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Pioneering driverless electric vehicles in Europe: the City Automated Transport System (CATS)

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Abstract

The City Automated Transport System (CATS) was a collaborative FP7 European project that lasted from 2010 to 2014. Its objective was to evaluate the feasibility and acceptability of driverless electric vehicles in European cities. This contribution explains how the project was implemented by 11 teams in five countries, culminating with practical trials of driverless vehicles in Strasbourg, France; Ploiesti, Romania; and Lausanne, Switzerland. The Navya vehicles used were able to transport up to eight passengers, in an open vehicle where passengers could recline against lumbar support cushions. After extensive road testing in Strasbourg, the final demonstration took place at the EPFL campus in Lausanne, where around 1600 people were transported safely during 16 days of vehicle operation. Three vehicles were used, a fourth remaining on campus as a back-up. Although no driver was present, a student was available on board of each vehicle to respond to questions from the passengers and to handle the three points on the 1.8 km route where there was insufficient leeway for two vehicles to pass each other. Passenger reactions to the driverless vehicle concept were collected by questionnaire and were overwhelmingly positive. Caveats include limited access for people with disabilities and the risk that a regular service based on this new concept might compete with walking and cycling rather than with transport by car. Implications for the acceptability of driverless electric vehicles in Europe and elsewhere are discussed.

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Keywords: electric driverless vehicles, urban transport, last mile, Europe, FP7

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1. Introduction

1.1. Background

Most automobiles are used only during short periods and remain unused for most of the day. Therefore, in a city with shared automated cars the total number of vehicles would be lower, freeing up urban space previously used for parking (Alessandrini et al. 2015). Autonomous vehicles may also bring about savings linked to vehicle safety, congestion and travel behaviour, in the range of US$ 2000 to US$ 4000 per vehicle and per year according to a recent US-based evaluation (Fagnant and Kockelman 2015). At a practical level, such systems could become efficient and cost-effective by minimizing travel time paths, combining requests for trips and optimizing the location of parking and recharging stations (Awasthi et al. 2011).

The City Automated Transport System (CATS) is a European FP7 project which lasted 5 years (2010-2014) and whose objective was the development and experimentation of an urban transport service based on a new generation of driverless vehicles. In practice, the service aims at covering the last mile between a public transport hub and people's workplaces, thus achieving a more efficient mobility profile in cities through a balanced use of small clean vehicles and mass transit options. The new transport system is inclusive in the sense of being adapted to the needs of people with slightly reduced mobility, senior citizens, young passengers and tourists. However, no specific provision was made for the vehicles to be accessible to wheelchairs, because the system was intended to operate at similar speeds and along similar paths to those used by people in wheelchairs.

Through mobility needs analyses, on-site demonstrations and showcases, the impact of the introduction of a driverless electric vehicle system was evaluated in three European cities: Strasbourg, France, Ploeisti, Romania and Formello, Italy. Later on in the project course, practical demonstrations were carried out in Strasbourg, Ploeisti and especially Lausanne, Switzerland. The impact on environment and especially on CO2 emissions, as well as the acceptance and the evaluation of market take-up of the system were investigated. The CATS project initially investigated a modular electric vehicle called Cristal, which was able to operate alone in a driverless format or in a convoy of several linked-up vehicles driven by a professional driver. Due to practical constraints, the CATS consortium finally opted for a different system called Navia/Navya, which was similar to Cristal in many ways but unable to operate as a convoy.

1.2. Origin and timeline of the project

The CATS project was set up in 2009 to answer FP7 call number SST.2008.3.1.1 entitled "New mobility concepts for passengers ensuring accessibility for all". The winning consortium brought together eleven partners in five countries (France, Israel, Italy, Romania and Switzerland), including transportation systems manufacturers, research institutes, services providers and end users. The project began on 1st January 2010 and its initial objective was to promote the Cristal system, designed and operated by the French company Lohr Industrie. The initial phases of the CATS project included a mobility needs analysis on three cities: Strasbourg, France, Ploiesti, Romania and Formello, Italy. After a detailed user needs analysis (data not shown), Strasbourg was selected as the most suitable for a public demonstration. Further research identified the Illkirch Innovation Park, which combines University buildings, laboratories and other businesses as the best location within the Strasbourg area. Detailed impact analyses on the environment – including CO2 emissions – were carried out, as well as an evaluation of the acceptance and market uptake of the Cristal system, whose infrastructure and operating principles were redesigned in accordance with city and citizen needs (data not shown). A discrete events model was created in order to simulate the functioning of the Cristal system (Mahari and de La Fortelle, 2011).

For economic reasons, Lohr Industrie abandoned the production of the Cristal prototype in 2013 and partially withdrew from the CATS consortium. In order to pursue the objectives of the project, a second innovative transport system was identified by the consortium: an innovative driverless vehicle, with a capacity of around 10 people, developed by French manufacturer Induct Technology and called Navia. The Navia system was chosen for its similarities with the Cristal system in terms of capacity and certain operation principles, although it could not circulate as a convoy. The entrance of Induct into the CATS consortium in late 2013 enabled the completion of the first phase of the demonstration in the first months of 2014, whereby three Navia vehicles navigated successfully through the Illkirch Innovation Park for several months, but without taking passengers for legal reasons. Thereafter, following a period of receivership, the Induct Company was declared bankrupt in May 2014. The assets of the company were acquired by a new owner who was interested in the CATS project and who renamed the vehicles Navya.

The road tests in Strasbourg highlighted the difficulties of integrating automatic vehicles on the public domain without significant flanking measures to reduce the speed of other traffic. Significant horizontal and vertical signposting would have been needed, with physical safeguards and speed controls at key locations on the route. The road tests led to substantial progress in the approval process of autonomous vehicles on the public domain in France. Following a meeting with several French ministries, the Urban Community of Strasbourg received the first national authorization to operate a fleet of autonomous vehicles on the public domain. Nevertheless, for security and legal reasons it was decided to carry out the second phase of the demonstration, open to the public, on a more protected site. In order to achieve the project objectives, the following solutions were found: on the one hand, the buyer of the Induct assets agreed to lease the vehicles for the CATS project until the end of the demonstration; on the other hand, the demonstration site was transferred to the EPFL campus in Lausanne (Switzerland).

1.3. Legal and administrative aspects

Following its purchase of a Navia/Navya shuttle in November 2012, the EPFL had already contacted the Swiss competent authorities to request permission to operate automated vehicles on its campus. Due to the private status of the campus, the proposed free access to the shuttles and the demonstration character of the project, the Federal Office of Transport and the Federal Office of Roads both decided not to ask for a certification procedure and delegated the task to the authorities of Canton Vaud. A meeting with the canton in March 2013 had enabled initial clarification of the certification process, in partnership with the canton’s police authority.

After a site visit in early July 2014, the authorization for the CATS demonstration was delivered jointly by the transport office of Canton Vaud, the cantonal police and the cantonal office for vehicle approval and testing (Service des automobiles et de la navigation). The conditions were a maximum speed of 12 km/h, no more than 9 persons per vehicle (8 passengers + 1 operator), and adequate insurance coverage.

Once permission to operate the vehicles had been obtained, the demonstration was implemented by three local partners: the EPFL Vice-Presidency for Planning and Logistics (VPPL), which contributed one vehicle, Navya which provided three vehicles on a rental basis and was available for heavy maintenance on demand, and BestMile, an EPFL start-up company that ensured day-to-day vehicle management and maintenance, data collection and team management. The setting up of the campus demonstration took place on 7-9 July 2014 and the demonstration was open to the public between 10 and 31 July after receiving authorization from the competent Swiss authorities on 9 July 2014.

2. Methods

2.1. The vehicles

The demonstration was carried out using prototypes of the electric Navya shuttle, which has no seats but has a cushion around its middle enabling passengers to recline in a relatively comfortable position. It was not necessary to charge these vehicles during the day, thanks to powerful batteries that could be charged during the night in a maintenance centre that was created on campus, in an underground garage. On board of each vehicle, a computer continually generates a 3D map of its surroundings while monitoring the vehicle’s position and behaviour. This is enabled by a GPS system, stereoscopic optical cameras and 4 Lidar (light radar) sensors. Each sensor has a range of 200 metres and is able to cover the entire environment 25 times per second. Acceleration and speed are analysed according to three axes: forwards-backwards, laterally and vertically (descent-ascent). The vehicle is able to detect any obstacle (pedestrian, cyclist or car) to adapt its speed accordingly and stop if necessary. Each vehicle can carry up to 10 people, this was legally limited to 9 in this demonstration project, the number of passengers being reduced to 8 due to the presence of a warden. The vehicle has an approved maximum speed of 20 km/h and requires no specific infrastructure such as rails or contact lines.

The EPFL rented the vehicles for the duration of the demonstration from the owner (Navya). A previously purchased shuttle also participated in the demonstration. Initially thought of as a back-up if one of the three main vehicles failed, this fourth shuttle was in fact used as a reservoir for technical components. A laser, the on-board screen and other pieces were replaced on the three main shuttles thanks to the fourth shuttle, thus allowing the demonstration to keep running without having to wait for repairs personnel to intervene.

The vehicles were operated on a 1.8 km route within the EPFL campus (see map) which served important venues such as the University library (Rolex Learning Center) and the so-called Innovation sector which hosts many of the start-ups and spin-offs related to the EPFL. However, it did not serve the light rail train station, because this would have implied driving along a road with fast-moving traffic (authorisation for this could not be obtained at short notice, however at the time of the demonstration discussions were on-going with local authorities and ultimately permission was given for this route to be used by similar driverless electric vehicles in the framework of another European project called CityMobil2). The speed at which the vehicles were operated meant that the time to accomplish the route was slightly faster than walking for the average person (most people walk at 3-5 km/h). It should be mentioned that no other in-campus transport system has ever been available.

The implementation of the on-site demonstration was carried out by BestMile (a spin-off company based at EPFL campus) from 10 to 31 July 2014, on weekdays from 7:30 to 18:00. This represents a total of 168 operating hours over 16 days. This period is part of the summer break during which most students are on vacation. Although less people were available on campus, potential users were also less likely to be students. Furthermore, if the demonstration had taken place during a semester, demand might have exceeded the capacity of the system.

The demonstration was operated daily according to the following scheme. A student was present aboard each shuttle to explain how the vehicle worked, answer questions, distribute and help complete questionnaires, manage vehicle crossings and engage the emergency brake if necessary. A more senior person, the operator, was located midway on the shuttles route to manage the students, supervise the vehicles, intervene quickly in case of incident or failure, and list any encountered incidents. The students and the operator communicated with each other using walkie-talkies. The operator leased an electric car for the duration of the demonstration in order to store the necessary equipment for maintenance and to be able to intervene quickly in case of incidents.

2.2. The demonstration route

The CATS demonstration route (see Figure 1) was defined on the basis of a territorial study carried in the framework of the CityMobil2 European project in 2013. This study intended to identify the needs for mobility not yet answered within the campus and the integration constraints for automated vehicles. The study was conducted in order to prepare a 6-month demonstration of automated vehicles for CityMobil2, to start in November 2014. It was thus well adapted for the CATS demonstration and had the advantage of being readily available. For practical reasons, the route selected for CATS was shorter than the route defined for CityMobil2, not serving the Metro station. This choice was dictated by short-term feasibility criteria. The CATS demonstration on campus had to be organized in less than a week and the inclusion of all the sections needed to perform the entire link was not feasible in the available time.

In some sections, the pathway width did not allow two vehicles to pass each other. To manage these sections, two crossover points were defined. The students on board communicated with walkie-talkies to find out if the sections were free or if they had to wait at the crossing point. The students resorted to regularly announcing their position to each other. Given a little practice, this effectively minimized waiting times. Signposts and banners were installed along the route to inform users of the presence of autonomous vehicles. During the night, the vehicles were brought into a protected parking lot on campus, where each vehicle could be connected to the mains (15A) and where spaces had been reserved. Barriers were used to protect the vehicles and prevent other cars from entrenching. The parking lot was also used as a maintenance centre when needed. The students aboard the vehicles were responsible for distributing questionnaires to users and helping them respond. The students were occasionally helped by other project participants during periods of heavy attendance of the demonstration. The questionnaire was made available in French and English.

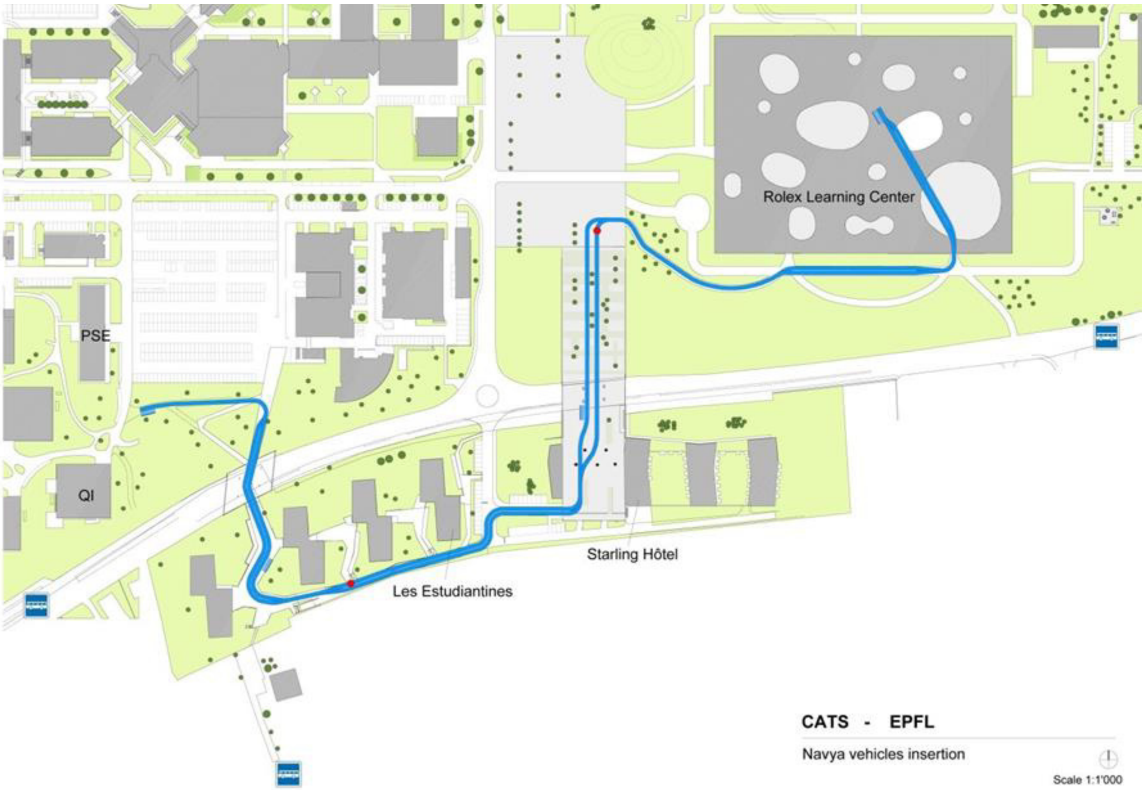

Fig. 1. The route used by the Navya/CATS vehicle within the EPFL campus in Lausanne. The route begins underneath the cover of the Rolex Learning Center, then passes twice underneath a main road.

3. Results

The evaluation took place during the second half of the demonstration period: 21-31 July. Altogether 800 people were transported during the 8 days of evaluation. In total, the vehicles travelled for 16 days, including a full week without any rain between 14 and 18 July. Therefore, it can be estimated that at least 1600 people were carried during the demonstration phase in Lausanne. A total of 181 questionnaires were completed by users during the two weeks of assessment.

Most users were male (66 %). This is only slightly more unbalanced than the gender split on campus, where only 27% of students and 31 % of personnel are female. Around 70% of the respondents were aged 20-50 years. Moreover, none of the respondents were less than 10 years old although many families with young children were observed using the Navya shuttles. The children did not respond to the questionnaire as such, but some may have participated in the assessment via their parents. Only one-third of the respondents were students (see Figure 1). The timing of the demonstration during the summer holidays enabled a more diverse set of users to discover the shuttles than would have been the case during term time.

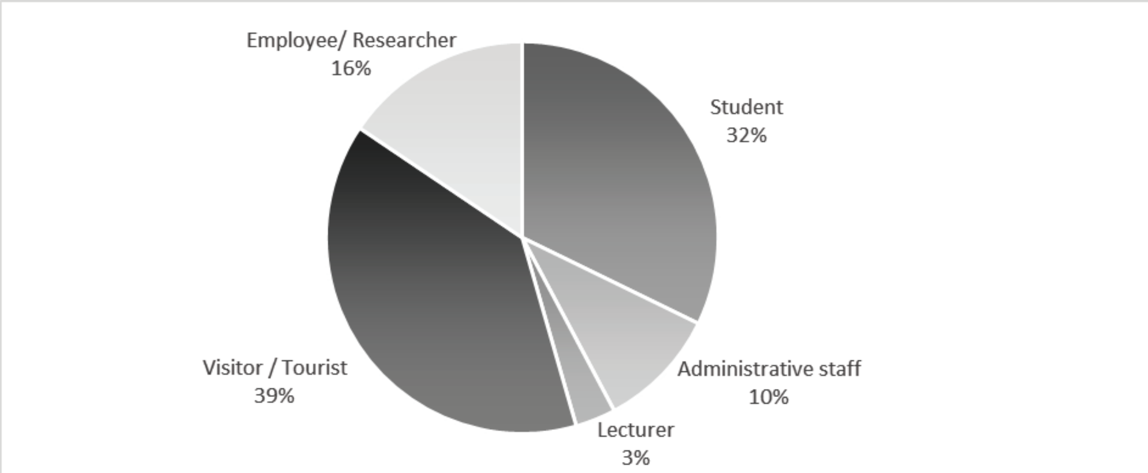

Fig. 2. The profiles of the 181 persons who answered the CATS questionnaire on EPFL campus.

The transport modes used to reach campus were varied. Around 40% of the respondents came by car and a similar proportion used the so-called Metro (in fact, a light-rail transit system). A further 12% came by foot and 8% by bicycle. Attitudes towards the Navya shuttle were investigated by asking respondents whether they agreed with a series of statements. Responses were coded on a Likert-type scale from 1 (totally disagree) to 5 (totally agree) with each statement. The results for a selection of these statements can be seen in Table 1.

Table 1. Opinions expressed about the Navya experience on EPFL campus.

Statement	Agree or totally agree
The vehicle is aesthetic	81%
The vehicle is futuristic	77%
The vehicle is functional	80%
The vehicle is user-friendly	92%

Regarding frequency, 61% of respondents said that the proposed frequency (one trip every 7-10 minutes) was sufficient. However, when asked specifically about waiting times only 21% of respondents said they were willing to wait more than 6 minutes for such a service on a daily basis.

To the question “How much would you be willing to pay to board such a vehicle”, 76% of respondents said less than 2 CHF (approximately 1.20 Euro or 1.20 US$ at that time). A full-fare public transit ticket for one hour costs 3.50 CHF in Lausanne, or 1.90 CHF for a short trip (maximum 3 stops) which is similar to the average price quoted in this survey. Comfort was rated on a five-point scale, ranging from 1: not comfortable at all to 5: extremely comfortable. Some 76% of respondents found the lumbar support cushion to be comfortable or very comfortable. Direct observation yielded evidence that the proposed support system is ideal for people of average height. While taller people can prop themselves up against the side cushions, smaller people found it more difficult to find a comfortable position. Regarding the quality of the ride, only 14% of respondents found it excellent. During the demonstration, the ground on which the vehicles were travelling gradually deteriorated due to bad weather and repeated passage of the vehicles. Holes formed within the stabilized soil, causing jerkiness. Another important element affecting comfort was speed management on the slopes. When accelerating or slowing down on slopes – which was experienced as stop-and-start by users although the vehicle did not stop – this impacted the general smoothness of the transport experience.

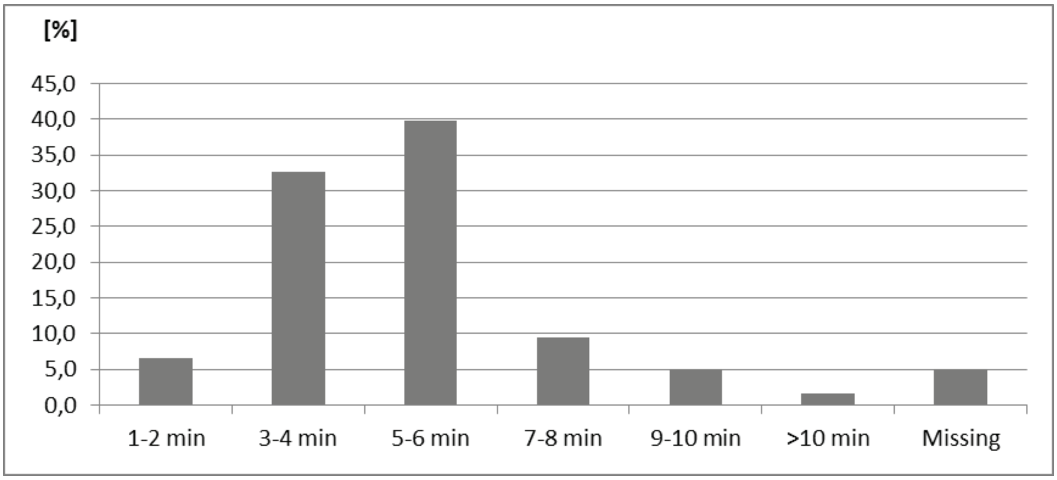

Fig. 3. How long would you be willing to wait for such a vehicle?

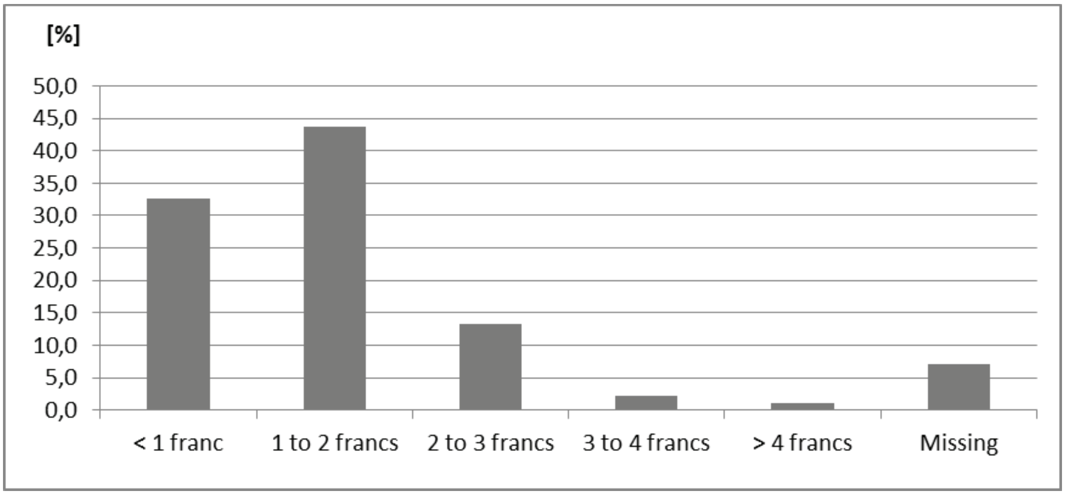

Fig. 4. How much would you be willing to pay to board such a vehicle? (1 Swiss franc = approx. 1US$)

Ease of use was rated very highly: 92% of respondents found it easy or very easy to get into the vehicle, although disabled people and those with reduced mobility had little access to the system since no ramp was made available. Likewise, 91% of respondents felt safe or very safe inside the vehicle and 72% felt safe walking around the vehicle (a further 14% had no opinion for this item since they did not walk around the vehicle). The size and the speed of the vehicle were considered well adapted to the EPFL campus environment. For both size and speed, around 82% of respondents agreed that the integration was a success. The size of the vehicle is an important element in ensuring the integration of autonomous vehicles in their environment. This is true from the point of view of people's perceptions (it forms an important part of acceptance), but also regarding practical constraints. Indeed, vehicles must be neither too large, in order to be able to use urban roads and manoeuvre through parking lots, nor too tall, so they can pass beneath arches.

Some 58% of respondents found Navya to be an innovative or highly innovative vehicle. Around 39% of respondents said they were willing to use autonomous vehicles regularly in the future. Only 5% of respondents are reluctant to do so. When asked why they boarded the vehicle, a large majority said it was out of curiosity or to test the vehicle, and only a small minority to their destination, in effect using the shuttle as a public transport service. Respondents found the vehicle user-friendly, futuristic, functional and aesthetic (despite the bad weather which accompanied much of the demonstration phase). The operating speed of the vehicle was divisive: half of the respondents said it was too slow, while the other half saw no problem with the speed. The absence of a driver was not perceived as a problem by 78% of respondents. This important result may be correlated with the type of person likely to be found on the EPFL campus at any time including the summer holidays: often people interested in technology and innovation. The absence of true seating and the lack of window panes were experienced as a problem by some users. Open comments from users included suggestions to extend the service in various directions, especially towards the Metro station and towards the neighbouring University of Lausanne campus. Spontaneous comments included: “Very friendly and impressive idea”, “Wonderful innovation, keep your research going!”, “(is this) the place for an after-work drink?” or “You should think of adding music during the ride.” We interpreted these data and comments as a sign that Navya, while being taken seriously as a technological innovation and transport system, is also viewed as being fun.

4. Discussion

The CATS project faced challenges during its five years of existence, including a change of vehicle and two changes of industrial partner. Nevertheless, it proved possible to organise a large-scale public demonstration involving several vehicles and over 1600 participants, although the location had to be switched at short notice from Strasbourg to Lausanne. It may be useful to consider the legacy of CATS as lying in-between pioneering European projects such as CyberCars in 2002-2004 (Awasthi et al. 2011) and more recent frameworks such as CityMobil2 (2012-2016). It would therefore make sense to view CATS as a step along on a path rather than an isolated project.

One limitation of this study is that the public demonstration took place in a technical University setting, where passers-by are likely to be interested in technology. Indeed, a recent internet-based survey in Austin, Texas, found that higher-income, technologically-oriented males living in urban areas were more likely than others to be interested in smart-car technologies and strategies (Bansal et al. 2016). However, an indication that the public acceptance of autonomous electric vehicles might be more general in European cities was supplied by a showcase which took place in October 2014 in Ploiesti, Romani, organised within the framework of the CATS project and using another type of autonomous electric vehicle (INRIA Cybus). The initial plan was an exhibition, but the municipality of Ploiesti decided to organize a larger event using a Street of the Future format (an out-of-doors circuit) where members of the public could be transported on a secure route within a pedestrian area in the historic centre of the city. Transported passengers were conservatively estimated at 300. The evaluation of this showcase was qualitative rather than quantitative, and overwhelmingly positive. This is in keeping with other studies suggesting that urban users in Europe tend to be receptive to the idea of using automated road transport systems (Payre, Cestac and Delhomme 2014; Alessandrini et al. 2014).

The main challenges encountered during the demonstration in Lausanne concerned vehicle hardware. The vehicles used during the demonstration were prototypes and were therefore slightly different versions of the same vehicle. They regularly encountered hardware problems during the demonstration: loosening of screws, loss of lasers alignment, problems of fuses, soldering requirements at short notice. In addition, the vehicles occasionally faced software problems such as location loss which were solved thanks to the prompt intervention of the operator and the experience gained progressively by the students inside the vehicles. The intervention of the manufacturer was required only once during the entire demonstration. Another challenge was that the demonstration route on the EPFL campus had several sections whose width did not allow the crossing of vehicles. Operators on board therefore had to anticipate crossings so that they did not occur on one-way sections. This involved some “exploitation stops” of the shuttles to wait for the oncoming vehicle to releases the one-way section. With experience, operators increasingly succeeded in anticipating and avoiding such unexpected stops. Finally, in some places, the repeated passage of the vehicles for four weeks partially damaged the soil on which the vehicles were traveling.

At the administrative and legal levels, the CATS experience suggests that the federal political structure in Switzerland is an advantage for moving projects forward in a context of innovation which necessarily includes a degree of improvisation and creative thinking. It appears that the Swiss contribution was decisive in helping this project evolve towards success. However, the contributions of the other partners should not be underestimated. For example, the on-road testing of the Navya vehicles in Strasbourg was a prerequisite for the project being authorized in Lausanne. Likewise, although it may be thought that time was lost while developing the first part of the CATS project with the Cristal vehicle which was finally abandoned, it should be remembered that it is the Cristal concept that inspired the project in the beginning, that led to the constitution of the project consortium and ultimately therefore to the success of the project. The main lesson learned, for the participants in this project, is that innovative transport projects may not advance in a predictable manner. It is sometimes necessary to allow leeway so that solutions to new problems can be found.

One implication of this finding is that the creators and constructors of innovative vehicles should not be left alone to design and test their products. There is a need for academic support – especially around modelling and monitoring and evaluation – and a strong need for external funding. It follows that European projects such as FP7 and Horizon2020 are the instruments of choice in order to pursue the development of innovative and sustainable mobility solutions in Europe. This is important in a broader context where a review of 2500 research solicitations in EU Framework Programmes has found that, while socio-technical integration tended to increase between 1998 and 2010, projects integrating socio-ethnical and stakeholders into scientific research actually decreased in time. We therefore suggest that future projects investigating and promoting driverless vehicles continue to address the points of view of the end-users and indeed of potential non-users of these systems.

5. Conclusion

The demonstration conducted in July 2014 in Lausanne as part of the CATS project was followed in November 2014 by another demonstration in the same campus area, organized in the framework of another European project, CityMobil2. This demonstration lasting six months involved 6 automated vehicles on a longer and more complex route connecting the campus and the Innovation Park with a metro station. These demonstrations and the continued involvement of EPFL and its partners in European projects show the strong interest within Europe for deploying automated transportation systems. Although it is not part of the European Union, Switzerland has shown through its participation in the CATS project that it can help develop and showcase innovative transportation projects which may then be developed further or implemented in other countries.

Passenger reactions to the driverless vehicle concept collected by questionnaire in Lausanne and Ploiesti were overwhelmingly positive. However, reactions at the administrative and regulatory levels were – perhaps predictably – less enthusiastic. By definition, when a new transport concept is introduced, it is not likely to find a freely available legislative or administrative slot into which to insert itself. The policy implications are that it may be useful, for the sake of innovation, to allow new transport concepts to be experimented in certain areas. Caveats regarding the concept experimented in Lausanne include limited access for people with disabilities and the risk that a regular service based on this new concept might compete with walking and cycling rather than with transport by car. Indeed, the so-called last mile is an area where competition already exists between different transport modes and as more innovative concepts hit the market this competition is likely to increase.

6. Acknowledgements

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