MOBILICITY PPT AUTOMATED TRANSPORT SYSTEM

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Abstract

The mobilicity PPT (Personalised Public Transport) system uses automated vehicles to provide sustainable mobility within large metropolitan areas. It has been designed to address the three major challenges of congestion, air quality and energy use. The 5 metre long vehicle offers up to 12 seats including one wheelchair space. It can also carry 12 standing passengers, giving a capacity of 24, all within the length of a premium sector car. These modules can operate in platoons of up to six units giving a total capacity of 144 passengers. Operated in this way, the passenger capacity per direction per hour can easily rival rail-based systems at a fraction of the roll-out time and infrastructure cost.

The drive is series hybrid using a Li-Ion battery energy storage system. The three energy conversion options make the platform future-proof over the coming decades. The first version employs a bio-fuel ICE, the second stage uses a hydrogen ICE and the third and final drive configuration uses a low power hydrogen fuel cell. The vehicle has been designed to suit the low speed of modern urban conditions and combines the benefits of low power ratings, low noise, and increased safety.

The service operation is planned initially in closed communities such as exhibitions or airports and later will be deployed in exclusive lanes, like Bus Rapid Transit. Once the technology is fully mature, the system will cover the majority of the central city areas. This will allow flexibility in both timetable and routing to offer the best of both worlds – personal mobility within a public transport system.

Keywords: Pubic Transport, Automated Transportation Systems, Series HEVs, Environmental Impact, Sustainable Mobility.

1 Background

The mobilicity project had its first developments in 2002 when our company, Capoco Design Limited reached its 25th year of incorporation since it was formed in 1977. The approach at Capoco is always to look forward so the company decided not to concentrate on a reprise of its past activities, but to investigate the fairly urgent requirements for future city mobility.

Capoco Design concentrates in public transport projects across all the global markets and has products running in successful service on all the continents. These products centre on both city buses and long distance coaches. The bulk of the recent work has been new designs of low-floor city buses for Europe, Asia and North America. The Capoco bus projects have taken about 65% of all UK city bus sales over the past fifteen years, with market leaders in all the sectors.

With this public transport background, it seemed natural to commission a research project into the needs of city transport over the next 25 years up to 2027. This was to take into account all the major trends acting on the transport scene as a whole. This particularly included population growth and the rural-to-urban drift. It was therefore logical to study the transport needs of the mega-cities that will increase in number as we move from a 50% urban share of a 6 billion global population, to a 65% urban share of a 9 billion global population.

This demographic trend is being accompanied by an ageing population profile in many countries, with its impact on national finances, individual wealth, social exclusion and different mobility needs. These effects will run parallel to the equally well-known trends of reducing oil supplies, environmental pressure on local and global air quality and ever-greater societal losses through traffic congestion.

To study these major trends in our transport world, Capoco collaborated with the Helen Hamlyn Research Centre, headed by Jeremy Myerson, at the Royal College of Art, London. Also part of the team was the famous Vehicle Design department of the RCA, led by Professor Dale Harrow.

The work commenced with an in-depth review of the current situation, the many pre-determined global trends and all possible transport solutions. The project team invited a range of experts, from a range of sectors including city and transport planning, the built environment, social mechanisms, to ideas workshops to discuss and develop different approaches to the challenges ahead. To assist this investigation process, actual city journeys in London, Istanbul and Hong Kong were analysed by tracking actual individuals through a range of different commuter scenarios.

From studying the requirements, an idealised system was proposed that used automated vehicles, effectively of variable size, running over the assorted routes. Then a process of back-casting, or retropolation, was applied to discover how this ideal system could be achieved in practice.

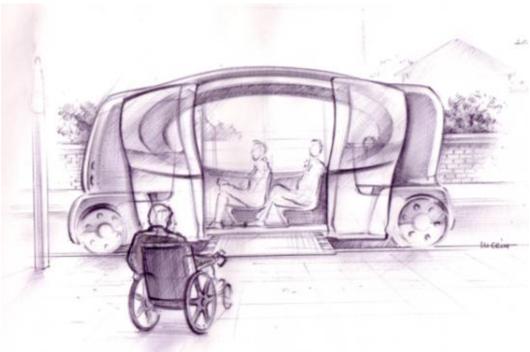


Figure 1a: Universal access

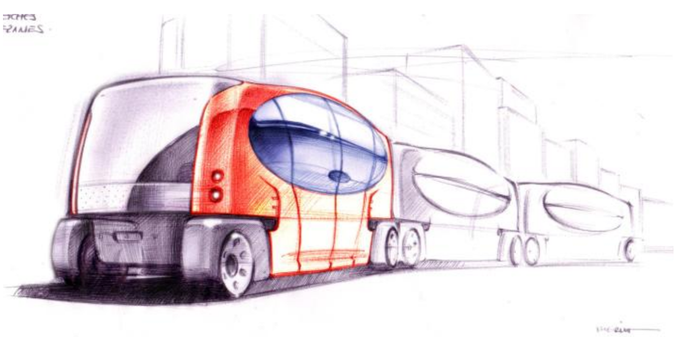


Figure 1b: Platoon capability

It is important to confirm that the mobilicity system was never seen as a universal solution to all the transport challenges in all cities. The characteristics were developed to be complementary to other existing systems based on the various existing road, rail and water vehicles.

One fundamental feature of the study was the need for strict technical and commercial realism. The approach had to be able to deliver practical solutions over the time-frame being studied. Therefore any solutions involving exorbitant costs, and those requiring total new city infrastructures were not pursued. This pre-condition of practicality related particularly to the road and fuel infrastructures.

2 Concept development

Together with the RCA team and some ten other project partners, the concept was researched through 2003 to 2004 and this developed the fundamental concept of the system now being presented. The mobilicity transport system uses automated vehicles to provide eco-friendly mobility within large metropolitan areas. It has been designed to address the three major challenges of congestion, air quality and energy use, plus deliver the sustainable solution that both the growing population and our shrinking world require.

The 5 metre long vehicle offers up to 12 seats including a wheelchair space. It can also carry 12 standing passengers, giving a capacity of 24, within the current EU bus regulations, all within the length of a premium car. Further, the vehicles can operate in platoons of up to six units giving a total passenger capacity of 144. In this way the system offers unparalleled flexibility in terms of capacity.

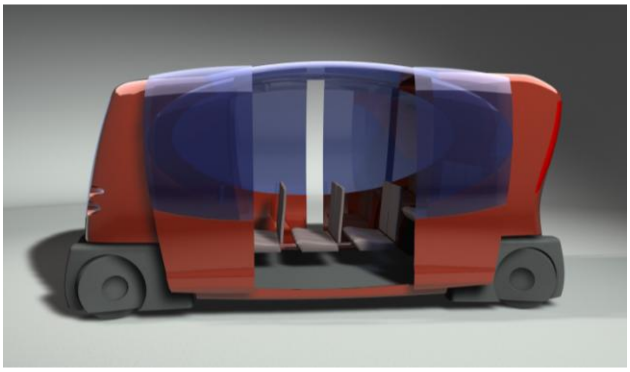
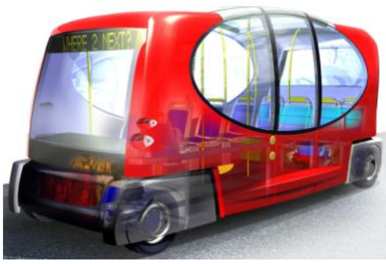
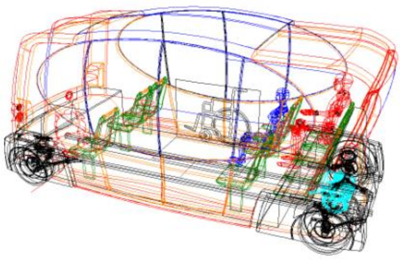


Figure 2a: Single unit in 'taxi' configuration Figure 2b: Platoon in 'tram' configuration, London

The program moved into much greater detail through the next design stage during 2005. The vehicle design was further developed, in much greater detail, into a full 3D CAD Virtual Prototype as below.





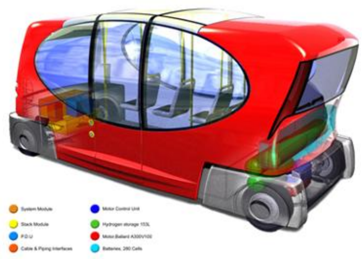


Figure 3a: Bio-fuel ICE Figure 3b: Packaging design Figure 3c: H_2 fuel cell version

3 Vehicle technology

The mobilicity design has now entering its third design generation, as displayed and presented at numerous conferences. The research and development work continues with the refinement of all systems, notably the series hybrid drive plus the navigation and control systems. These are covered in further detail below. The actual vehicle is a two axle design, with steered front axle and driven rear axle. The energy converter/generator is front mounted, together with the electronics cooling radiator. The fuel tanks and hybrid battery pack are rear mounted, over the electric drive motor.

The integral frame is all aluminium to minimise vehicle mass, and mounted on air sprung, independent suspension systems. The panels are mainly polypropylene for the vertical panels and self-reinforced polypropylene for the horizontal panels. The selection of the polypropylene approach was driven by its very low stock material input and manufacturing process energies. The whole rolling shell is both low in weight and also readily recycled.

The tyre and wheel selection goes entirely against the current passenger trend to fit locomotive wheels to small vehicles. The tyres have been selected on a mix of attributes including rolling energy losses and compact packaging space. Unlike cars, there is minimal brake energy to dissipate due to the controlled 1.5m/s2 maximum acceleration and 2.0m/s2 maximum deceleration and the regenerative capacity within the hybrid system. Similarly, the system design limits for lateral acceleration are set for passenger comfort and reliable control so the application does not warrant a wide tyre section.

The vehicle unladen mass is 2740kg and the laden mass is 4540kg, giving a payload of 24 passengers at 75kg. The passenger fraction at 38% is lower than some of the usual Capoco bus projects, but this is in part due to the hybridisation and also the scale effects with the smaller vehicle.

In early 2006, this latest design configuration was developed and displayed in model form at the North American Auto Show in Detroit. This was part of the Michelin Challenge Design competition to produce new designs to meet the needs of tomorrow. It was awarded an Outstanding Design prize by the Michelin company team.

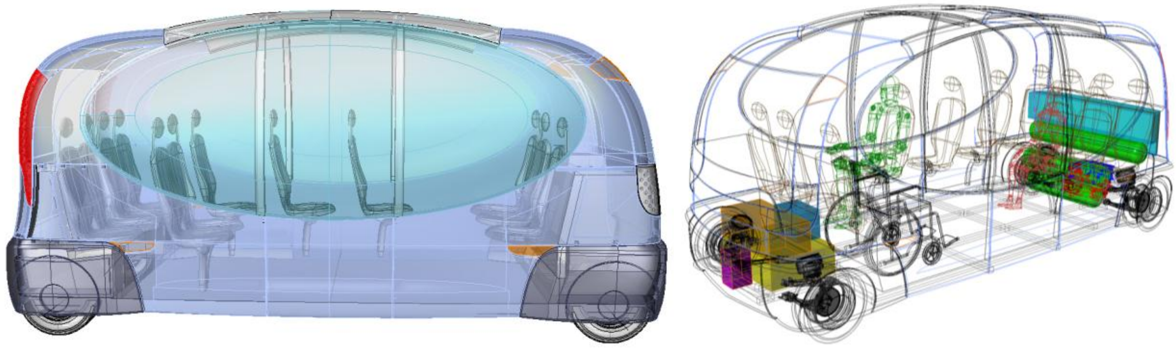


Figure 4: Latest 2006 design configuration

4 Powertrain

The drivetrain is series hybrid in all versions using a Li-Ion battery. The unit ratings are in the 30 to 40k continuous range. These seem low from a car standpoint, but the 6.7 to 8.9kW/tonne power-to-weight ratios have been extensively proven to be adequate in modern traffic conditions. One significant proving trial could be taken as the fifty year long, successful operation of the famous red London double decker bus. These use a 86kW power unit to propel the 12 tonne fully laden bus, so have a 7kW/tonne rating. These have been totally acceptable in all city operational modes over this long and arduous period.

The energy conversion includes three main options to make the platform future-proof over the coming decades. The first model is fitted with a bio-fuel ICE, the second format uses a hydrogen ICE and the final configuration uses a low power rating, hydrogen fuel cell. The initial fuel infrastructure requirements are therefore tailored to be ready right now using the existing diesel distribution network.

Both the generator, on the ICEs, and the drive motors, use permanent magnet configuration. Two rear drive motor options are currently being studied. One uses a central motor with integrated controller, reduction gear and differential. The alternative arrangement is using two wheel motors, which aids the packaging considerably. One really important feature with the specific mobilicity design is the effect this wheel motor approach has on suspension performance.

The vehicle has been designed to suit the low speed of modern urban conditions and combines low power ratings, low noise, with increased safety. The vehicle has a low power-to-weight ratio of under 9kW/tonne as described, and the resultant drive motor mass is linked to these lower power and torque outputs. Likewise, the maximum suspension unsprung mass limits are closely related to the wheel ground loads, so there is a quite different relationship between these parameters in this application, when compared to a high power, low mass car approach.

These fundamental factors, relating to specific power and specific cost, apply even more importantly to the whole economics of introducing new powertrain technologies and new fuel infrastructures. Although neither absolute nor linear, the trend effects of unit power and unit costs are quite clear. There are many significant cost barriers to the introduction of new systems such as fuel cells.

Currently, the heavy duty, low volume commercial power units range from USD50/kW for diesel, to USD500/kW for a series hybrid diesel to perhaps USD5,000/kW for a hydrogen fuel cell system. If the costing calculation then factors in a mobilicity power-to-weight ratio of under 10kW/tonne, against 100kW/tonne for a typical car, there is an immediate order-of-magnitude gain on affordability.

However this beneficial effect is compounded by the much higher public transport annual vehicle operating distances and also much higher average passenger load factors. The overall result is an increase in economic viability by a factor of around 400 to 500 times, judged on the fundamental basis of USD/passenger.km.

This essential cost-based approach to public transport, relating to introducing new technology, becomes particularly relevant with the innovative mobilicity concept. Since all current vehicle operating costs are dominated by the driver labour cost, the automated approach can actually finance, even at today's high fuel cell unit costs, the viable application of a hydrogen based, emission free transport system.

5 Control and navigation systems

The greatest challenge during the development of the new mobilicity system is the automation of the vehicle operation. This links the primary control modes of lateral and longitudinal control, with the associated systems for collision and obstacle avoidance. Also there are the needs of the service operation requiring the land-based supervisory system to control the vehicle routing and scheduling.

This guidance technology, although new, is not without precedent. There are a number of applications across the aerospace, military, marine and industrial sectors. Three examples showing the basic practicalities are shown in Figure 5. The first application is the widespread use of AGV's (Automatic Guided Vehicles) in many factories. The second is the recent DARPA Challenge winner from Stanford University, using a modified VW Toureg. The third example is the automated ECT container port at Rotterdam, Netherlands. In this installation there are over 200 driver-less vehicles that have been operating there for a period of 14 years. As is well known, a commercial dock is a long way from laboratory control conditions, in terms of environment, service surveillance and tender, loving care!

Figure 5: Automated vehicle operations in factory, desert and dock

The mobilicity guidance system uses three levels of control. The top level is route planning which is similar to the process used with factory AGV's. The required routes are prepared within a computer package essentially similar to a 2D plan view. The second control marries into this by measuring the distance traveled and computes the vehicle position against the route planned in the first level.

The third and final level of control is calibration by checking the vehicle position against the fixed track markers. These markers are multiple magnetic markers embedded in the road surface. The vehicle control system checks the predicted position with this frequent re-calibration and any small route corrections are input in a damped manner.

These route markers are quickly and cheaply installed, such that the 'sunk costs' in any route are remarkably low. Routes can be economically installed, modified and moved to new locations, totally unlike any rail based systems.

The vehicles are also equipped with obstacle detection sensors that feature both long and short range sensors. These are based on scanning lasers to provide a detection shield that is linked into the longitudinal or braking system. This will slow, or stop, the vehicle as required, if and when obstacles are located.

The automated service operation is planned initially in closed communities, such as exhibitions and airports and later will deploy in exclusive lanes, like bus rapid transit systems. Once the technology is fully mature, the system will cover the majority of the central city areas. This will allow flexibility in both timetable and routing to offer the best of both worlds – personal mobility within a public transport system.

6 Infrastructure

As mentioned under the control and navigation system section above, the hardware on the ground is very limited. The main route control is computer-based and the system uses any existing hard surfaced roadway. However it is planned that the systems will be largely exclusive lane to enjoy the benefits of free traffic flows and to minimise the interaction with other vehicles and pedestrians.

It is hard to imagine that any new lanes could ever be found in the existing centres, clogged with traffic. However, the bus industry, in hand with various city authorities, has recently proven this can be achieved. The roll-out of Bus Rapid Transit, or BRT, systems around the world have demonstrated perfectly that changes can be achieved in a short time and at low cost. The BRT system use dedicated bus-ways, rather than the usual bus lanes, that are prone to illegal disturbance from other traffic flows.

Figure 6: Bus Rapid Transit in Europe, North America and Asia

However, it is planned that some civil engineering will be required to optimise the new mobilicity systems. As well as the mobilicity lanes, new stops will be required and the system will need adequate information systems to inform passengers of the system status and current service level.

Again these new facilities have the advantage of being able to be phased during their installation due to their low cost and speedy installation. Also partial systems can be operated as new neighbourhoods are developed. This contrasts strongly with rail systems that are ‘all or nothing’ as any train or tram is left stranded if gaps are incomplete through certain areas or interchanges.

7 System performance

The system capacity is vitally linked to the much higher effectiveness of public or collective transport, compared to private or individual transport based on the passenger car.

A collective public system is essential to greatly reduce the demands of both road space and energy. The three images below show the same total number of travelers, of 150, in three different modes. Whereas the car approach immediately results in total system blockage, the bus or tram-style platoon leave huge amounts of space. As mentioned above, the first reaction is who can any new system get the space to operate. These pictures dramatically show that integrated, high capacity public transport systems can be installed, PLUS wider sidewalks PLUS bicycle lanes PLUS tree lined lane dividers.

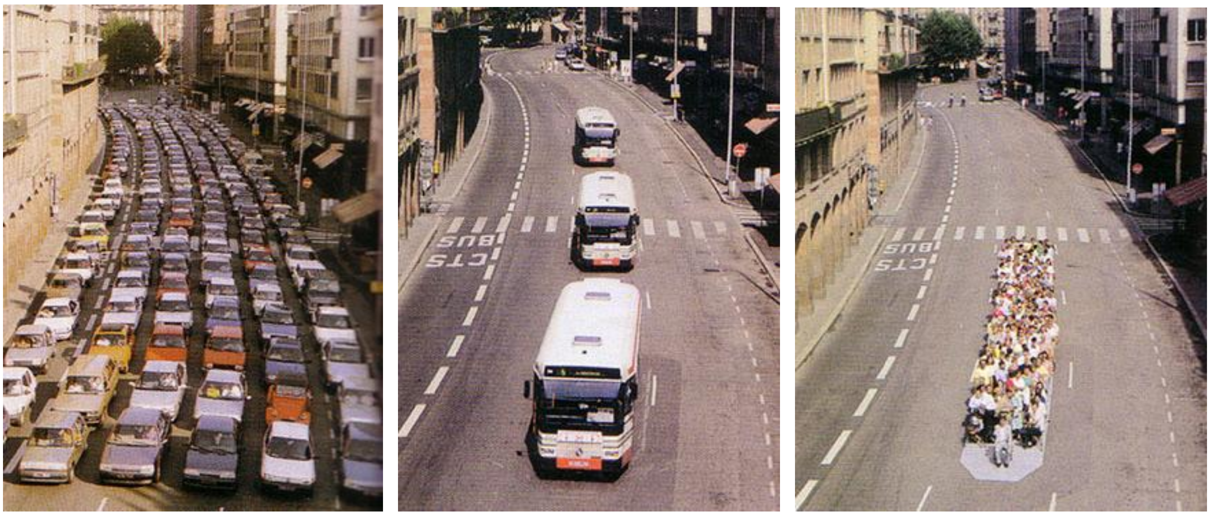


Figure 7: Road space utilization

It is informative to compare the mobilicity approach with what is widely regarded as a successful attempt at a city car design, the Smart Fortwo. One interesting aspect about the car is it is only 2.5 metres long, but carries only 2 people so has a lower passenger linear density than most other cars at around 1 person per metre. So the mobilicity vehicle is exactly double the length of the tiny city car, but offers 12 seats and 12 standing places. Interesting, the mobilicity has the lower total power rating.

Figure 8: 5 metre long mobilicity and 2 x 2.5metre long Smart Fortwo

Three traffic scenarios were studied, all based on the usual metric of passenger capacities per lane (so same as per direction) per hour. Three vehicle conditions were analysed. All the cases operated with the same time-based running clearances between the vehicles, which varied with vehicle speed.

The first case was the Smart car operating in the most frequent private car mode of 1 person aboard. The second case was individual mobilicity vehicles running with 12 seated passengers. The third mode was mobilicity vehicles running at full seated and standing capacities, and also operating as a six vehicle ‘tram’ platoon. This last condition would be for heavily-used arterial corridors or at major city traffic nodes.

The relevant lane densities are shown in Figure 9a in the form of passenger per linear lane metre. As expected, the car approach is limited to fairly low values due to first the poor vehicle packaging, but also critically the multiple inter-vehicle gaps when running at higher speeds.

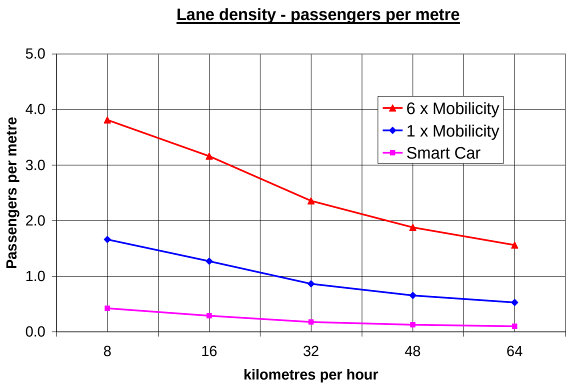


Figure 9a: Passenger densities per lane metre

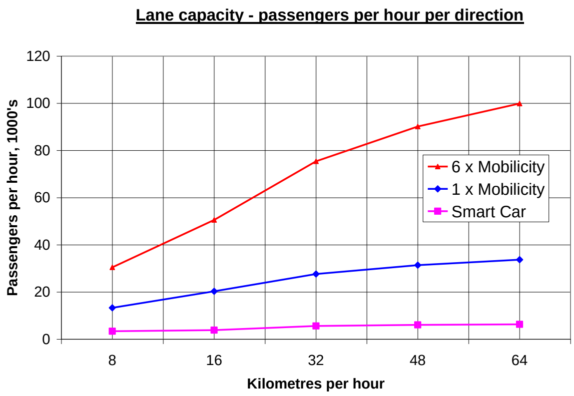


Figure 9b: Passenger flows per lane per hour

This effect is more marked when shown as the fundamental passenger capacities per direction per hour as Figure 9b. The car again is strictly limited to very low values and it is this basic characteristic that currently clogs up our cities. Even if these car values are acceptable on straight road sections without junctions, the values will not provide enough flow at bottlenecks and where routes converge. The two mobilicity configurations offer very high capacities that rival rail-based solutions. It is recognised that these high values will not be achieved over the complete routes, but it demonstrates the potential for the system to absorb very high passenger flows within a single lane, where required by the city layout.

8 Future program

The mobilicity program is now reaching the final stage of the research and development activities. The prototype stage will be the next phase with the construction and testing of two vehicles. These will be assessed in the controlled environment of vehicle proving grounds to validate the various functionalities and ensure their safe and legal operation.

The subsequent phase is a batch of six 'seed' vehicles to operate a trial service at a selected exhibition centre. This service will be used to ferry visitors on a shuttle service between the halls and the car parking areas. Further applications are currently being planned for airports, national expos, large sporting installations plus systems being integrated into new retail and residential developments.

The key aspect here is the vital preparation for all our tomorrows. The world is changing rapidly and transport systems will need to change as well. It is essential that personal mobility is maintained within the huge city complexes in the modern world. Likewise, it is essential that the remaining scarce energy resources, limited road space and clean, healthy air cannot be consumed, as it is today, by the uncontrolled, and uncontrollable use of the private car.

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