Cybercars : a Solution for Urban Transport?

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ABSTRACT: 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 cars 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 autonomously at high speed on dedicated tracks. With the development of the cybercar infrastructures, private cars with fully autonomous driving capabilities could also be allowed on these infrastructures while maintaining their manual mode on standard roads.

Cybercars are members of the general family of automatic people movers and close to PRT (Personal Rapid Transit) but they offer the advantage of being able to run on any ground infrastructure which means they are cheaper and more flexible.

Several transportation systems based on cybercars are already in operation and several more are now at the planning stage. This paper will review all these projects with their main characteristics.

A consortium of 15 European research institutes and private industrial companies, have grouped together to form the CyberCars/CyberMove programs. The programs objective, sponsored by the EC, is to create a new option of Intelligent Transport Systems based on road vehicles with fully automated capabilities, or CTS (Cybernetic Transportation System). This article describes the first projects which are now running or which are at the planing stage.

RÉSUMÉ : Les Cybervoitures sont des véhicules routiers capables de conduire de manière complètement automatisée. Un parc de tels véhicules forme un système de transport, pour les voyageurs ou les marchandises, sur un réseau routier capable d’offrir des services à la demande et à domicile. Le parc de voitures est sous le contrôle d'un système de gestion central pour satisfaire des demandes particulières dans un environnement particulier. A la base, les cybervoitures sont conçues pour des voyages courts à une vitesse réduite dans un environnement urbain ou sur des terrains privés.

À long terme, les cybervoitures pourraient aussi rouler de manière autonome à une vitesse élevée sur des voies prévues à cet effet. Avec le développement des infrastructures pour les cybervoitures, les voitures individuelles capables de conduire de manière complètement automatisée pourraient également accéder à ces infrastructures tout en conservant leur mode manuel sur les routes classiques.

Les cybervoitures sont des membres de la grande famille des modes de déplacement automatiques des voyageurs et sont proches du TPR (Transport Personnel Rapide) mais elles offrent l'avantage de pouvoir rouler sur n'importe quelle infrastructure terrestre, ce qui signifie qu'elles sont moins onéreuses et plus flexibles.

Plusieurs systèmes de transport basés sur des cybervoitures sont déjà en exploitation et plusieurs autres sont maintenant à l’état de projet. La communication passera en revue tous ces projets et leurs caractéristiques principales.

Un consortium de 15 instituts de recherches européens et des sociétés industrielles privées, s'est groupé pour former les programmes Cybervoitures/Cyberdéplacement. L'objectif de ces programmes, sponsorisés par la CEE, est de créer une nouvelle option de Systèmes Intelligents de Transport basés sur des véhicules routiers avec des capacités entièrement automatisées, ou STC (Système de Transport Cybernétique). Cet article décrit les premiers projets qui fonctionnent déjà ou qui sont encore à l’état de projet

INTRODUCTION

Most European cities faces numerous challenges associated with the use of private vehicles. Problems include road congestion, energy expenditure, noise and pollution, all of which degrade the quality of urban life. Therefore, historical cities centres are facing severe problems, traditional commerce in them declines, moving to the periphery, and they become less attractive to tourists.

The CTS (Cybernetic Transportation System) concept started with car-sharing: a fleet of individual vehicles shared among a relatively large number of users, offers the possibility of using a car for some time or having a car available at both ends of a train trip. These systems are increasingly popular in Switzerland and Germany. They work well in specific areas where the demand is properly structured, but have yet to offer a door to door service : currently, the vehicles are only available at a few locations and have to be returned. Modern fleet management technologies have recently improved the service, e.g. also allowing short trips without the need to return the car to its point of origin. Such systems are called station-car systems and have been developed since the mid-90's (Praxitèle and Liselec Projects in France, City-Car in Switzerland, IntelliShare in the USA, Crayon in Japan,…).

Specific vehicles, well-adapted to city driving, have generally been used for these systems: small size, convenient, energy efficient, quiet, often based on electric power. They even compete with public transportation in terms of energy consumption on per passenger-km basis. To date, these systems have not generally proven that they can compete economically, one reason being limited vehicles availability in too few locations, thus limiting the number of potential customers (see European Project Utopia).

The car-sharing concept can be dramatically improved if the vehicles are made to move by themselves in order to respond to the demand or possibly to move passengers or goods automatically. We will call them cybercars. The first such system started in December 1997 at the Shiphol airport in Amsterdam. Now, several companies in Europe are offering similar CTS and all these companies have joined forces with research labs in order to improve the technologies and look at the diffusion of these systems in cities. A large European project has started in 2001 financed by the IST programme (CyberCars) and by the EESD Programme (CyberMove)

This paper will present three of the eight detailed projects which were studied among the initial 17 CyberMove sites all over Europe. For more details, see the web sites www.cybermove.org and www.cybercars.org.

Fig. 1 Crayon Car-sharing

RIVIUM PROJECT

The Rivium Project is the most advanced of all CTS projects since it is an extension of a previous project which started its operation in 1999 with three vehicles which have been running very satisfactorily for three years.

Urban and mobility context

The City of Rotterdam in the Netherlands is surrounded by other towns that over the years have grown together into the largest urban area in the country. Together they form the 'Stadsregio Rotterdam' (Urban region Rotterdam).

Rotterdam wants to be known as a modern, hardworking, and innovative city that cares for its inhabitants and companies with striking urban development and state of the art facilities. Rotterdam cares for transport.

However transport is a problem for the Stadsregio. As everywhere in the Netherlands, road congestion offers daily problems. Miles of traffic jams surround the city every day despite of motorways of up to 12 lanes. Inside its boundaries the Stadsregio provides a closely knitted network of roads, subways, trams, busses but nevertheless commuters find it difficult to reach their daily work. Rotterdam looks for new solutions.

The city of Capelle aan den Ijssel, also a part of the Stadsregio, borders on Rotterdam on the east side. Capelle has about 65 000 inhabitants and is a fast growing community, both in size and in economic activity.

On the east side of town, near the A16 motorway and the huge 'Van Brienenoordbrug' over the river Maas Capelle has developed a prestigious business park 'Rivium'. It has been under construction for about 10 years and is near to completion.

Site-specific problems and strategies

The development of the Rivium area has brought about new transport problems. As customary in this timeframe Capelle has minimised the number of parking spaces for office workers. Official regulations in the Netherlands rule that parking space should not exceed 10% of office places. In spite of bikes being a popular commuter tool, this policy calls for a public transport share in the modal split that is very different from public preferences. As a result cars are being parked along the streets and everywhere.

Figure 3 Rivium in progress.

As the building of the area proceeded this problem would get worse. A good public transport connection was required, especially to the nearest subway station of Kralingse Zoom. The bus to Kralingse Zoom offers 15-minute service but necessarily makes a detour that increases commuter time. In hours of low demand between commuter shifts the frequency of the bus service was reduced to half, making it an inconvenient alternative for people having to travel midday.

Capelle wants to promote public transport by offering a good connection to the nearby subway station of Kralingse Zoom. Important for the two cities and the Stadsregio is to adopt new durable ways of transport with minimal effect on the environment. They actively stimulate innovation in this field and value the effect this has on the image of the area. For Capelle a new level of transport service as provided by a CTS helps to achieve the expression the city wants to give to the new prestigious Rivium Business Park.

A bike path was planned to provide a short and direct connection to Kralingse Zoom. It was decided to transfer the bike path into a track for a cybercars system. This became the first CTS in the world in public service. The installation was meant as a pilot for this new concept and was planned to run for a year after which period an evaluation was to give directions for further decisions. A site-specific problem was that the subway station is on Rotterdam territory which requires mutual decision processes in two municipal organisations, united in the Stadsregion

Goal of the ParkShuttle pilot was to:

- investigate customer acceptance of free ranging automated transport
- evaluate public appreciation of tailored transport service
- compare operational aspects and costs of such

Figure 4 ParkShuttle Version 2

system with a traditional bus service
- influence the modal shift of Rivium commuters towards public transport
- become a reason for companies to choose Rivium as their office location

The system was immediately accepted by the public. What seemed the biggest hurdle proved to be the easiest. Customer surveys immediately showed high customer appreciation. As transport demand increased with the office space in Rivium the capacity of the three prototype vehicles (90 people/hr) became a problem. A reliable operation was difficult and the over-demand created waiting times having an impact on customer satisfaction. Although the appreciation of the Park-Shuttle in the end was not much higher than for the bus the percentage of users of the ParkShuttle measured over the service area was much higher than for the bus.

The first ParkShuttle system proved the potential of the concept. This fact stimulated the local authorities and the public transport company Connexxion that operated the system to decide for a continuation in spite of prototype problems of the pilot. The new system would have to provide a >500 people/h capacity. This requires a totally new track and a new system generation.

With a joint effort of Capelle, Rotterdam, the Stadsregio, Connexxion and Frog Navigation Systems, this plan finally got a go-ahead in December 2001. This was greatly helped by the positive governmental and the consistency with national, regional and local strategy plans like the NVVP (van A naar Beter), promoting new technology to solve transport congestion, the BOR (Bereikbaarheids Offensief Randstad), specifically focussing on the accessibility of the metropolitan region in the west of the Netherlands and the local innovation initiatives represented by the OBR (Ontwikkelingsbureau Rotterdam) and the local strategy of Capelle.

User Needs

The first ParkShuttle system started in Feb 1999 and operated until Jan 2002 when it was stopped to start preparations for rebuilding the track. During its three years of operation the system was evaluated several times. This and the discussion about its continuation have produced detailed insights on user needs for the new system.

The new system in Rivium has to be better in all respects

- Short waiting times (max 5 min) by higher capacity, more and larger vehicles and turning loops on two intermediate places to provide a quicker return of vehicles.

- Short travel times by better traffic management rules that are variable over the day, by higher speed of the vehicles and a double track to avoid waiting for oncoming vehicles. (4 min for single trip from Kralingse Zoom to first station in Rivium)
- Larger service area by a longer track. The intention is that this way the ParkShuttle will eventually replace the present bus line.
- Less disturbance on the track by making adjacent bicycle paths and adapt the vegetation alongside the track and reduced vulnerability of the vehicles for 'ghost obstacles'.
- Reliable transport service and better travel information
- Higher security for passengers by ample camera surveillance
- Reduced operation costs
- Better ride with reduced noise and improved climate comfort.

New site-related aspects in 'phase2'

- A passage over a crossing of public roads. This will be a unique experiment that will provide new information on the effect of such a prioritised crossing on road capacity and provide directions for solutions to the legal issues involved.
- A housing area along side the track over approximately 1 km. This will give new insights on how the neighbourhood (children) reacts to the passing automated vehicles.
- Crossing places for bikers

Figure 5 Rivium Project

Main site characteristics

- 1.8 km most double track
- 1 tunnel (single track)
- 1 bridge (partly single track)
- 2 road crossings
- 2 bike path crossings
- 2 intermediate turning loops
- 5 stations (double execution)
- 1 garage with automated charging facilities

Legal and institutional framework

The vehicles will run on a separate track. The track is private property. This is an essential element for the legal framework in which the system operates. This way the system does not need to fulfil requirements for road vehicles that require a driver in the vehicle and are thus contradictory to the nature of an AGV.

The road crossing presents a special problem here. The intention is to solve this by creating an analogy with a public crossing of a rail system.

It is clear that there is no readily applicable legal framework for a CTS in the Netherlands. The ParkShuttle project of Frog Navigation Systems and TNO will jointly endeavour to outline, develop and test a certification approach that could become the basis of future legislation. Both companies are part of the CyberCars consortium and will specifically study and provide solutions for site related regulatory aspects.

This work benefits greatly from the willingness of Connexxion and the co-operative approach of Dutch governmental institutions.

ANTIBES PROJECT

The city of Antibes Juan les Pins is located on the French Riviera, in the south of France, and is part of an urban agglomeration called Sophia Antipolis, the name of an International Science Park dedicated to information technologies. The total population is 160 000 habitants. The population of Antibes city is 73 000, with a density of 2 780 h/sq. km, and more than twice that in summer.

The Graeco-Roman historical city centre covers 1% of the total city area and attracts 1 millionvisitors a year. The geographical situation in both the historical and the modern cities creates problems of traffic, parking and public transport.

Mobility

Economic activity is intense, causing 335 000 internal daily trips, 80% of them made by residents. Apart from the ancient city, where pedestrians have more or less gained some priority over cars thanks to a 3 ha pedestrian area, Antibes is an "all car" city. Surprisingly, 50% of private car trips are shorter than 2 km. The road network (220 km/26.48 sq. km) is spread unequally over the area: a high density in the historical city not adapted to cars, a good network density in the modern city, which is more suitable to car traffic but with insufficient motorway infrastructure all around. Bicycles have only 30 meters of dedicated lanes at the moment.

Public Transport has a modal share of only 4%. Public Transport provides quite good connections, with a network of 15 bus lines, but the service quality is poor due to a lack of reserved lanes. A free service of small shuttles (4 lines) is gaining success. A small, old-fashioned road train is offering loop visits to tourists. The regional railways bring a total of 2 million passengers a year.

The attractiveness of the sightseeing is reinforced by intense cultural activity. For more than one third of the year, exhibitions, opera, concerts, a jazz festival, sailing races, markets, and other activities, are organised on public spaces.

Strategies

The local authorities include the following in their planning:

- define historical centre as a pedestrian area connected to the suburbs by urban shuttles;
- create intermodal platform (with P + R);
- create a better Public Transport service with dedicated lanes;
- build new railway lanes (Metro) to improve the accessibility to the centre and the connection with the main cities (in direction of Nice and Cannes);
- enlarge the Public Transport offer (frequency, comfort, connections).

The political desire to revamp the public spaces and improve the quality of life in the city centre is a good opportunity for the CTS project.

The mid-term strategy is clearly to move away cars not adapted to the historical city street network in order to decrease traffic consequences (e.g. noise, atmospheric pollution, damaging monuments, time loss) and improve public spaces devoted to cultural and commercial activities. This strategy requires finding innovative and complementary solutions to Public Transport and cybercars, including automated people mover or car-pooling or car-sharing, are seen as a way to introduce new mobility management. The experiment could be a pretext to suppress roadside parking.

User Needs

The CTS application in Antibes should show evidence of the potential of such systems for a sustainable solution for urban mobility. The project expected impacts were defined, with the local authorities, in the project user needs phase. Main needs of the authorities are to quantify, by mean of this project, the possible expectation for an extension to the entire city of the CTS network (full-scale implementation).

Numerous applications were envisaged in the first discussions. The first concrete application is an automatic transport system to connect the historical city entrance (Porte Marine) to one of the Port Vauban carpark (1 000 places total) which is used little and is 1 500 m away, as can be seen in Figure 5.

The system to be implemented has to cope with variable traffic and transport conditions. It will face a very high demand and congestion especially during the events that the city hosts; two examples are given below.

- "Salon des Antiquaires": during 15 days in April, 60/70 000 visitors will park their cars and being proposed the CyberCars. Including the assembling and taking down of the exhibition, it is totally 2 months of parking places used for the exhibition.
- "Musique au cœur" in the Opera: concerts starting from 8 p.m. to 12 p.m. during 10 days in July, the opera capacity is 1 500 persons. The peak capacity is a problem to solve, with a need of accompanying measures like innovative payment strategy including the opera admission.
- Other events are foreseen like "voile d'Antibes (5–9 June) for the demonstration period (April–July) or the funfair.

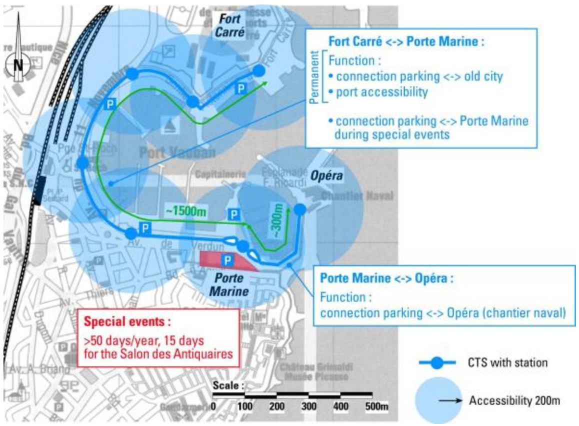

Figure 5 Antibes project

Description

- Distance: 1 400 m with an added 350 m option for the Opera events.
- Service: on demand, 24 hours a day, about 5 minutes maximum of waiting time. Comfort and service designed in order to increase the standing of passengers not used to PT.
- Vehicle capacity: 10-20 passengers/vehicle, easy access to disabled and elderly peple.
- Technical speed: 20 km/h.
- Commercial speed: 10 km/h (6 stops).
- System capacity: ~300 persons/h, 4 vehicles in service.
- Integration: it is proposed to reorganise the traffic and reserve one way road for the CTS. This way of integrating the CTS should minimise the demonstration costs. The main difficulty is foreseen on the section between the Porte Marine and

the Opera (one way path).

- System operation:

  ♦ Basic mode of operation is “on demand” but, as the concept is unusual to the population, a test on a continuous running CTS is necessary. It is also the occasion to experiment “on demand” calls by mobile phone.

  ♦ Information System and Vehicles: incentive communication measures should be adopted to inform the visitors. On board vocal and display information in order to deliver explanations on the automated operations (“You are arrived to the destination”) by vocal or display means. Possibility of Multimedia messages to test City oriented advertisement.

  ♦ A direct vocal link with the supervisor should be accessible.

- Accompanying measures:

  ♦ Specific parking policies along the harbour (free access at the Fort Carré and carparks close to the Porte Marine, chargeable to the users).

  ♦ Combined tickets for special exhibitions.

- Test period: the ideal period for tests & demonstration is from April to July.

Finally, safety and security of passengers are of course the mandatory criteria.

Legal and Institutional Framework

The local partnership is with the “Pôle Développement – Aménagement” (urban layout and development) of the municipality in charge of the whole aspects of the city management (infrastructure, urban planning, tourism; security, commercial activity, transport) but especially the Mobility service. A collaboration is being set-up with the local INRIA research centre. A national program, the Predit, is pushing project proposals to develop information systems for inter-modal platforms where CyberCars could be one of the transport options.

Studies of existing rules and procedure have started in accordance to the project planning. The test path is on city owned public roads (lanes dedicated for PT).

WERFENWENG

Werfenweng is a tourist resort developed in a protected area close to Salzburg in Austria. An innovative transportation system is being studied to maximise the transportation capabilities inside the resort and to minimise the impact on the environment.

The resort is accessible by bus from the Salzburg train station and by car. Cars will be kept in a peripheral parking lot located 1 km before the village of Werfenweng. The centre of the village will be kept car free so to improve the liveability of the area and reduce to the minimum interactions between the new system and other motorised transport modes.

The proposed CTS is based on the “Serpentine” capsules (see figure 7): small, fully-automated electric vehicles four wheel steering and driving receiving electricity directly from the ground by an induction transfer system (magnetoglisseur ®) of 88% measured transfer efficiency.

The capsules have the possibility to drive autonomously, on demand, to respond to any transport request (dial-a-ride) or to provide an high capacity public transport service. Any transport service, including cars although drivers sometime ignore it, has to obey to the “brick-wall-stop” safety distance criterion; a criterion that establishes that each vehicle has to keep a “long-enough” safety distance from the previous one to stop without colliding even in case of instantaneous sudden stop of the preceding vehicle. The capacity of a road link, as well as that of a railway, decrease with the speed after a peak at very low speed. Trains increase capacity by increasing the number of passengers on board to each convoy. Similarly “platooning” techniques allow the capsules to run in convoys (chain mode) so to have less distance (in average) between the capsules and then an higher capacity. Both the services (on demand and chain-mode) ensure a much shorter waiting time than conventional public transport in the same demand conditions.

The transportation system has four objectives:

- Offer public transportation capabilities inside the village (700 m)
- Link the peripheral parking lot to the village (1 000 m)
- Link the village to the ski domain (1 500m)
- Link the village to the next one, Wengerau (1 500m)

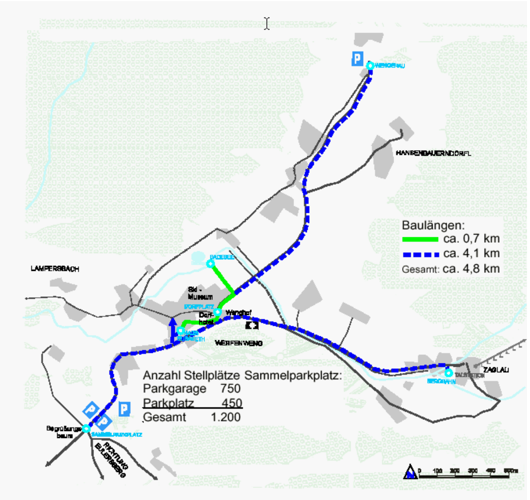

Figure 6 Werfenweng Project

Key-numbers:

- Inhabitants: 767, including 594 in the car-free area.
- Lodging visitors: 75 000 in summer 2 000 and 105 000 in winter 2000/01
- Daily visitors: 540 to the ski domain and 50 to the next village
- Annual traffic through the village: 553 000 trips/year
- Peak traffic through the village: 1 500 trips/hour

Site-specific problems and strategies

Site-specific problems:

- The system has to comply with high level of environment protection and the high standing of the resort.
- Traffic daily profiles differ from one section to another one.
- Users loading/unloading difficulties are increased due to the ski equipment
- Snow makes the traffic uneasy

Site-specific strategies:

- Electrical-powered small and light vehicles with low peak velocity offer a safe and quiet transportation system with low nuisance.
- Capsules will be operated in chain mode during peak traffic hours to maximise the transportation capacity. The rest of the day, capsules will be operated individually to maximise the flexibility and minimise the waiting time.
- Methanol or natural gas powered busses that carry the visitors from Salzburg may be allowed to unload passengers at Zaglau station (ski-lift departure) to reduce the peak traffic.
- Capsule characteristics make loading/unloading much easier and quicker than in a bus, even with baggage and ski equipment: e.g. few passenger per capsule, wide doors, no seats.
- A thin snow layer will not interfere in the energy supply through electromagnetic features. Since the whole infrastructure is drowned inside the asphalt layer, snow will be evacuated with common equipment.

User needs

- An engineering company specialising in traffic planning, Trafico was contracted by the local authorities to provide a traffic plan for the resort of Werfenweng.
- Due to the environmental high sensitivity of the site, the Austrian Ministry of Environment contracted Trafico and CN Serpentine SA to conduct jointly a feasibility study of the Serpentine applied to Werfenweng.
- A delegation of Austrian Authorities (Local, Regional and Ministries of Transportation and Environment) visited the existing indoor pilot in Yverdon and the final pilot in construction in Ouchy.
- Last hesitations concern the operability of the system during severe winter conditions.

Application objectives and description

Application objectives:

- Feasibility report is currently finalised
- In case of acceptance, the detailed project study shall be conducted starting in summer 2002, for the construction of a pilot in Werfenweng.
- The detailed study and construction of the final system shall be started after 6 months of operation of the pilot: in spring 2004.
- Peak capacity for the longest trip: 270 capsules/hour/direction or 1 218 passenger/hour/direction
- Expected passenger demand: 550 000 trip/year
- Expected travel time for the longest trip from 9’ to 12’ with an average of 10’
- Expected waiting time for the longest trip from 1.5’ to 9’ with an average of 3’
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Figure 7 Serpentine capsules

Application description:

Pilot

- Longest trip: 680 m
- Network made of 3 sections and 4 stops

  A: 150 m single lane

  B: 180 m double lane

  C: 350 m single lane

- 7 capsules will be operated in chain mode or in individual mode depending the requested capacity. Capsules can automatically switch from one mode to the other at any time Manually driven operating mode will also be tested.
- Peak capacity for the longest trip (A+B+C): 53 capsules/hour/direction or 238 passengers/hour/direction
- Expected passenger demand: 150 000 trip/year
- Expected travel time for the longest trip (A+B+C): 3.5' min in average with a minimum of 3' and a maximum of 4'
- Expected waiting time for the longest trip (A+B+C): 3' min in average with a minimum of 1' and a maximum of 6'

Final system:

- Longest trip (E1 +A+B+E2): 2800 m
- Network made of 3 extensions and 3 complementary main stops

  E1: 1 000 m double lane

  E2: 1 500 m double lane

- E3: 1 500 m single lane Total 49 capsules will be operated in chain mode or in individual mode depending the requested capacity. Manually driven operating mode will also be extend the network between peak traffic hours and allow users to bring their baggage to their own door.

Legal and Institutional Framework

Such a system, classified at the moment in Switzerland as trolley-bus, is in conformity with laws on electric installations, especially because it does not involve the dangers of systems with galvanic contact. It should also pass without difficulty the road traffic regulation tests, all the more so as simplifications are provided for low-speed vehicles. Furthermore, civil liability insurance has been granted to this system for commercial use on shared transportation site; it seems, though, that a European convention adopted in 1968, before the arrival of personal computers, opposes cybercars and requires a physical driver on vehicles.

CONCLUSION

As it can be seen from these three examples, CTS are currently being studied, and in some instances, implemented in various contexts in Europe. 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 CybreCars project while the tools for their implementation and their economic justification are at the center of the CyberMove project which looks also at the benefits in term of sustainable development.

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Visit :
www.cybercars.org
www.cybermove.org

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