CyberCars: An Alternative Public Transportation for City of Tomorrow

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ABSTRACT

Most European cities faces numerous challenges associated with the use of private vehicles. In order to solve the problems by the overuse of private vehicles, such as road congestion, energy expenditure, noise and pollution, a consortium of 15 European research institutes and private industrial companies, have grouped together to form the CyberCars/CyberMove programs, sponsored by the European Community. The programs objective is to create a new form of public transportation, which can offer an alternative between the private vehicles and the mass public transportation. Cybercars are an Intelligent Transport Systems based on road vehicles with fully automated capabilities, or CTS (Cybernetic Transportation System). This paper describes the background, main objectives, basic idea, and key technologies of the programs, and their experimentation in several European cities. The possibility of applying CyberCars technologies inside the Shanghai World Expo 2010 is discussed in the end of this paper.

1. Introduction

Most European cities faces numerous challenges associated with the use of private vehicles. The private vehicle is certainly one of the most convenient transportation means and this has led to its huge success during last century. However, the overuse of private vehicles brings problems like road congestion, energy expenditure, noise and pollution, all of which degrade the quality of urban life. Beside that, it is a fact that not everybody has access to the private vehicle. Although in developed countries, there is almost one car per person able to drive, the young, the poor, the elderly, the handicapped, often cannot drive.

The solution, which is now widely accepted, is to offer modern public transportations, which are both convenient and sustainable. The mass transportation, such as trains, metros, trams or busses, are highly efficient in terms of number of people transported per unit of space or energy, as long as the demand is sufficient. However, if the demand decreases, the operation cost remains the same and the system loses money. This is why most mass transit systems stop at night and also sometimes during off-peak hours.

If we want an efficient alternative to the private vehicles, we must provide a flexible public transportation system, which offers the same level of service. Existing flexible public systems include taxis, dial-a-ride services, self-service cars and PRT(Personal Rapid Transit). However, all of them have some practical problems[1]. This problem can only be solved through a combination of mass transportation for the high flows and flexible public transport for the times or places where mass transit is not appropriate.

A consortium of 15 European research institutes and private industrial companies, have grouped together to form the CyberCars[2] / CyberMove[3] programs, sponsored by the European Community. The programs objective is to create a new form of public transportation, which can offer an alternative between the private vehicles and the mass public transportation. Cybercars are an Intelligent Transport Systems based on road vehicles with fully automated capabilities, or CTS (Cybernetic Transportation System).[4]

In this paper, section 2 first describes the main objectives, basic ideas, and key technologies of the CyberCars program; Then, section 3 introduces the existing and future experimentations in several European cities; Section 4 discusses the possibility of applying CyberCars technologies inside the Shanghai World Expo site; Finally, section 5 ends this paper with some concludes.

Figure 1 Cybercars

2. CyberCars

2,1 Introduction

Cybercars are road vehicles with fully automated driving capabilities. A fleet of such vehicles forms a transportation system for passengers or goods on a network of roads with on-demand and door-to-door capability. The fleet of Cybercars is under control of a central management system in order to meet particular demands in a particular environment.

At the initial stages, Cybercars are designed for short trips at low speed in an urban environment or in private grounds. In the long term, Cybercars could also run automatically at high speed on dedicated tracks. With the development of the CTS infrastructures, private vehicles with fully automatic driving capabilities could also be allowed on these infrastructures while maintaining their manual mode on standard roads.

The advantages of automatic driving capabilities and the new transportation systems, based on environmental friendly vehicles, are numerous.

- First, they provide reduction of congestion, and better traffic flow, air quality and energy conservation;
- Second, the system (in its automatic mode) is much safer. And there is no need for a drivers' license so anybody can use it, including also people with handicaps and in particular elderly persons;
- Third, the cars can be moved easily from one location to another, using fully automatic driving platoon formations with a single driver;
- Fourth, the cars can drive automatically to a remote parking area when not needed, hence leaving valuable urban space free for pedestrians and cyclists;
- Fifth, the concept and technologies are also appropriate for delivery of goods in city centers and even for garbage collection: the same infrastructure could be used by specifically adapted vehicles with delivery (or collection) boxes;
- Finally, flexible design will make it possible to optimize the overall system performance, taking into account the needs and requirements of the private consumer, the system operator and the public (e.g. municipality), permitting the system to operate in different modes at different times of the day, week and year.

2.2 Key Technologies in Vehicle[5]

Research and development work have been carried out in order to develop and test new techniques of *navigation and guidance*, which will also lower their costs. Existing commercial non-mechanical devices rely on wires, magnets or transponders in the ground. Improvement of these technologies as well as new methods for navigation and guidance are the subject of intense research throughout the world in public research organizations as well as in the industry. Recent bibliography on these subjects is already enormous and a large majority of the partners in the consortium (from academia as well as from industry) is well aware of these new developments and participate actively.

One of the most important challenges of Cybercars is road safety, in particular **-** *obstacle detection and collision avoidance* **-** while preserving an acceptable commercial speed. Existing technologies rely on tactile bumpers and expensive laser systems. The novelty in this task will be reducing the cost of the laser system and developing new technologies based on stereo vision and on new scanning ultrasonic sensors developed by Robosoft.

For adapting the throughput of the transport system to the instantaneous situation, Cybercars should be able to run in trains of vehicles – *platooning*, with a single driver and/or automatic guiding systems. Present-day commercial techniques are based on ranging systems and concern only the longitudinal guidance. New improvements are under way which can perform longitudinal and lateral guidance using vision and targets or radar and markers on the pavement.

In order to insure reliable, smooth and flexible operation of the whole transportation system, the vehicles must have optimized and safe *control systems*. Novel hardware and software components of the control system will be developed, based on existing techniques with the necessary adaptations and improvements, and integrated into the Cybercars.

Figure 2 CyCab

2.3 Key Technologies in Infrastructure[5]

Compared to traditional transportation systems which often rely on heavy material infrastructure such as rails or heavy road infrastructures, the Cybercars will need only a very light one, often no more than the equivalent of a bicycle path, or even just two small tracks for the wheels. Even with such light infrastructures, high transportation needs can be satisfied just by increasing the number of vehicles when needed. On the other hand, the road infrastructure is replaced by a non-material infrastructure based on information, in particular on telecommunications. These *communication networks* are now readily available, even if the bandwidth needed is high. The Cybercars systems will use these capabilities to their full extent and there is no need to incorporate new developments for them. The innovation will be placed on the use of these communication networks in order to perform essentially three tasks: management of the resources, user interface and remote control of the vehicles.

The *management of resources* implies that the vehicles and the infrastructure are optimized globally by a central system which knows in real time the availability and the state of all the resources of the system: vehicles, virtual tracks, parking places, energy stations, man-power,…. Depending on the customer requests, the system must make choices to send commands for the movement of vehicles and for other operations such as recharging of energy in the vehicles, maintenance, redistribution,… These tasks are extremely complex to optimize and require advanced management techniques. Some of these techniques have already been developed for car-sharing systems. With the possibilities of automatic displacement of the vehicles, the optimization techniques are needed even more in order to respond immediately to the demand.

Depending on the way the Cybercars systems will be designed, the *interfaces with the users* will be more or less complicated. On very simple systems, where the network is simple and the number of stopping points quite limited, a system of calling buttons as for the elevators is quite sufficient and easy to understand. However, if the system becomes more complex with a large number of origins/destinations, this system of calling buttons is difficult to implement and costly. The program will hence develop an interface based on mobile phone technologies and in particular on Wap or similar standards to take advantage of digital short messages and graphic interfaces. However, in order to make the system easy to use by any user, including first time visitors, extreme care has to be taken for the design of these interfaces. It is the aim of this program to define recommendations which could become a standard at least at the European level for these graphical interfaces. The Cybercars interfaces are not limited to mobile phones. We must also have similar interfaces inside the vehicle and at some "stations" or in the homes or offices of the users. In these cases, the interfaces will be on larger graphical screens such as the ones found on micro-computers or "Web-phones". The interfaces will be essentially developed on Web standards using languages such as XML and compatible with existing or under development tools for other transportation systems.

Figure 3　Park Shuttle 2

All of these interfaces on mobile or fixed units or in the vehicle, must also be compatible and easily connected to other *information systems* concerning the city and the purposes of the trip. We think about interfaces with commercial destinations and also with tourist and cultural information.

The last technology we will develop is the *remote control* of the vehicles from the central management system. This is needed for the monitoring of the state of the vehicles but also for the possibility to remotely drive the vehicles. This is considered as an important back-up function for the automatic driving when a vehicle is stopped for an unknown reason. In these cases, it would be convenient for the operator in the control room to take control of the vehicle and see if he/she can eventually operate it. If the remote driving is possible, then the conflict could potentially be resolved and the vehicle returned to its automatic mode or removed from the operation.

3. Experiments in European Cities

The definition of these new transportation systems will be based on the identification of user needs and requirements – private consumer, system operator and society (e.g. municipality). The novelty here is the joint work of partners with collaborating cities, focused on characterizations as guidelines for necessary technologies. For example: vehicle type and its performances, need to share the road with other vehicles, service to be offered, demand for the system, certification and safety. These specifications should then be translated into operational objectives for each component of the system such as commercial speed, size and distance of obstacles detected, accuracy of

Figure 4 Park Shuttle in Schiphol

tracking, etc.

CyberMove program, a three years project, start with the analysis of user needs, a definition of operating scenarios and a pre-design phase. The first milestone is the selection of sites in the 12 Cities which have officially expressed their interests[6]. The second milestone consists of guidelines for safety design in those selected Cities. A design review is the last milestone, which will clarify demonstration plan and budget.

The major event in CyberMove program is the concrete implication of historic cities such as Rome, Antibes, Biarritz, La Rochelle, Rotterdam, Lausanne, Coimbra,... Those Cities are in the heart of European cultural heritage, specially concerned by a win-win strategy between Tourism Development and a sustainable local business development.

Till now, several transportation systems based on Cybercars are already in operation and several more are now at the planning stage, such as Park Shuttle in Schiphol and Rivim in Netherlands, Serpentine capsules in Lausanne, etc. Although these first systems are small in scope, it is believed that this will allow for the demonstration of the full benefit of such systems on a larger scale. These first systems are also needed to fully develop and understand all the technologies implied while also defining the legal framework for their operation. These two aspects are at the core of the CyberCars Program while the tools for their

Figure 5 Serpentine capsules in Lausanne

implementation and their economic justification are at the center of the CyberMove project which looks also at the benefits in term of sustainable development.

The improvement of vehicle and infrastructures technologies will be evaluated on the INRIA Rocquencourt test site, and the conceptual design of new transportation systems in several test sites are expected to demonstrate during the CyberMove project in at least 3 European sites[7].

4. Potential Application in the Shanghai World Expo 2010

4.1 Mobility to the Expo Site

On December 3rd 2002, Shanghai wins World Expo 2010 Bid at the 132nd general assembly of the Bureau of International Expositions (BIE) in Monte Carlo[8]. As a comprehensive exhibition, the Shanghai World Expo 2010 will run for 183 days and according to the predictions in 2002, the total number of visitors at World Expo 2010 Shanghai can exceed 70 million with a daily average of 400,000 visitors and will create a new record in the history of World Expo.

Furthermore, during the six consecutive months of World Expo, there will be a number of holidays (such as the "May 1" and "October 1" Golden Weeks) and summer vacation. During the World Expo, Shanghai will also hold various activities including theme days and national days. This will result in obvious peak periods for passenger flows. According to "Year 2002 report on the development of integrated urban transportation in Shanghai", the daily average passenger flow of rail transportation throughout 2002 was 979,000, and in the same year, the 3 rail traffic lines for "October 1" Golden Week exceeded a daily average of 1.29 million passenger trips, 1.3 times normal levels. The authorities believe that during World Expo, passenger flows during the "May 1" and "October 1" Golden Weeks will be at least 40% higher than usual, with an at least 25% growth on weekends and 20% rise during the summer vacation period. This will naturally place significant pressure on the transportation system.

Faced with the pressure on transportation caused by the World Expo's huge passenger movements, responsible officials of the city's Transport Bureau[9] have raised the following overall objectives for the development of transportation: By 2010, the city will have formed a transportation system based on the four principles of humanization, acceleration of transportation, informatization and the incorporation of ecological criteria.

By 2010, the city will have formed a *road network* with a length of 650 kilometers. The public bus system will still be the base of public transportation, while the taxis will act as a complement. In the north-east and west of the World Expo 2010 site, there will be several main arteries, by which it will be convenient to connect

Figure 6 Schematic of the 10th Five-Year Plan(2001-2005) on Shanghai Rail Systems

airports, railway station, and wharfs through overhead expressways. Besides that, six bridges and six tunnels will be built to cross the river, which divides the city.

By 2010, the city will have formed a fundamental *rail transport network*, which will be the backbone of the public transportation. The number of rail lines will increase from 3 to 15, while the total length will increase from 65 kilometers to 400 kilometers. This will enable the capability of rail system to reach 6-7 million trip per day. According to the current plan by Shanghai Municipality, there will be 5 rail lines passing by the World Expo site to satisfy the requirements of 400,000 visitors to the Expo site per day.

By 2010, the city will develop a parking system that fits in with the city layout and matches road capacity to enable dynamic transportation. The city will develop public parking places nearby rail transport hubs in the outer ring road that charge special rates to encourage car passengers to transfer to public transport into the central city. According to the prediction, the parking lots near the entrance of the World Expo site are designed to hold 1000 coaches, 15000 cars, and 7500 bicycles.

4.2 Mobility inside Expo Site

The site of World Expo 2010 is selected along the riverside of the Huangpu River between the Nanpu Bridge and the newly-built Lupu Bridge on the edge of downtown. An ellipse-shaped area of 540 hectares has been set aside on both sides of the Huangpu River. The area of World Expo Park will be 310 hectares, with an additional 60-hectare-parking lot and 30-hectare-World Expo Village making a total area of 400 hectares. Most of the area will lie on the Pudong side with an area of 260 hectares, while an area of 50 hectares lie on the older Puxi side.

The winning Expo bid proposal is a French designer –Architecture Studio company. A nine square-kilometer site will span both banks of the Huangpu River and include a highly representative structure - a *floral bridge*, which is a walking bridge linking artificial islands on both sides of Huangpu River, with a height of 200 meters, a length of 600 meters, a width of 50 meters. This proposal also incorporates the lines of the Huangpu River to form an *oval canal* shape. The 3rd highlight of this proposal is the *plant corridors*, which run along the river banks to the Expo site.

Although the mobility to the Expo site seems to be perfectly solved by building new rail systems, roads, bridges, tunnels according to the current plan by the municipality, the mobility inside the Expo site is seldom mentioned. The main difficulties with the mobility inside the Expo site may include,

- The area of the Expo site will be 400 hectares, which is too big to visit solely by walking.
- The parking lot itself is about 60 hectares, which may result a long walking distance (from several hundreds meters to more than one kilometer) to walk across the parking lot and reach the entrance of the Expo site.
- The *floral bridge* is 600 meters long, which is a little long for visiting, especially for the elders and handicapped. Similar problem exists with the *plant corridors*.
- The mobility along and across the Huangpu River need to be considered for the residents near the Expo site and staff of the Expo.
- The operating scenario requires flexibility for the passenger capacity, the path and the period of operation in the day, week, etc. For example, the requirement could be much higher in the weekend and holidays than that in usual time.
- Shanghai is famous for its magnificent nightscape. The World Expo site should not be an exception. Special traffic service need to be considered for the visits in the night.
- The system inside the Expo site has to comply with high level of environment protection and the high standing of the Expo.
- The system must have high safety because the Expo site is mainly pedestrian.

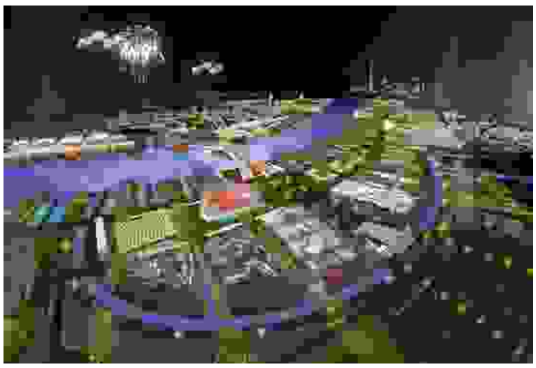

Figure 7 Site proposal by Architecture Studio

4.3 Potential Application of CyberCars

The CyberCars technology could be one possible solution to the mobility problem inside the World Expo site. By applying the CyberCars technologies, it is possible to provide a flexible public transportation, which can

- Offer a 24h, flexible public traffic service for the visitors to the Expo site, staff of the Expo, and residents living near the Expo site;
  - Linking the stops of mass public transportation to the Expo site;
  - Linking the parking lot to the Expo site;
  - Linking the artificial islands on both banks of the HuangPu River (600 meters long);
  - Linking the activities inside the Expo site.
- Provide the visitors with a friendly, enjoyable, comfortable, and safe transportation system to visit the Expo site;
- Decrease environmental impact of public transport on the site, and improve the attractiveness of the World Expo site.

The advantages of applying the CyberCars technologies inside the Expo site could be:

- Cybercars are electrically driven small and light vehicles with low peak velocity, and able to offer a safe, comfort, and quiet public transportation with low impact on the environment. It is also possible to use the fuel cell as its energy source;
- As a complement of mass public transportation, Cybercars have better flexibility, and able to provide better individual service. During the peak hours, Cybercars can operate in platooning mode to maximize the transportation capability. During the non-peak time, Cybercars will be operated individually to maximize the flexibility and minimize the waiting time;
- Thanks to the automatic driving, Cybercars are able to operate 24 hours per day without human drivers, which will also decrease the operation costs;
- The automatic driving can also increase the safety and comfort of the trips by sophisticated control technologies;
- The optimum central management can improve the traffic efficiency, and deduce the consumption of energy;
- Cybercars can improve the attractiveness of the World Expo site by its advanced automatic driving and modern appearance, and will be integrated with the Expo site seamlessly, which will also meet with the theme of the 2010 World Expo "Better City, Better Life";
- Cybercars can provide comfort individual service with modern vehicle design and on-board information system, especially for the elders and handicapped;
- Cybercars can also serve for automatic good delivery with special loading / unloading equipments;
- The application itself offers a very attractive demonstration to exhibit the innovative transportation system.

Detailed application proposal can not be made at this moment, because the Expo 2010 Shanghai's site proposal is still to be further refined[9] and the detailed plan about the site is not published yet.

5. Conclusions

In this paper, we introduce the background, main objectives, basic ideas, and key technologies of CyberCars / CyberMove programs, sponsored by the European Commission, and their experiments in several European cities. These two sister program provide an alternative flexible public transportation between the private vehicles and the mass public transportation. As an example of application, the potential application of CyberCars in the Shanghai World Expo 2010 is proposed after the analysis of the mobility to/inside the Expo site.

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REFERENCES

[1] M. Parent, Intelligent Vehicles and New Services for the City of Tomorrow, Singapore, 2000
[2] http://www.cybercars.org/
[3] http://www.cybermove.org/
[4] M. Parent, G. Gallais. Intelligent Transportation in Cities with CTS. *ITS World Congress*, Chicago, Oct 2002
[5] M. Parent. User Needs Analysis and Analysis of Key Technologies - Part 2: Report on Existing Technologies, *Technical Reports of CyberCars Project*, Jan. 2002
[6] Site Selection Report (D2.1). *Technical Reports of CyberMove Project*, 2002
[7] M. Parent, G. Gallais. CyberCars: Review of First Projects. In: Proceedings of *the Ninth International Conference on Automated People Movers*, Singapore, Sept. 2003
[8] http://www.expo2010china.com/
[9] http://www.jt.sh.cn/