Driverless electric vehicles at Businesspark Rivium near Rotterdam (the Netherlands): from operation on dedicated track since 2005 to public roads in 2020

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ABSTRACT: This paper reports about the operation of the automated and electric ParkShuttle at the Rivium Businesspark in the Netherlands. The ParkShuttles operate without a driver on a designated lane where crossing traffic is managed with barriers. The second and current generation ParkShuttles have been operating since 2005. Having been operational for over 10 years, the ParkShuttle operation may be considered 'proven technology'. The Rivium ParkShuttle is the only operational automated shuttle application without a steward on board. In this paper we also look forward to operation on public roads in 2020.

KEY WORDS: Automated, autonomous, EV (Electric vehicle), public transport (B3)

1. INTRODUCTION

This paper reports about the operation of the automated and electric ParkShuttle at the Rivium businesspark in the Netherlands. To fulfil the last mile from the metro station Kralingse Zoom to businesspark Rivium, the municipality of Capelle aan den IJssel and other stakeholders invested in automated electric people movers from 2getthere. These ParkShuttles have been operating since 2005 on a designated lane equipped with artificial landmarks (magnets) embedded in the road surface. Having been operational for over 10 years, the ParkShuttle operation may be considered 'proven technology'.

The Rivium ParkShuttle is unique since it is (to the knowledge of the authors) the only operational automated vehicle in Europe in permanent (revenue generating) service. There are many projects and test cases with automated vehicles, but most of these projects do not result in an operational system. A case study was conducted as part of the Spatial and Transport impacts of Automated Driving (STAD) project, aimed at learning from practical applications/projects with automated vehicles to get from experiments or pilots to more permanent applications of automated vehicles. The Rivium ParkShuttle is one of the case studies conducted within the STAD project. Other case studies, such as the 'application of driverless electric automated shuttles for public transport in villages: the case of Appelscha' (presented at EVS30), can be found on the STAD website (1).

2. THE CASE

2.1. Purpose of the ParkShuttle

The ParkShuttle has been developed to fulfil the last mile transport between metro station Kralingse Zoom and businesspark Rivium (see figure 1). Public transport is not always efficient and timetables don't always match (2). Therefore, an on demand automated vehicle can provide frequent and flexible transport. The municipality did consider other forms of public transport, but the distance was too short for a bus, tram or train (3). Also, by implementing such a futuristic vehicle the municipality hoped to attract more businesses to the (then in development) Rivium Businesspark. Furthermore, the municipality was aiming to decrease the amount of parking space to steer the modal split of the companies towards more use of public transport. The implementation of the ParkShuttle also fitted in the 'Fileplan' (traffic jam plan) which the municipality developed in collaboration with private companies (4). To reduce the use of cars, public transport to the businesspark needed to be efficient and attractive (5).

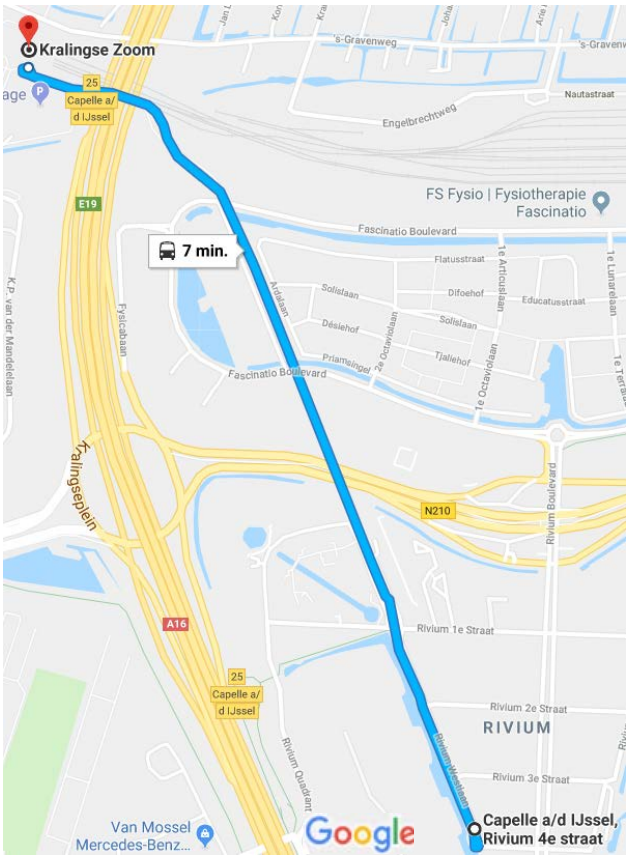

Figure 1: Route of the Rivium ParkShuttles (6)

The ministry assigned ZWN (now part of Connexxion, which is part of Transdev) to realize a connection with an automated vehicle from metro station Kralingse Zoom to Rivium Businesspark. ZWN asked Frog Navigation Systems, known for their automated vehicles in the Rotterdam harbor, to develop a vehicle (4).

Initially, the ParkShuttle was set up as an experiment. The experimental phase started in 1997. The vehicle drove without any passengers for the first three months. The next three months test passengers rode the vehicle and crossing traffic was simulated. During the experimental phase a steward was in the vehicle. Eventually regular passengers were able to use the vehicle and the steward was no longer needed in the vehicle (7).

2.2. Two generations of vehicles

From 1999 until 2001 the first generation ParkShuttles were in operation. The vehicles drove on weekdays between seven am and seven pm. There were no vehicles in operation during the weekends. The vehicle had one stop at ‘Rivium 1e straat’.

Based on the experience with the first generation, it was decided that the route should be extended and the vehicles should be upgraded to a second generation. The second generation was developed to improve the comfort of the travelers and to improve the software. Also, an evaluation showed that the new vehicle needed to be able to move more passengers and the waiting time had to be reduced. Furthermore, there was a need for a reliable system and better travel information. Also, operational costs had to go down. To secure safety, cameras were installed along the track (5).

The design of the second generation vehicle started in 2001 and the vehicle was built in 2003. 2getthere, a business unit of Frog Navigation Systems, was the main contractor for the system, subcontracting the design to Duvedec and chassis and driveline to Spijkstaal. Frog provided projectmanagement, engineer, the soft- and hardware of the vehicle and the supervisory system as well as the installation and commissioning services. The track of the ParkShuttle was extended to ‘Rivium 4e straat’.The new route contains five stops, including an additional stop on the previously existing route as new developments had been realized.

After a testing phase, the second generation is in operation since 2005. There was a break in operation due to a collision (explained in paragraph 3.2), after which the vehicle has been back in operation since September 2008. The second generation is still operating today.

The third generation ParkShuttle is in production. These shuttles will be smarter, since the route will be extended once again also partially over public roads in mixed traffic. The route of the ParkShuttle will be extended to the waterfront where a Waterbus stop will be established. Operation on the current route is planned for September 2019, with the extension in mixed traffic coming online in 2020 (8).

2.2. Route of the vehicle

The ParkShuttle operates between metro station Kralingse Zoom and businesspark Rivium. When developing the Rivium businesspark, several transportation modes have been considered. The municipality chose the automated shuttle as preferred transportation mode for the businesspark. The starting point of the ParkShuttle, metro station Kralingse Zoom, has been chosen because of the different (public) transportation options. The metro station is connected by metro line A, B and C towards Schiedam centrum, de Akkers, de Terp, Nesselande and Binnenhof. Next to the metro station is a bus stop for city and regional busses from

public transport company Connexxion, Arriva and RET. Also, the highway A16 is close by and there is a P+R with 1700 parking spots next to the metro station (9).

The ParkShuttle operates on a designated lane. The designated lane is two-lane, except the overpass over the Abraham van Rijckevorselweg and the tunnel near the metro station. The lane was initially designed as a bicycle lane, hence the one-way viaduct and tunnel. Crossing traffic is managed with barriers (see figure 1). Because the vehicle is operating on a designated lane, there is minimal disturbance of other traffic (10).

Figure 2: The Rivium ParkShuttle in operation (11)

The Frog system is integrated in the infrastructure which means the asphalt contains artificial landmarks (magnets) to help the vehicles navigate. There is a magnet every four meter. The route is 1800 meters and contains five stops. See figure 2 for the route of the vehicles.

Figure 3: Public transport at Rivium (the ParkShuttle is the green line) (12)

2.3. Timetable

The Rivium ParkShuttle offers on-demand service. Passengers have to push the button at the stop to call a vehicle. The signal will be sent to the supervisory system. The supervisory system will sent a vehicle to pick up the passenger. An operator is supervising the system in a control room next to the metro station.

The vehicle can carry up to twenty-four passengers (twelve seats). In peak hours all six vehicles will be in operation. This means a maximum waiting time of two and a half minutes. In off-peak periods three vehicles are in operation and the maximum waiting time is six minutes. The Rivium ParkShuttle is in operation from Monday till Friday between six am and nine pm. Currently, the ParkShuttle carries 1200 passengers on a daily basis (13).

2.4. Vehicle specifications

The Rivium ParkShuttle is built in 2003 by 2getthere, at that time a business unit within Frog Navigation Systems. The vehicle design was subcontracted to Duvedec, with Spijkstaal delivering the chassis and driveline. They run on the FROG (Free Ranging On Grid) system. Integrated in the software is an electronic map with route planning software. The vehicles also contain odometers and calibration software. An antenna is mounted on the vehicles to communicate with the control room. Two laser scanners are installed at the front of the vehicle for obstacle detection (10). When the ParkShuttle was developed, it was unique to install laser scanners on a moving object instead of stationary (14).

An operator is monitoring the vehicles from the control room. The operator can, if necessary, order the vehicles to drive or to stop from the control room. The route of the vehicles is divided in different route sections. When a vehicle comes to the end of its current route section, the system will give permission to enter the next route section when this section is available. Besides monitoring the system and intervening when necessary, the operator also makes sure the vehicles are clean. Furthermore the operator sells tickets and fulfills a role as a host (15).

The ParkShuttles are equipped with lead-acid track-air batteries from Hoppecke (3). The maximum speed of the ParkShuttle is 32 km/h and the range is 75 kilometer on a single charge. Charging the vehicles takes approximately six hours. The vehicles charge at night and alternate charging during the day during off-peak periods (16). The batteries of the vehicles have been renewed twice since the start of the operations (3).

3. CHALLENGES

3.1. Obstacle detection

The first generation ParkShuttle stopped for all obstacles on the road, including pigeons or newspapers flying by. 2getthere decided to install an extra laser, so the vehicles have two lasers for better detection and allowing to avoid 'ghost obstacles'. Adjusting the lasers was challenging, but they managed to find the right adjustments. The settings have been modified in such a way that the vehicles no longer stop for newspapers or pigeons (pigeons or other birds are assumed to fly away), but the vehicles will stop for humans and other traffic (3).

Some people used the designated lane as a cycling lane or footpath. Skaters sometimes used the smooth asphalt to skate and cyclists tend to use the overpass as a shortcut. Detecting people on the track will initiate the (emergency) brakes. Once the vehicle comes to a stop, the horn will sound. The operator is able to communicate with people inside and outside the vehicle via an intercom system. He/she can instruct the person to leave the track or he/she can go to the track. Having people on the track does not happen very often (3).

3.2. Collision of two ParkShuttles

On December 6th of 2005 a collision between two ParkShuttles occurred. After this collision, the vehicles were temporarily shut down while awaiting the investigation. The investigation concluded that the collision was due to an 'unfortunate coincidence'. One of the vehicles had a communication malfunction with the supervisory system while driving. This is not a dangerous situation in itself, because a vehicle that cannot make contact with the supervisory system will not be allowed to enter the next route section. This means that the vehicle itself will stop when it reaches the end of its current route section. In this case, the vehicle came to a standstill on the single-lane overpass. As a result, the vehicle blocked the passage. Manually, the operator released the zone allowing it to be granted to another vehicle. Unfortunately the operator released the zone twice, giving permission to vehicles from both sides of the single lane section to enter it. Due to vertical radius of the bridge not being according to specification, the vehicles encountered each other at the location where the obstacle detection sensors were unable to detect the other vehicle in time to come to a full stop. No passengers were present in the vehicle during the collision (17).

To prevent such collisions from occurring, Connexxion and 2getthere worked together on safety precautions. The software of the vehicles and the supervisory system were adjusted and the coverage of the communication network has been improved. In addition the procedures for the operators were adjusted and additional training was provided. After the adjustments, the damaged vehicles were repaired and the vehicles (extensively) tested again. No other accidents occurred (3).

4. COSTS

4.1. Investment

An overview of the costs of the initial investment is not available. A press release from the 8th of July 1997 states that the municipality of Capelle aan den IJssel invested 2.84 million euro (4) for the delivery of the 1st generation ParkShuttle. Another press release relates to the delivery of the 2nd generation system, stating that the municipality invested 5 million Euro and that the public transport company Connexxion invested 1.8 million Euro (18). Also, Frog Navigation System received an undisclosed amount of European funding via the Cybermove project (19).

4.2. Current deployment

With regards to the operational costs of the vehicle, the following costs must be taken into account (in order of magnitude):

Staff (direct and indirect)	Three operators are currently working in shifts at the Rivium ParkShuttle.
Housing	There is a garage for the ParkShuttles and an operator room for the operators.
Maintenance	Maintenance is partly carried out by 2getthere based on a maintenance contract. The operators carry out small maintenance and they keep the ParkShuttles clean.
Energy	The vehicles are electric vehicles.
OV-chipcard	Dutch public transport ticketing system.
System/ICT costs	CCTV, Wi-Fi and devices to check in- and out are installed.
Headquarter fees	Headquarter fee is determined by the turnover.
Insurance	Just like other public transport modes, insurance is mandatory.
Financing costs	Such as interest on loans.

Despite the absence of a driver, personnel costs are still the highest costs in operation (20).

In the Netherlands transport concessions are needed to transport passengers. In this case the Metropolitan region Rotterdam-The Hague determines via public tendering who will fulfill the concession. The company with the concession has the sole right to provide public transport in a specific region (21). The Rivium ParkShuttle is a separate concession. Connexxion, a public transport company, currently has the sole right to operate the ParkShuttle up until 2033(8).

5. CONCLUSION

The second and current generation automated electric ParkShuttles are in operation since 2005. The ParkShuttles operate without a driver on a designated lane where crossing traffic is managed with barriers. The Shuttles have shown that the system is robust and reliable. Also, the system seems to be cost-effective since the route is being extended to the waterfront. The current ParkShuttles will be replaced by the third generation vehicles. These vehicles will be 'smarter' and will operate partly on public roads (± 300 meters). This will be the first automated vehicle operating on public roads without a steward on board. Currently, it is not possible to test on public roads without a steward/driver on board. The new law 'Experimenteerwet zelfrijdende auto' (translate: governing the experimental use of self-driving vehicles) is expected in 2019 and will make it possible to experiment with automated vehicles without a steward/driver being physically in the vehicle. An operator will always be able to intervene via the control room. RDW (Dutch Vehicle Authority) is responsible for the admission to the public roads. The third generation ParkShuttle will be able to carry up to 500 passengers per hour per direction (22). Operation of the third generation is planned for September 2019 on the existing route with the extension in mixed traffic coming online in 2020 (8).

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