoid sharp turns, since the speed needs to be reduced significantly to enable smooth and comfortable curves. The cabin is spacious and light, and it is well illuminated at night. Large windows provide excellent all round vision and add to the security feeling of the passengers. The vehicles have a lowered floor, accommodating easy access for passengers as well as wheelchairs.

User control functions are grouped together on the centrally placed user console. Passengers will find useful travel information on the interior display and they can communicate directly with a monitoring station via intercom. Interior video surveillance can be installed as an option, as well as heating and air conditioning systems.

Six 2^{nd} generation ParkShuttles will start operation at the extended trajectory between subway station Kralingse Zoom and the Rivium business park in Capelle aan den IJssel (near Rotterdam) end of summer 2005. The vehicles replace the three first generation vehicles that were operational here during a two-year test period. The infrastructure is made double lane and extended deeper into the business park, adding three stops in the process. The operator, Connexxion, expects that the new line will see volumes of 1600 to 2000 passengers per day, up from 700 in the earlier stage.

3.2.2 CyberCab – a Personal Rapid Transit concept

The CyberCab can be compared to an automated taxi. It is fully flexible, capable of stopping anywhere, picking up passengers and transporting them directly to any desination – via the shortest route – in the network. The rights to the CyberCab are owned by 2getthere – a wholy owned subsidiary of Frog Navigation Systems. 2getthere is actively marketing the CyberCab concept.

The CyberCab seats six passengers, while leaving sufficient space for a wheel chair or luggage. Standing passengers are not accomodated to increase the safety of the passengers. Various designs of the CyberCab body have been made – tailored for service at either resorts or inner city applications. The CyberCab operational at the Floriade horticultural fair in 2002, had an open design (without doors) to accommodate the intregration between new, clean-energy, innovative transportation and nature.

The maximum speed of the CyberCab is 40 km/ph. Just as with the design of the ParkShuttle, large windows for good visibility and maximum social safety have been taken into account for all designs. User control functions are present in the vehicle in similar fashion as well. A voice module has been taken into account for audible information to passengers – announcing the next stops as well as more specific messages (all pre-programmable).

3.2.3 Phileas – a Mass Rapid Transit concept

Although the Phileas with its’ rubber tires in first instance seems to resemble a bus, a closer look at its’ characteristics soon makes apparent that it ought to be compared to light rail – but in this case without the heavy infrastructure normally required. The Phileas concept is owned and marketed by APTS (Advanced Public Transportation Systems) from the Netherlands. Frog Navigation Systems supplies the guidance and controls for Phileas.

The Phileas is available in a 18-meter single articulated version for 152 passengers and a 24-meter double articulated version accomodating 205 passengers. The Phileas features several distinctive features on top of the electronic guidance that ensures it has an advantage over competitive systems. The all-wheel-steering concept in combination with the electronic guidance enables the bus to 'crab' (drive sideways) towards a stop. Positioning is far more accurate, lining up all entrances exactly with the platform, and shortening the duration of the stops. Also the infrastructure needed to line up the bus is greatly reduced in comparison to manually driven systems.

The Phileas can be operated in three different modes : manually, semi-automatic and automatic. In manual mode the driver controls both the speed and the position of the bus, while in automated mode these are both controlled by software controls. In semi-automatic mode the position of the bus is controlled by software, while the driver controls the speed. The software drives far more accurate than any human, reducing the width of the road bed required and making the seperate lanes easier to install within dense city environments. The ability to drive the bus manually, a dual mode concept, makes it possible to take the bus of the dedicated lane and on to the normal city streets – and vice versa.

The routing is characterized by straight lines with a limited number of stops (1 to 2 per kilometer, or 2 to 3 per mile), a high average speed and a large capacity. It will be able to achieve the best performance as a 'High Quality Public Transport' vehicle by:

- Offering as many dedicated concrete lanes as possible
- Adapting pavement height a platforms to 320 mm or 12 inches.
- Offering dynamic information systems at the stops, which can be updated real-time
- Keeping the number of stops to a minimum but turning normal platforms into transfer station

Fewer stops contribute to a higher average speed of a transport system, but require a high degree of accessibility to the stop – since people will also walk or cycle to it. If travelers spend more time getting to the stop, the time saved by the higher average speed will be cancelled out, defeating the entire objective : Chain Mobility.

3.3 Chain Mobility: CyberCab, ParkShuttle and Phileas

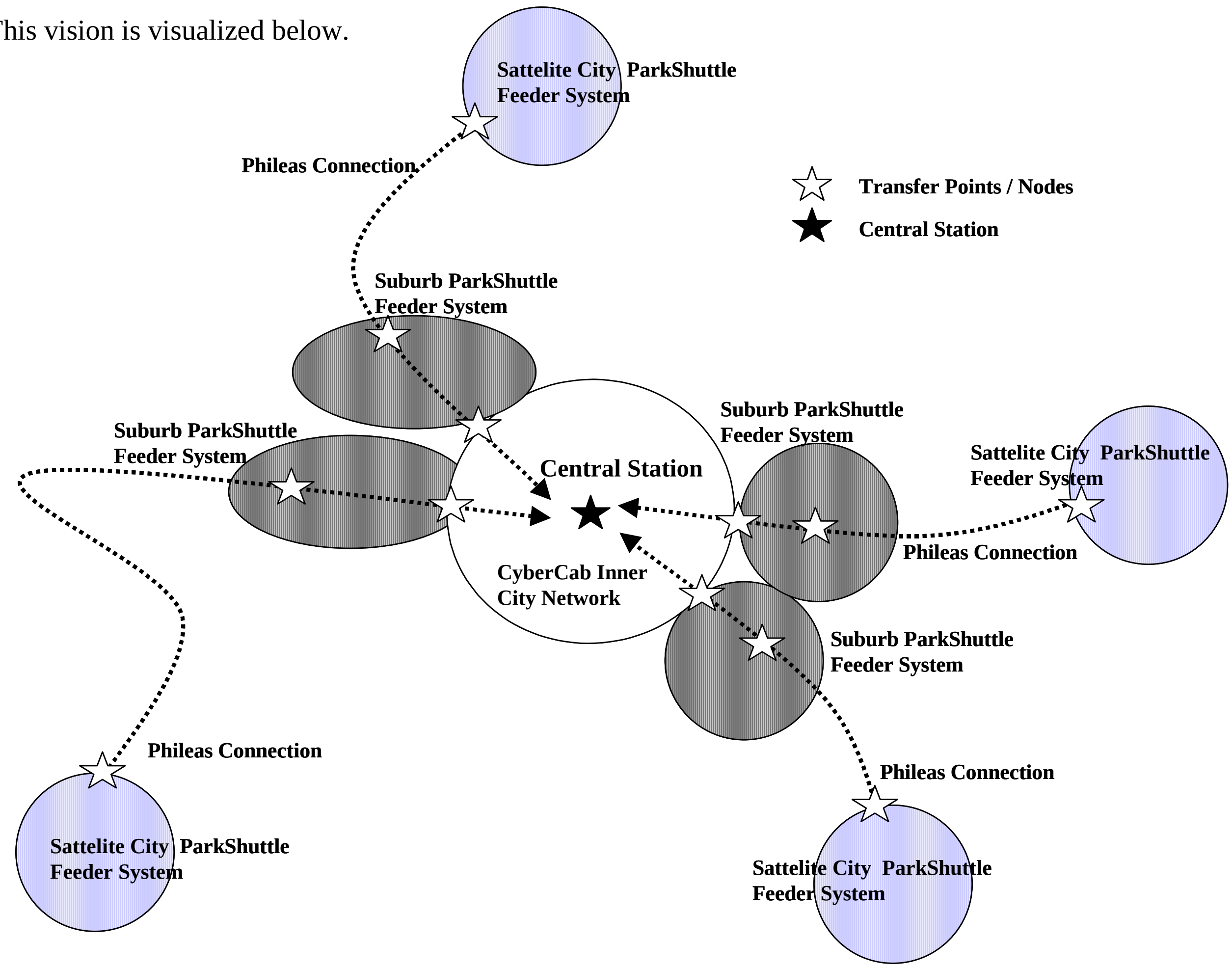
To improve the transporation chain it is important that the systems are interconnected, minimizing the waiting times at transfer points. If all systems operate using the same supervisory control system, synchronization is achieved more easily. A transportation network connecting the whole city, synchronizing the services by public transportation and minimizing travel times. The service will be comparative, if not better than than provided by the car.

Within a public transportation network such as this, the Phileas would connect sattelite cities, suburbs and other more remotely located areas with a relatively high activity density with the city centre. The ParkShuttle would serve in a network in those locations, sattelite cities and suburbs, as a feeder towards the Phileas. Finally, the CyberCab operates in the inner city, directly connecting the most important locations – such as downtown business parks, financial districts, shopping and entertainment venues and public transportation nodes.

To optimize the transportation network, the average speed of the different modes should be a high as possible, while there should also be a dense network of stops. For this reason the feeder system, a ParkShuttle application, will be equipped with a dense network of stops, minimizing the distance to be covered towards the first stop (usually either covered on foot or by bike). The traveling distance with the ParkShuttle will be restricted to a maximum of 6 kilometers, as a longer journey would make public transportation less attractive. The ParkShuttle will dock at a station of the Phileas, synchronized with the Phileas services – allowing for an immediate transfer. Because of this the stops of the Phileas can be spaced further apart, allowing for a higher average speed. In the end, the improvement in the first link of the transporation chain thus improves the chain as a whole : it is as strong as its' weakest link.

The personal rapid transit system would be installed in inner cities, providing direct connections. The CyberCab will dock at Phileas stations at several points, allowing for transfers. In principle, however, it is not designed to allow transfers, but rather to establish direct connections. Where Phileas is used to connect sattelite cites and suburbs to the city centre, e.g. the central station, the CyberCab connects the different facilities within the inner city (also with the central station).

This vision is visualized below.



4 Conclusion

Mobility growth requires a balanced approach by governments as it contributes substantially to the economy, but also has a negative impact on the environment through the traffic it generates. Increase in collective transport will reduce the traffic burden, without impeding on the freedom of mobility. To achieve this, public transport has to become more like the automobile and vice versa.

Trips per automobile normally require only short first-and-last-link sections. By taking a chain mobility approach to the transport system, these first-and-last-link sections will get the attention they deserve. Task for vehicle manufacturers is to provide tools and vehicles that allow for easy management and control, making it possible to reduce transfer time between travel modes.

Automated people movers can be fully controlled in their movements and hold good prospect for real time interaction with other transport modes. Automated people movers have proven their qualities in large and medium scale applications like metros and light-rail systems. Interesting developments are taking place for the smaller vehicles that allow influence by the passenger in destination and routing.

The blueprint for Chain Mobility is available today! It consists of a main line (Phileas) with a high frequency, supplemented by a demand-dependent system (ParkShuttle & CyberCab) to serve the capillaries of the network, thus guaranteeing optimal connections within a network. The more vehicles become automated, the easier it is to gear them to each other and achieve a higher level of Chain Mobility.

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