Greater Bristol BRT: Technology Update

1.0 Fuel

1.0.1 One of the principal selling points of public transport is its "green" credentials. One bus can carry the occupants of 20 full cars, and do so using considerably less fuel. But the type of propulsion, and its effects on the environment both at the point of emission and at the point of production, can today be chosen from a wide range. There are several options available as described below.

1.1 Diesel

1.1.1 From October 2006 new buses and coaches must be powered by engines which meet the Euro IV standard. This is much tougher than the previous Euro III standard in respect of reduced particulate emissions, but effects reductions in permitted emission levels across all indicators. For the first time in many years, as emissions standards have become more stringent, the move from Euro III to Euro IV has been accompanied by an improvement in fuel consumption. So diesel powered vehicles are becoming cleaner and more fuel-efficient.

1.1.2 The next level in the emissions standards will be Euro V, due to be introduced in 2008, and further reducing the limits for emissions of oxides of nitrogen. A handful of operators have already placed Euro V standard vehicles into service. It is not anticipated that there will be any significant impact on fuel consumption with the change to Euro V.

1.1.3 First already operates its bus fleet on 100% ultra low sulphur diesel, further reducing atmospheric pollution.

1.2 LPG

1.2.1 Liquefied Petroleum Gas is a low emission fuel, most commonly used for cars and often in a "dual fuel" application where the car can switch between LPG and petrol. LPG was also used for buses in the 1990s, as its emissions were then considerably lower than the prevailing Euro standard diesels.

1.2.2 There are problems with the use of LPG however. Initial vehicle capital cost is higher than that for diesel. LPG is incompatible with diesel fuel in that it requires significant changes to be made to the vehicle engine. This gives inflexibility of operation, as a separate spare pool of vehicles is required to cover the LPG fleet. Maintenance costs are also higher, in part due to the lack of economies of scale with manufacturers which increases the prices of spare parts. There is a need to train engineers in the specific skills required to maintain LPG engines. LPG also requires separate storage and fuelling facilities which take up depot space and are expensive to provide. LPG fuelling facilities are uncommon in the UK.

1.2.3 First operated LPG powered vehicles in Northampton for several years but has now ceased.

1.2.4 Now that Euro standards have progressed such that diesel power is "cleaner" in its emissions than LPG there is no advantage in taking the LPG fuel route, and UK applications for buses outwith First are also believed to have all ceased.

1.3 CNG

1.3.1 Compressed natural gas is similar in nature to LPG. It too has now been somewhat superseded by events as its emissions can be bettered by the latest Euro diesels. It has similar drawbacks to LPG in respect of vehicle cost, reliability and maintenance, and due to its volatility, the need for special storage and fuelling equipment and comparatively long fill times makes it even less attractive.

1.3.2 Vehicle capital costs are higher than for LPG as the nature of the fuel requires larger volumes for storage and most applications have utilised roof-mounted fuel tanks.

1.3.3 First has experience of operating CNG powered vehicles in Bristol and Southampton, but both applications have now ceased.

1.3.4 Similarly to LPG, UK applications for buses are believed to have all ceased, but CNG remains comparatively popular in continental Europe, particularly France and Spain, where some major operators made significant investment in the 1990s and now need to persevere with CNG in order to make an appropriate return.

1.4 Bio fuel

1.4.1 Bio fuels, including Bio Diesel and Bio Ethanol, are a more recent initiative. The emissions produced at the vehicle differ little from conventional diesel, but the production of the fuel is considerably more sustainable, being derived from crops rather than crude oil.

1.4.2 In some applications it is possible to combine bio fuels with conventional diesel and to run diesel-engined vehicles with little or no modification. However there is little evidence yet demonstrating what if any effect there is on vehicle life and on maintenance costs resulting from the use of bio fuels.

1.4.3 Interest in developing ethanol powered buses is building in mainland Europe with Scania in particular developing vehicles, but this technology is still in its infancy.

1.5 Hybrid

1.5.1 A hybrid vehicle combines electric power with an internal combustion engine. The principle a “series” hybrid drive is that power is provided to the wheels by electric motors, which receive current from batteries. The vehicle can operate on battery power alone for short lengths of route, thereby minimising noise and airborne emissions. The batteries are charged by the internal combustion engine which, as it can be run at constant (and optimal) power, is also capable of producing minimised emissions. It is also possible to operate using a “parallel” hybrid drive that can provide power from the internal combustion engine and batteries simultaneously in short bursts.

1.5.2 The design also reduces the need for mechanical parts on the vehicle as the transmission system is replaced by electronic control of the motors. Quality of ride is significantly improved due to the elimination of jerking from gear changing. The costs of maintenance remain high however, as a result of the need to replace the battery packs after a given period of use. Battery technology is continually improving and battery weight is falling and life is increasing.

1.5.3 First and other operators have undertaken experiments with hybrid vehicles powered by both conventional diesel engines and with turbine units. The former are generally more acceptable to the industry, being of tried and tested design and familiar to maintenance staff. Whilst turbines have lower emissions of nitrogen oxides, their carbon based emissions are higher than conventional diesels and these are now considered to be the most preferred power source, operating at their optimum efficiency. Only two routes currently use hybrid vehicles in more than a one off application, the most recent being the TfL route 360 between Elephant & Castle and Kensington. There are six hybrid vehicles currently operating this service. A double deck version of the same type has been prepared for operation in London and a hybrid articulated Streetcar is also under development for Las Vegas. In Newcastle upon Tyne, a quayside shuttle service is operated by a fleet of single deck vehicles.

1.5.4 TfL research undertaken at Millbrook Proving Ground has yielded up to 89% reductions in oxides of nitrogen, 83% reductions in carbon monoxide, 38% reduction in carbon dioxide emissions and a significant (30%) noise reduction. Fuel usage fell by 40%. All results are by comparison with equivalent Euro III engined vehicles. Whilst reliability remains an issue, it is improving and in service testing affords the opportunity to prove the technology and ensure acceptable levels of availability for service.

1.5.5 The drawback with the hybrid option is its capital cost. Typically vehicles cost approximately £60k more than the same design would with a conventional diesel engine. But recent commitment by TfL to a programme of hybrid drive investment in London is likely to drive the price down due to competition between suppliers and the benefits of economies of scale.

1.6 Electric

1.6.1 Battery powered vehicles without an auxiliary power source are almost entirely ruled out of local bus service provision as a result of their limited range of operation without recharge. Whilst two services remain in operation in Merseyside and experiments in the 1990s in Bristol and Oxford operated for some years, the improvements in battery design remain insufficient to make promotion of battery power for local bus services a realistic alternative at present.

1.6.2 Trolleybuses have not operated in the UK since 1972 (with the exception of an off-road experiment in Doncaster in from 1985-1989). In mainland Europe their fortunes have varied, with many systems closing but others investing in low floor state of the art vehicles such as the Cristalis (Lyon in particular has invested heavily in these vehicles to replace its 1980s trolleybuses). The reason for abandonment in many cases is the high maintenance costs associated with the overhead power supply. This can also be controversial as a result of its visual impact on the environment.

1.6.3 Whilst the capital costs of trolleybuses are very high (typically 2 to 3 times that of a conventional UK bus), they do have low mechanical maintenance costs and can be depreciated over a longer time period as they generally last longer (subject to obsolescence) being less prone to vibration etc.

1.6.4 It is also necessary for a local authority to seek constructional and operational powers, usually via a Transport & Works Act Order, to provide a trolleybus system in its area of control, and the costs and procedures in making such an application for a geographic area where such powers do not historically exist is likely to preclude such an option being pursued.

1.6.5 To afford operational flexibility a trolleybus also requires an auxiliary power source, usually in the form of batteries or a small diesel generator, to provide a means of avoiding obstructions and otherwise moving vehicles without reliance on the overhead wires. This adds to the cost, weight and complexity of the vehicles.

1.7 Fuel Cell

1.7.1 The latest fuel technology is use of fuel cells. This is in its infancy and the first major experiment, a three-year trial, has just (January 2007) been concluded across several major European cities including London, Amsterdam, Hamburg and Madrid. The fuel cells combine hydrogen and oxygen, the only emission being water vapour. Whilst operationally successful, the problem with fuel cell applications is the high cost due to there being as yet no economies of scale. The vehicles used by First in London cost over £1.5m each. Fuelling infrastructure is also very expensive.

1.7.2 It is highly likely that the use of fuel cells will increase, at least in those areas with the highest environmental sensitivity. But there will need to be dramatic reductions in the capital costs of vehicles and associated infrastructure if this technology is to have wider applications.

1.8 Summary

1.8.1 For the present and the short and medium term, diesel power is likely to remain the most appropriate for local bus vehicles. The ongoing development of hybrid drive systems is likely to reduce their cost and increase their capability and reliability. Therefore hybrid is likely to be a viable alternative in the next few years, subject particularly to reduction in capital cost.

1.8.2 The power plant used within the hybrid to charge the batteries is most likely to be a conventional diesel engine, possibly powered at least in part with bio fuel.

2.0 Guidance

2.0.1 Public transport priority is most effective where the vehicle is removed from the effects of congestion entirely. This must not be done at the expense of providing access to the local demand, otherwise the benefits are eradicated.

2.1 Rail

2.1.1 Rail guidance effectively means tramway systems or other forms of light rail. These are generally very expensive compared with bus-based systems, typically at a cost of up to 10 times a bus-based solution per route km. Trams are also relatively inflexible, being unable to divert from the guided route to serve areas of demand, particularly at the ends of routes in low density housing areas, and therefore limited in their potential contribution to social inclusion.

2.1.2 As the current proposals do not include a fixed track rail bound proposal no further consideration is given to trams in this paper.

2.2 Kerb

2.2.1 After the initial development of guided bus ways in Essen (Germany) and Adelaide in the early 1980s, the first application in the UK was introduced in Birmingham in 1984 on the Short Heath guided busway demonstration project (TracLine 65). Although later abandoned, this was only ever intended as a demonstration of the technology. It led to other, commercial applications in the UK and these are currently in successful operation in Leeds (two corridors), Bradford, Ipswich, Crawley and Edinburgh, with a further scheme planned for Cambridge. First operates kerb guided buses in Ipswich, Leeds and Bradford.

2.2.2 The principle is that the bus runs in a dedicated roadspace "channel" between concrete kerbs. These guide the front axle of the bus by means of horizontal wheels fitted to guide arms, such that the driver no longer is required to steer the vehicle. That is not the principal purpose of the guideway though. Bus priority is at its most beneficial where it is clear of obstructions, allowing passage of the bus unimpeded by external events such as traffic congestion or parking obstructions. This generally requires a high level of enforcement activity, which many local authorities cannot or will not provide, due to cost and other constraints. But the construction of a guided busway is self enforcing, as both the presence of the concrete kerbs, and the usual absence of any surfacing between the narrow running surfaces adjacent to the kerbs, act as a significant deterrent to use by vehicles not suitably equipped with guide arms.

2.2.3 In combination with appropriate signal priority where the guided section merges with the conventional highway, such guided busways can provide comprehensive bus priority over large sections of route, providing bus operators with the necessary degree of running time stability to provide good schedule adherence (and thus an attractive service to passengers). In addition, guided busways can be provided where bus only routes could not, as their width requirements are reduced due to the self-steering characteristics. Where the bus can use a dedicated track, separate but parallel to the main carriageway, to avoid the effects of traffic congestion, this can have a major impact upon modal shift. For instance the first Leeds busway saw a lot of modal transfer from private car resulting from car driver frustration at seeing a bus speed past a static queue of cars on the route into the City Centre in the morning peak.

2.2.4 Infrastructure costs are relatively modest and comprise a cast concrete guideway and associated signalling (based on traffic signal principles), and an approximate £2000 capital cost addition to new buses (many modern designs being capable of fitment). Maintenance costs of vehicles are not appreciably different and the cost of maintaining the guideway itself is modest due to the reduced volume of vehicles carried.

2.2.5 The technology is now considered to be mature and proven.

2.2.6 Buses fitted for guideway operation can operate on conventional roads, both at the ends of routes or in city centres beyond guideway sections, or indeed on routes entirely without guideways. They are able to provide level boarding at docking stops, either within the guideway itself, or elsewhere along the line of route where nearside raised kerbs are provided to facilitate "docking" at the stop using the guidewheel.

2.3 Optical

2.3.1 Optical guidance works by means of a camera fitted to the front of the bus. This picks up images of special paint markings on the road carriageway and thereby guides the vehicle to follow a pre-designated path.

2.3.2 Optical guidance can be highly beneficial in allowing the vehicle to "dock" accurately at kerbs in a similar manner to kerb guidance, but without needing the provision of the profiled kerb. Otherwise the benefits are not as great as with kerb guidance, as the presence of additional road markings is not as great a deterrent to use by other vehicles as that afforded by the construction of a kerb guided busway. Optical guidance may have benefits in particular locations in pedestrianised areas and on sharp curves in city centres where it provides vehicles with a predictable swept path. However the vehicle can still be driven manually to deviate around any obstruction.

2.3.3 Application and renewal of the road markings is inexpensive. The camera equipment fitted to the vehicles is more expensive than the use of kerb guidewheels, but many modern vehicle types can be fitted.

2.3.4 The largest scale use of this technology at present is in Rouen, operation commencing in 2001, where initial fitment was to two Civis vehicles, similar in concept to the Wrights Streetcar, but these have now been taken out of use. Many of the city's fleet of conventional low floor vehicles have been fitted with the new technology and three optically guided TEOR routes (comprising 38 route km) now operate, mainly using articulated buses. As with kerb guidance, the vehicles can be driven conventionally on the routes beyond the optically guided sections, or indeed on any other routes. The history of the Rouen scheme is noteworthy as, having introduced a new rail based Metro line cross city north-south, Metro was rejected in favour of optically guided bus for the second, east-west line.

2.3.5 The system works well in day-to-day operation, although drivers must not assume that the camera will pick up the line markings, as might be the expectation with a kerb guided system. Optical guidance remains under consideration as an option for the proposed Cambridge busway.

2.4 Flange

2.4.1 Guided Light Transit systems such as those designed by Bombardier (and in use in Caen) and Translohr (in Clermont Ferrand) employ a central guidance system between the wheel track and employ conventional rubber tyres for traction. They are more like trams in operation, and indeed the latter cannot be operated in non-guided mode therefore shares the tram's inflexibility. However they do not incur the same infrastructure costs as trams.

2.4.2 Such systems are currently in their infancy and are not without reliability problems. Applications to date have employed very expensive tram-like rolling stock, but there is no reason why more conventional and cheaper bus based vehicles could not be used.

2.5 Summary

2.5.1 In order to retain the benefits of flexibility of operation and to serve the maximum catchment and maximise social inclusion, it is recommended that non fixed rail guidance systems be explored for BRT.

2.5.2 Of the three current technologies available, flange based systems do not always offer the required degree of flexibility, are high in cost and as yet not fully developed. Optical guidance can be cheaper in terms of infrastructure but does not necessarily offer the full benefits of segregation, and vehicle costs are higher than for kerb guidance. Kerb guidance has higher infrastructure costs but is well proven in operation and has very low vehicle costs. Both optical and kerb guidance offer the full degree of flexibility of operation and access to stops.

2.5.3 At this point, from a technical viewpoint First would recommend the option of kerb guidance with optical guidance also being worthy of further examination. Commercially and operationally, First’s preference is for self enforcing priority. Kerb guidance lends itself to this solution. Optical guidance does not give the same self-enforcement benefits, but has other benefits i.e. for stop docking (level boarding for passengers, every time) and in through the delineation of a clear “track” in pedestrianised areas.