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BURST: BRIGHT URBAN SYSTEM FOR TRANSPORTATION

***Abstract:** This paper describes an innovative transportation system based on non-polluting autonomous vehicles. The proposed solution lies between high-speed outdoor moving walks and low-speed urban cars platooning. It integrates the service modes and advantages of both, while avoiding their main drawback, which are respectively the lack of scalability and the usage of traditional automobiles. The present contribution highlights the potential socioeconomic and environmental impacts of this system, as well as the technological challenges paving the way towards a real-world implementation and a large-scale spread in the cities of tomorrow.*

1 Introduction

The BURST initiative aims at validating, developing and implementing a new urban transportation system for medium range displacements in small urban areas, recreation zones, fair sites or intermodal areas (such as airports connected to train stations). The new system consists of a series of autonomous vehicles inspired from an existing prototype of shuttles called “The Serpentine” (Saugy, 1997). These shuttles (Fig. 1) described in Section 2 are electrically powered and guided by means of a magnetic track integrated in the road pavement; they can link together and virtually form a continuous chain or platoons. The shuttles are designed to carry up to 5 passengers at relatively low speed (less than 20 km/h).



Figure 1 Serpentine autonomous shuttles in an urban area.

The major results and advances expected with this initiative lie, from a technological point of view, in electrical vehicle design, energy supply, motion control, safety concept, and information management. From a socioeconomic point of view, this innovative transportation system can prove more efficient than bus services for irregularly frequented lines. It may also ease access to city centers, reduce congestion, as well as enhance intermodal transport. To some extent, Serpentine-like systems can promote sightseeing tours and provide new possibilities of mobility for elderly or disable people. Environmental benefits are also expected in terms of lower emissions, decrease in car dependency and safer driving.

The environmental constraints taken into account in the design and implementation of the BURST concept are detailed in Section 3. The technological challenges to tackle are presented in Section 4. As illustration, the scenario for a possible implementation of the proposed new urban transportation system in the city center of Lausanne is introduced in Section 5. Finally, the perspectives for further studies are envisioned and the research units involved in the launching of the BURST initiative are described, respectively in Section 6 and 7.

2 Shuttle design

The idea of using small autonomous vehicles as urban shuttles and their design rely on interesting observations and concepts. A particularly relevant fact is that shopping and touristic areas are often difficult to access by car, when located in the center of the cities. To overcome this difficulty, dense public transportation systems have been implemented decades ago, such as bus networks or metro lines. However, these traditional services do not stop at every street corner and the vehicles are too large to enter narrow pedestrian zones. In this context, citizen, and particularly elderly and disabled people, would appreciate to have access to a fleet of user-friendly shuttles that would stop at request and carry passengers nearly anywhere along a given circuit.

These shuttles are extremely versatile to operate. They can be loaded and unloaded quickly, reducing traffic congestion. The size of the shuttle fleet can be adapted in real-time to the passengers' load. In addition to flexibility in time and space, this modular system can provide large transport capacity by gathering shuttles in platoons, using virtual towbars.

The versatility target has led to an optimal shuttle capacity of 5 passengers. In this condition, it is unaffordable to have one driver per vehicle. Moreover, to improve the weight-power ratio, an external source of energy should be used. As a consequence, the shuttles have been designed to be autonomous, electrically powered and guided by means of a magnetic track integrated in the road pavement. Minimal energy reserves are stored on board in cases obstacles have to be avoided or destinations away from the magnetic track have been chosen.

The nominal speed is below 20 km/h, letting the shuttles evolve in areas with a high density of pedestrians and facilitating frequent stops. This nominal speed is also interesting from a steering point of view. It has been shown (Arnet, 1998) that the chosen value corresponds to a speed where rear and front angles of a four-wheel steer should be equal to get a zero sideslip. In such a case, the speed vector is aligned with the vehicle axis and the users get an impression of comfort and safety. Moreover, the platoons stay on the path at turns.

The shuttles are equipped with a full set of sensors that are used for the fleet management, path tracking, platooning and security. Both GPS and on board detection of the magnetic track provide information about the absolute and relative position of the shuttles.

3 Towards sustainable cities

At the 1992 United Nations' conference in Rio, sustainable development has been defined as "Development that meets the needs of the present without compromising the ability of future generations to satisfy their own needs".

Transport and the environment prove difficult to conciliate. Our society, however, relies on both for long- term development. Assessment of the sustainability of an alternative transport system is a complex task. Spillman (Spillmann, 1998) provides a sound basis in his report for the Swiss national research programme 41 "Transport and the Environment". New developments may then be assessed under three different perspectives: ecology, economics and society as follows:

Environmental constraints: The ecological perspective derives rules for the usage of natural resources from their limited availability and, which is more crucial here, the limited carrying capacities of ecological systems or urban environments. In this respect, transport projects have to address matters such as air pollution, accidents, noise, severance impact and climate change. It thus draws clearly defined limits for economic development.

Economic stakes: In the economic perspective, sustainability is primarily a matter of optimal usage of resources, efficient markets, and improved general well-being. Relevant indicator concerning transport projects are economic viability, rational use of energy and fair prices. Hence, problems of distribution and equity are mainly disregarded.

Social issues: The distribution of wealth, implying basic social rights and the satisfaction of man's basic needs, stands at the center of the social approach. As for transport issues, equal access to mobility appears to be the most important question.

Once considered under the light of sustainable development, the BURST concept unveils fascinating perspectives for the cities of tomorrow. Indeed, such versatile systems provide the missing link between traditional public transport and the citizen.

4 Technological challenges

Because the BURST initiative deals with a really innovative transportation system, technological challenges have to be faced at many levels. Some of them have already been tackled, but a lot of research and developments are still ahead.

4.1 Mechatronics

At the opposite of the Californian PATH project (Tomizuka, 1997) where platoons of traditional cars are considered to develop an automated highway system, the BURST initiative relies on platoons of new autonomous shuttles. As a consequence, there is no a priori vehicle design to deal with. Any new chassis, axles, steering and motorization structures can be considered. One of the main ideas is to replace all the possible mechanical parts by electronics devices as proposed in a recent European project (Ebner *et al.* 1998).

4.2 Motion control

Optimal path planning has to be carried out before building the magnetic tracks. The curves have to comply with the mechanical and operational limitations of the shuttles (Dessimoz *et al.* 1998a), as well as with comfort and safety specifications for the passengers. Real-time tracking of the predefined path has to be implemented aboard. For that purpose, advanced predictive control techniques have to be used (Bemporad *et al.* 1997). To be efficient, these techniques require a highly reliable dynamical model of the shuttle. Not only path trajectories have to be followed, but also speed profiles in normal or emergency operation modes. Acceleration and deceleration have indeed to be acceptable for standing passengers. Collaboration for platooning (Large, 1997), obstacle avoidance (Dessimoz *et al.* 1998b) and even drivability recovery after crash also require advanced control techniques. Solutions can be derived from the ones developed for the Californian PATH project (Raza *et al.* 1996). However, they have to be adapted in accordance with the peculiarities of the designed autonomous shuttles.

4.3 Sensing and positioning

Sensing devices are essential for safety purposes, as well as for absolute positioning above the magnetic track and the relative positioning between the vehicles forming a platoon.

Short and medium range sensors are considered for safety. Emergency procedures are initiated when stationary or mobile obstacles are detected in a short range. In medium range, the situation is less critical and avoidance procedures or speed reductions can be implemented. Discrimination has to be possible between real obstacles and elements of the surrounding scene. In outdoor situations and in presence of pedestrians or pets, the choice of the sensors have to be made carefully. Images acquisition and processing is safer than the exploitation of laser detectors, but more challenging. Moreover, it is obvious than people will try to “play” with the detection and avoidance systems by interacting with the shuttle. There is no simple solution to deal with such behaviours.

The absolute positioning of the shuttle relies on digital maps, GPS information and detection of the magnetic track. If for any reasons a shuttle leaves the track, differential GPS or gyroscope have to be used for orientation and for tracking of virtual paths. When several measures are available, fusion techniques are applied.

4.4 Distributed information system

An advanced distributed information system is essential for the proposed new urban transportation solution, both from the users’ access and the fleet management point of view. Communication relies on GSM and radio networks. Signals transmitted using the magnetic tracks can be used in addition when the shuttles follow such powered paths.

The users are able to book rides from anywhere at anytime, and get relevant information about the shuttles coming and their destinations while waiting. They also get relevant information aboard during the trip. Advance interactive devices are needed for that purpose, as well as to compensate for the lack of driver.

Fleet operation requires centralised as well as decentralised management. The first one is dedicated to deal with the users' reservation and to optimise the shuttle supply according to the demand. The second one is mainly dedicated to platoons management, combining high level agents-based techniques for collaboration between shuttles and lower level techniques for real-time motion control.

4.5 Energy supply

Energy supply is realized through the magnetic track. High frequency currents going through the coils integrated in the road pavement induce a magnetic field sufficient to transmit the power to the onboard coil, despite the large air gap that separates the road and the shuttle base. For safety reasons, only the coils located below the shuttles are activated using the available information regarding the global position of the vehicles.

5 Scenario for Lausanne

5.1 Setting the scene

More than 10 different bus lines stop near the shopping area of the city of Lausanne (120'000 residents) in Switzerland (Fig. 2). The public service network has been designed as radial. Buses travel from periphery to the city center, where most activities are concentrated within a one square km pedestrian zone. In this context, there is of course no "circle line". Consequently, people regularly have to change buses or walk while carrying all their purchases.

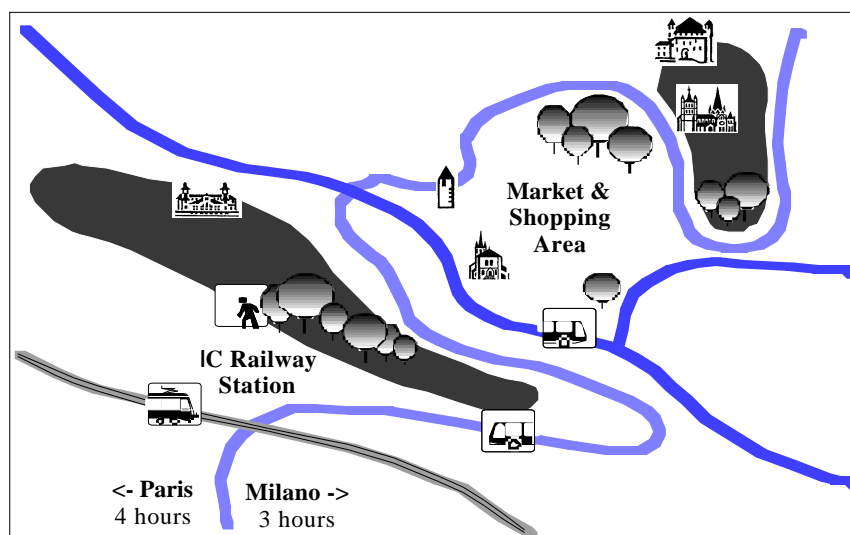


Figure 2 Lausanne, simplified view of the public transport system, with disconnected bus lines around the city center.

Given this context, we believe that implementation of a circle line (Fig. 3) of autonomous vehicles around the market and shopping area is feasible and useful. It would increase the attractiveness of the place and make it easier to reach. It would also facilitate intermodality and generate less environmental damage than the use of private cars.

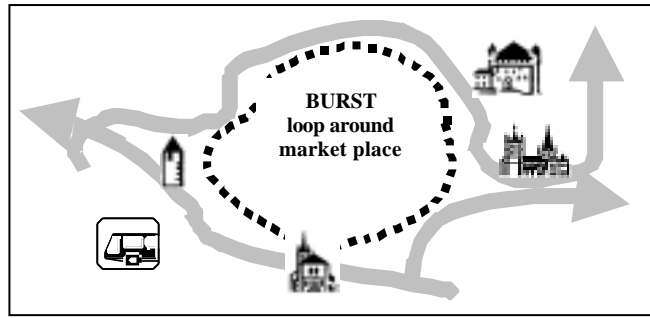


Figure 3 Autonomous shuttle loop.

5.2 Qualitative evaluation of the potentials

Qualitative evaluation of the implementation the proposed loop around the shopping area suggests that the BURST concept has a strong potential to drive the city’s development towards sustainability (Fig 4). More detailed project assessment based on a given vehicle type and a selected network is of course needed to produce a reliable statement.

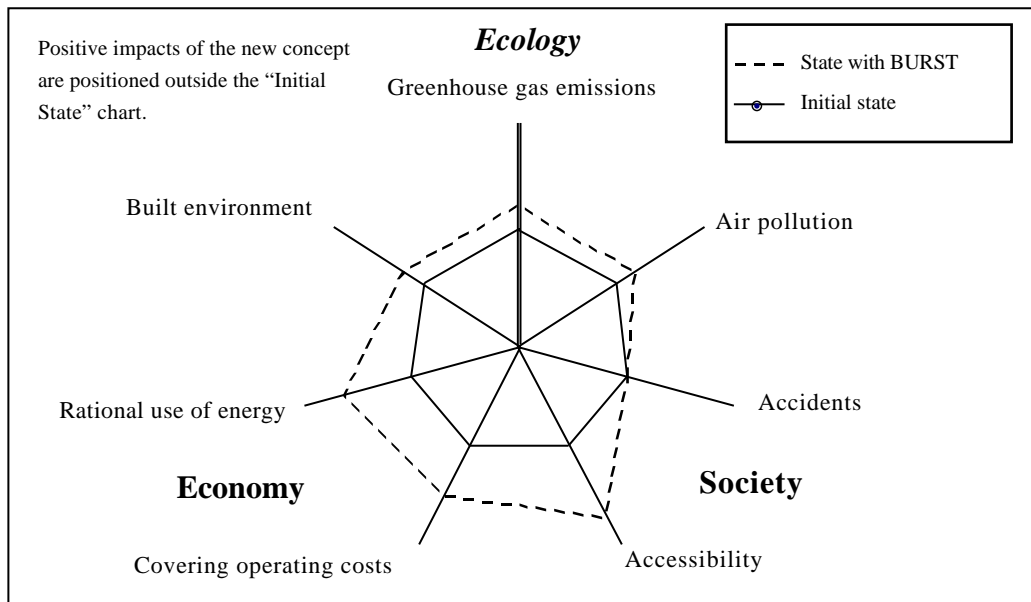


Figure 4 Qualitative evaluation of a BURST loop in Lausanne.

6 Conclusions and perspectives

The most significant environmental benefit expected is modal shift from car to less polluting public transport. In terms of economic benefits, one could expect more efficient use of urban roads, good return on operating costs, more rational use of energy, as well as lower need in expensive urban parking places. On the social point of view, BURST could provide better and equal access to urban mobility. It may even drastically improve the condition of elderly and disabled people.

At the current investigation stage, case studies for interested urban communities will be carried out in simulation and in reduced scale using mobile robots, probably in the context of a European research and technological development project within the EU 5th framework programme. The idea is to compare this new paradigm with traditional public transportation systems in various operation modes (i.e. continuous chain, platoons or shuttle bursts and individual commuting) and with different passenger loads. The issues of acceptance and benefits of a potential implementation within pedestrian zones will also be debated.

7 Involved research units

7.1 Institute for Automatic Control (<http://iawww.epfl.ch/>)

The Institute for Automatic Control (IA) is chartered within the Mechanical Engineering Department of the Swiss Federal Institute of Technology in Lausanne (EPFL) to teach automatic control to students specialized in various disciplines such as electrical, mechanical, micro, chemical and computer engineering. The course work is designed on the base of a highly interdisciplinary approach. It aims at suiting the students' different backgrounds and needs. Education, which is considered the EPFL's prime product, goes hand in hand with research. As a consequence both aspects are tightly linked. The research activities of the IA address modern cross-disciplinary modeling and control issues. Such activities include physical modeling, system identification, adaptive and robust control, dynamic optimization and nonlinear control, as well as all the related implementation approaches. Since its early days in the sixties, the IA has maintained a strong presence in the industrial environment. This enduring relationship results in continual transfer of modern control technology to industrial partners. As examples, important developments are carried out in the field of real-time prototyping for motion control in collaboration with National Instruments, and new solutions in intelligent transportation systems are investigated in collaboration with CN Serpentine SA.

7.2 Institute for Transport Planning, LEM Unit (<http://iteppc22.epfl.ch/>)

Logistics, Economics, Management (LEM) is an interdisciplinary research unit of the Institute for Transport Planning of the EPFL. LEM brings together an experienced team of economists, engineers, environmental scientists, logisticians, mathematicians and computer scientists in order to research into five issues: management methods, risk management, physical, financial and economical flow modeling, interactions between transport and environment as well as multimodal transport systems. These core issues have been supplemented by research work on the potential of new technologies for transport supply, the planning and management of large scale projects at regional, national and international scale, the development of monitoring and controlling techniques. LEM unit is strongly involved in the Swiss national research programme 41 "Transport and the environment: interactions Switzerland - Europe". LEM also contributes to the 4th Framework Programme on Research and Development, with two strategic research projects for the Transport Directorate of the European Commission.

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