INTEGRATION OF GUIDED BUSWAYS IN THE URBAN ENVIRONMENT

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Abstract

In the UK and globally the urban situation is a changing environment as the activities undertaken by society compete for limited space. One of the major impingements on: social progress in the community, economic development in a region, and the protection and enhancement of the environment is transport congestion. This has led to the re-emergence of the guided busway public passenger travel service as a method to reduce single occupancy car patronage. A busway provides an effective multi-occupancy vehicle service that can operate at relatively high speeds through dedicated routes in both urban and other locations.

Sustainable transport concepts are important for the future of towns and communities, and these will be outlined. Furthermore, a detailed description of the guided busway is provided together with information on design considerations and construction issues to include a busway within the urban landscape.

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1 Introduction

In the UK and globally the urban situation is a changing environment as the activities undertaken by society compete for limited space. One of the major impingements on: social progress in the community, economic development in a region, and the protection and enhancement of the environment is transport congestion. This has led to the re-emergence of the guided busway public passenger travel service as a method to reduce single occupancy car patronage. A busway provides an effective multi-occupancy vehicle service that can operate at relatively high speeds through dedicated routes in both urban and other locations.

Sustainable transport concepts are important for the future of towns and communities, and the political drivers will be outlined. In defining the guided busway a detailed description is provided together with information on design considerations and construction issues to include a busway within the urban landscape and finally there is a pictorial vision of current guided busway systems in operation.

2 Sustainable Transport

Brundtland in 1987 published the most commonly used definition for sustainable development, "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). The Environmental Directorate of the OECD defines environmentally sustainable transport as 'transportation that does not endanger public health or ecosystems and that meets needs for access consistent with (a) use of renewable resources that are below their rates of regeneration, and (b) use of non-renewable resources below the rates of development of renewable substitutes' (Organisation for Economic Co-operation and Development – OECD).

The European Union of Council Ministers of Transport (ECMT) defines a sustainable transport system as one that:

- 'Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations;
- Is affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development;
- Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimising the impact on the use of land and the generation of noise'.

The UK Government has expanded the Brundtland definition of sustainability to mean; "*ensuring a better quality of life for everyone, now and for future generations to come*" (DETR, 1999). At the national level, the DfT's White Paper for Transport outlines an underlying sustainability objective of the strategy, which involves balancing the need to travel with the need to improve quality of life. This means seeking solutions that meet long term economic, social and environmental goals (DfT, 2004).

The main policy document relating to transport at a European level is the European White Paper, 'Transport Policy for 2010: Time to Decide', which was published by the European Commission in 2001. There are a number of principal measures proposed in the White Paper, which are based on 13 guidelines, including safety, quality, intermodality, users, economy and the environment. With regard to sustainable transport issues, the White Paper stresses:

- The risk of congestion on the major arteries and regional imbalance.
- The conditions for shifting the balance between modes.
- The priority to be given to clearing bottlenecks.
- The new place given to users, at the heart of transport policy.
- The need to manage the effects of transport globalisation.

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The White Paper states that a sustainable transport system for Europe needs to be defined in operational terms in order to give the policy-makers useful information to go on. Also, the objectives put forward need to be quantified. A monitoring tool has been put in place by way of the TERM mechanism (transport and environment reporting mechanism) (EC, 2001).

3 What is a guided busway

A guided busway is a dedicated route only accessible to specially adapted vehicles to allow faster travelling times and avoidance of otherwise congested road pavements. Germany was the first country to introduce a public transport guided busway system in Essen in 1980 and there are now guided busway services also in operation in Australia, United Kingdom and France that use either kerb or central guidance systems.

Kerb guidance is provided by a fitiing an ordinary bus with a kerb guidance system. This is typically a horizontal guide wheel connected to the steering mechanism immediately in front of each front wheel (see Plate 1). The guideway consists of a concrete trough section where the road wheels travel on the horizontal surface and the guide wheels run along the vertical face of the upstands.

Centrally guided busways typically comprise a central guide rail embedded in the road pavement surface; this system can be seen in operation in Caen and Nancy, France. In Rouen optical guidance technology is used to enable buses to dock accurately at stops.

Plate 1 Guide wheel and arm on a road wheel

In the 1980s TRL developed and trialed an electronic guidance system based on a buried cable in the road pavement and the lateral/steering control is provided to the driverless vehicle by the vehicle electronically tracking the cable in the centre of the road lane. In this system speed was controlled by a cruise control and could also be changed externally, as the vehicle passed over electronic sensors in the road pavement. Although there was no take up of the system 20 years ago, more recently test trials are being undertaken for the service bore of the Channel Tunnel.

Guided busways have developed as a bus priority measure and also as an alternative to light rapid transport systems such as trams and light rail. The factors that favour a guided busway over these other systems are:

- Lighter weight vehicles reducing construction requirements and impact upon adjacent pavements and buildings.
- Reduced cost of rolling stock - bus v tram v train.
- Less infrastructure required e.g. overhead electrification, rails, turnouts, signalling.
- Flexibility to access city centres and feed network from outlying areas

In the UK, France, and United States there are plans in place for further implementation of guided busways. These plans verify the feasibility of guided busways and in the UK the planned increase in a number of locations are promoted by the promise of sustainable development to support local communities, businesses and society as a whole.

4 Transport Modelling

To select the guided busway as a public transport option to reduce congestion a detailed transport model is required in order to assess potential patronage. In the UK multi-modal studies are undertaken that consider public transport forecasts, scheme highway costs, land-use transport models, and in particular mode choice options.

At present in the UK the Cambridgeshire Guided Busway is currently out to tender for construction. When complete, this will be the longest guided busway system in operation in the World. The worst case scenario, with ultra conservative modelling presents a shift away from car journeys to public transport of 5%, 12%, 8.7% and 9% for current trips along the four sections to be constructed (TRL, 2003). Similarly in the UK reported growth rates in guided busway patronage are as follows:

- Birmingham 'Tracline 65' 29.3% patronage increase in 1987 during full-scale trial.
- Leeds 'Superbus' 75% patronage increase in 30 months.
- Ipswich 'Superoute 66' 43% in 16 months.
- Crawley Fastway
- Edinburgh Fastlink

Throughout the UK there are now a number of development plans in place that include the construction of guided busways to improve public transport utilisation and reduce congestion and its associated environmental pollution in UK towns, cities and across its countryside.

5 Building the Busway

In the UK guidelines for the design of kerb-guided busway infrastructure are to be found in the Britpave 'Guided Busway Design Handbook' (2004). Outlined below is a summary of some of the key aspects though for a full set of information it is recommended that a full review of the Design Handbook is undertaken.

5.1 Design Considerations

Aside from the requirements for pavement design and construction requirements there are a number of general issues that can influence the layout, design and construction of infrastructure for a kerbed guided busway.

- Operation - An important component of total journey time is taken to board a bus, a general rule of thumb , is that 20% of total journey time should be allowed for bus dwell time. Dwell time comprises deceleration, door opening, passenger alighting, passenger boarding, ticket purchase/check, door closing and acceleration.

- Vehicles - Most bus designs and configurations can be adapted for a kerb guided busway system. Though the choice of vehicle does affect the design of the infrastructure. In particular these relate to height, weight, articulation and varying body widths that are available.

  Loading - When considering the design loading, in the UK this is the legal maximum axle weights for buses, it should be noted that the load is applied repetitively in the same place and this presents a more onerous design criteria than that for all-purpose roads.

- Geometrics – The design values developed in the UK are those for single-decker and articulated buses. The designer must ensure that the parameters used are appropriate to the vehicle type intended to operate on the system. When designing the alignment it is important to consider:

  Access for maintenance and emergencies;
  Vehicle types;

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Driver error;
Buses cannot reverse on a busway.

For LRT-style operation the recommended maximum design speed for a UK busway is 120km/h (for 100 kph operation) and this is reduced for guideway entrance and egress and at junctions. For urban and on-street application, the operational and design speed of the guideway should be in keeping with the surrounding road network and local environment.

There are superelevation and transition length equations available and the normal limiting values for horizontal alignment are described as:

Minimum radius of horizontal curvature without guideway widening	500m
Minimum radius of horizontal curvature with guideway widening	120m
Maximum superelevation	5%

For vertical alignment the limiting values are:

Maximum vertical gradient	Normal 4.0%	Limit 6.0%
Minimum vertical gradient	Normal 1.0%	Limit 0.5%

- Safety – there are three main aspects to consider when ensuring that safety is maintained; these are trespass, maintenance and emergency access, and special provisions at crossing points and bus stops. Clear demarcation and signing should be in place to inform and deter unauthorised users. It is also possible to include physical deterrents such as automatic bollards that lower on the approach of buses and car traps at the exit and entry points, see Plate 2.

Plate 2 A car trap at a guideway entrance, Ipswich UK

5.2 Pavements

As previously mentioned the wheel load is applied repetitively in the same place with the wheels will always run in the same position; therefore the recommended guideway running surface should be constructed in concrete. There are two philosophies for the design of the guideway, either as a concrete pavement or as a concrete beam. In the UK the pavement approach is currently preferred as it generally requires much less reinforcement than a structural beam. The key aspects to the guideway design are: foundation and geotechnical conditions, length of guideway on structure, urban street integration / segregation and drainage requirements including sustainable drainage. The guideway can be designed as a continuous cross section or as two plinths, see Figure 1.

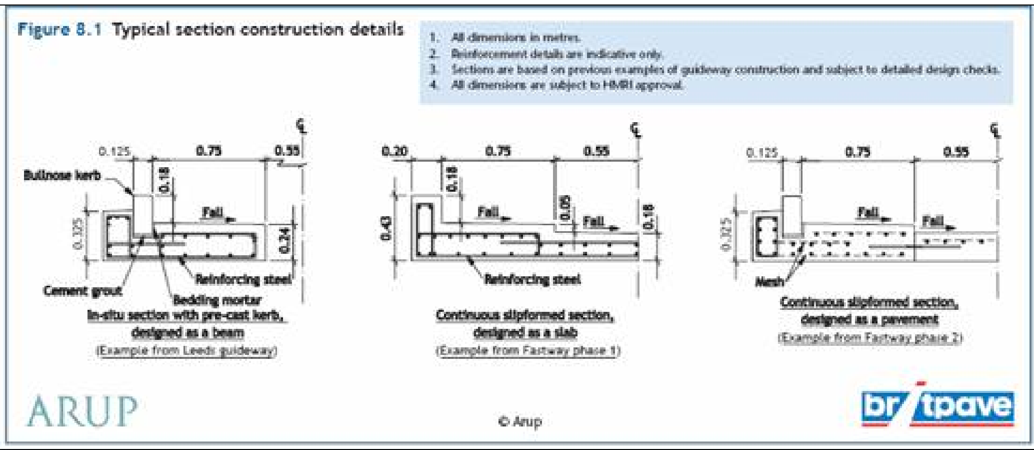

Figure1 Typical section construction details (Britpave, 2004)

For the continuous cross section, the concrete running surface is designed in accordance with TRL 630: New continuously reinforced concrete pavement designs (Hassan et al, 2005) for continuous pavement construction and TRRL RR87: Thickness design for concrete roads for jointed pavements (Mayhew & Harding, 1987). In this instance the upstands are considered to have a stiffening effect whereas for individual plinths an edge-load condition should be applied. There are a number of options for the pavement design:

CRCP – continuous reinforced concrete pavement (Plate 3).
Jointed unreinforced concrete pavement.
Jointed reinforced pavement.

A continuous approach is favoured as joints tend to lead to higher maintenance requirements and can, with time, lead to issues with ride quality and noise and vibration. These issues can also be exacerbated by using a granular base and for that reason a cement-bound sub-base is recommended

Plate 3 Steel reinforcement anchored to a base slab

Plate 4 Transverse texturing on a slip formed guideway.

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5.3 Typical Cross Sections

The minimum single-lane guideway adjacent to the highway requires 4.6m, which includes an allowance for 1metre evacuation strip either side of the guideway, and this can vary upwards to a 9.7m corridor for a typical segregated at-grade two-lane guideway with maintenance track. Samples of the typical cross-sections to be constructed are illustrated in Figures 2 to 5.

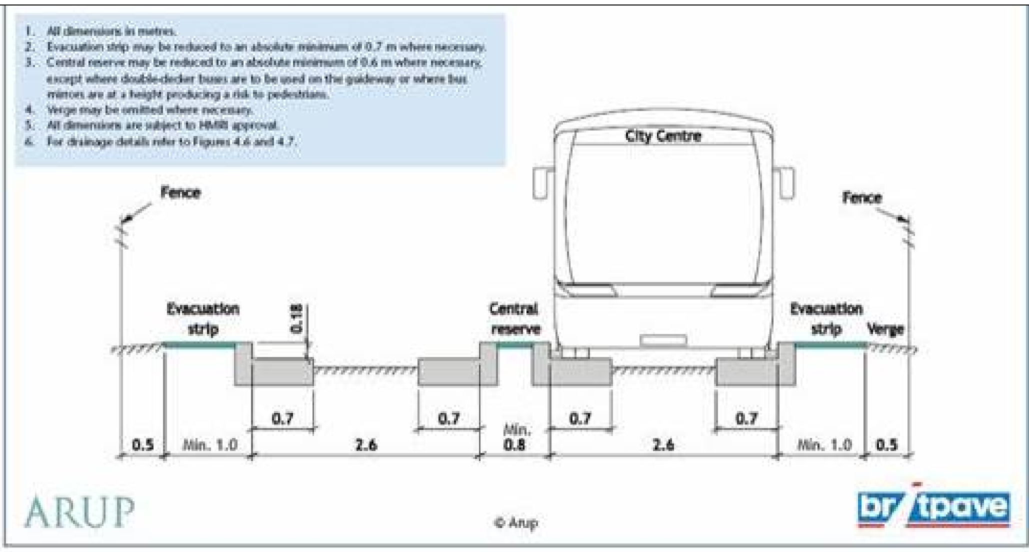

Figure 2 Typical at-grade cross section without maintenance track (Britpave, 2004)

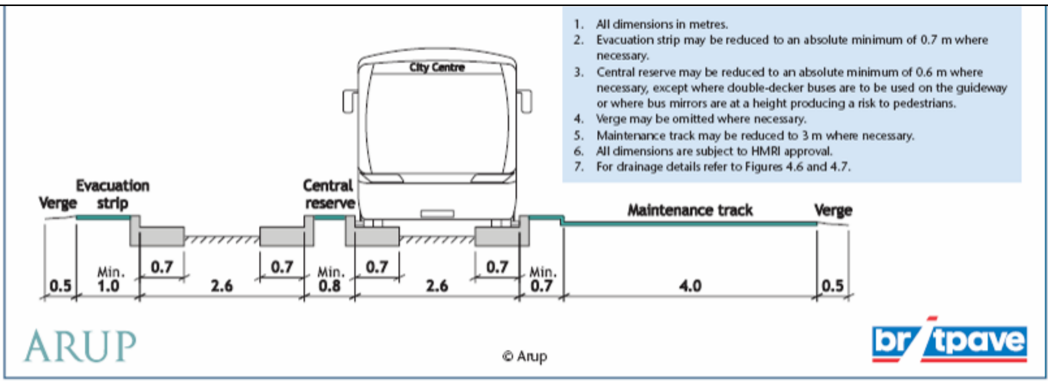

Figure 3 Typical at-grade cross section with maintenance track (Britpave, 2004)

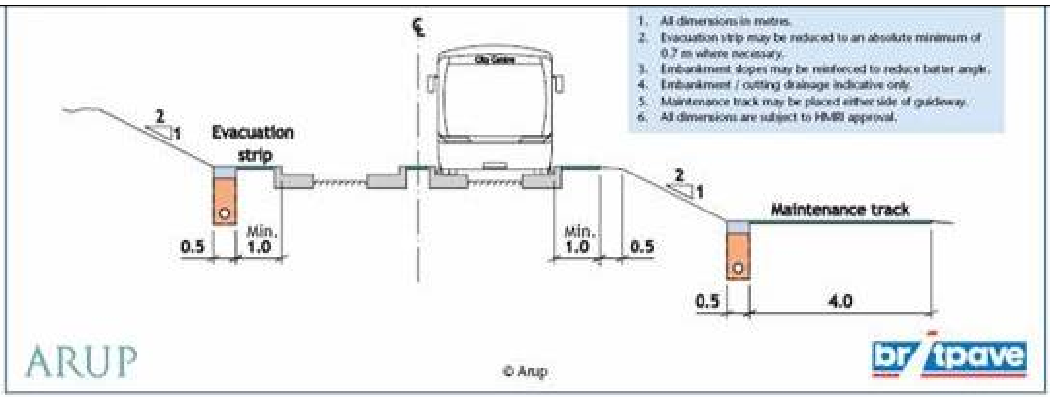

Figure 4 Typical section on embankment / in cutting (Britpave, 2004)

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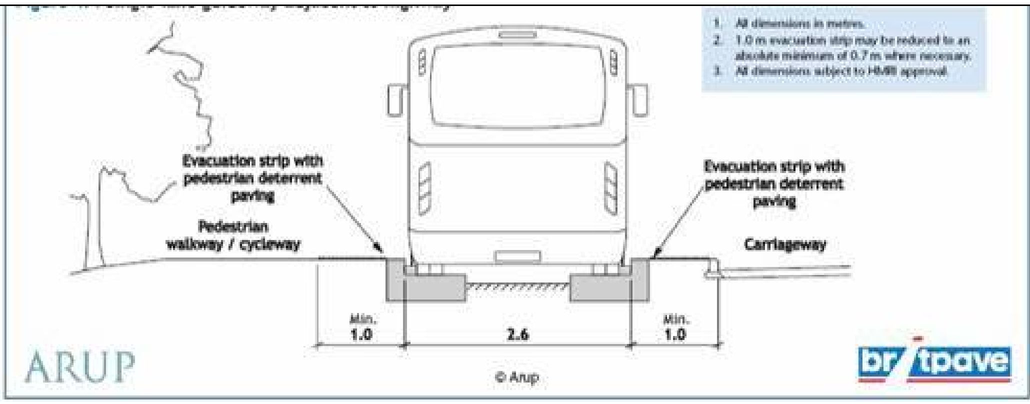

Figure 5 **Single-lane guideway adjacent to highway (Britpave, 2004)**

In section 6 a number of photographs will illustrate the possibilities for a very 'green' busway. Using a sustainable drainage option helps with this by preserving and enhancing the surrounding environment the engineering differences between the conventional hard landscape option and soft green option are shown in the cross sections Figures 6 and 7.

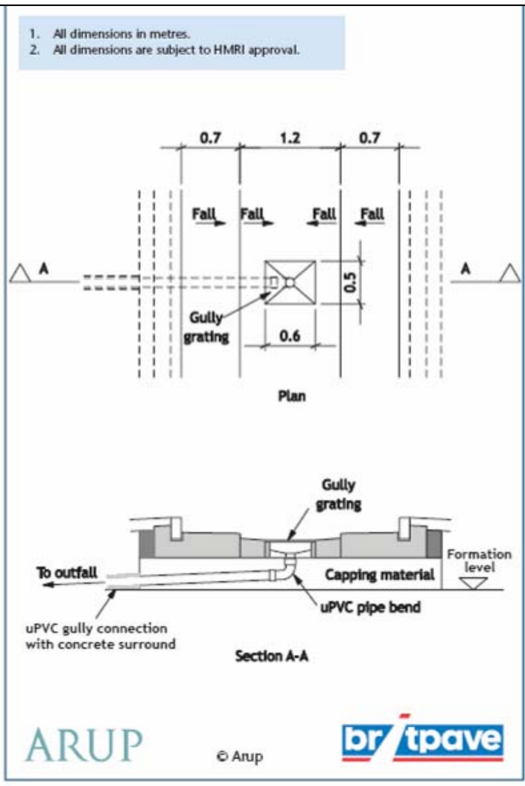

Figure 6 Typical positive drainage details (Britpave, 2004)

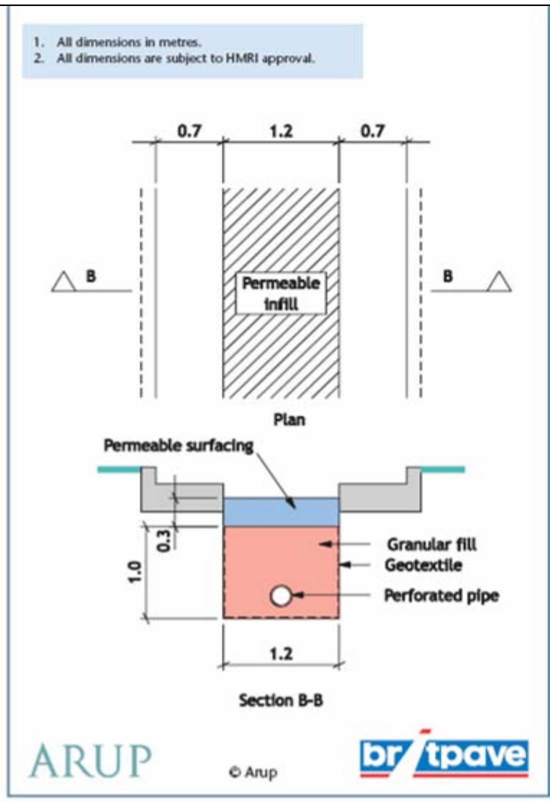

Figure 7 Typical sustainable drainage details (Britpave, 2004)

6 The working examples

It has been described in this paper that there is a growing interest in guided busways throughout the world. To illustrate the various aspects mentioned in this paper a number of photographs are now presented to assist the reader in visualising the finished product. Being a dedicated route that allows vehicles to faster and avoid otherwise congested road pavements (Plate 5).

a) Translohr vehicle, Nancy, France

b)Guided bus stop, Nancy, France

c) O-bahn kerb-guided busway, Adelaide, Australia

d) Guided bus stop, Adelaide O-bahn, Australia

e) Crawley Fastway, UK

f) Pedstrian crossing, Essen O-Bahn, Germany

Plate 5(i) The working examples

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g) Combined running with trams, Essen O-Bahn, Germany

h) Essen O-Bahn, A40 Autobahn route, Germany

i) Leeds, UK

j)Guideway entry, Leeds, UK

k) Pedestrian crossing, Edinburgh Fastlink, UK

l) Guided bus stop Edinburgh Fastlink, UK

Plate 5 (ii) The working examples

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7 Conclusion

In summary, this paper has aimed to provide background information that illustrates the feasibility of guided busways in the urban environment. As stated at the beginning the urban situation is a changing environment and in the UK it is one where the focus is moving to sustainable communities providing incentives for social progress for all in conjunction with prosperity for an area. Congestion is becoming an increasingly detrimental factor for economic development and as such any methods that could improve the situation are worth considering. The Buses International Association (2004) has stated that a guided busway system is estimated to give savings of 50% or more over an equivalent light rail system. By reducing congestion a guided busway does provide increased protection and enhancement of the environment and is a valuable part of an integrated network that provides sustainable transport both in the urban situation and wider.

At a European level the implementation of a guided busway system does respond to four of the key issues identified in the European White Paper with regard to sustainable transport. In this matter a guided busway does:

- Reduce congestion on the major arteries and can aid the balance of regional transport.
- Promote conditions for transport to shift between transport modes.
- Aid the clearing bottlenecks and has demonstrably done so.
- Considers the transport user to provide a safe, convenient and reliable transport service.

Overall there appears to be a likelihood of guided busways increasing their appearance in the transport network both in the UK and worldwide.

8 Acknowledgements

This paper has been prepared with the approval and assistance from The British In-Situ Concrete Paving Association. Furthermore, the ‘Building the Busway’ section is essentially a summary of information repeated from the Guided Busway Design Handbook and the authors are grateful for permission from Britpave to do this.

9 References

Britpave (2004). ‘Guided Busway Design Handbook’ Britpave, Camberley, UK.

Brundtland, G.H. (1987). ’*Our Common Future*’ WCED, Oxford University Press, Suffolk, UK.

Buses International Association (2004). ‘*British busways attract worldwide attention’*. http://www.busesintl.com/July_2002.htm

DETR (2000). ‘*Transport 2010: The 10 Year Plan’*, HMSO, UK

DfT (2004). ‘*The Future of transport: A Network for 2030’*, HMSO, UK

EC (2001). ‘*White Paper – European Transport Policy for 2010: Time to Decide*’, European Communities, Italy.

Hassan KE, Chandler JWE, Harding HM and Dudgeon RP (2005). *New continuously reinforced concrete pavement designs. TRL Report 630.* Wokingham, UK.

Mayhew HC and Harding HM (1987). ‘*Thickness design for concrete roads for jointed pavements’*. TRRL RR87. Wokingham, UK.

Smiler S (2005). ‘*Special feature on kerb guided buses (O-Bahn)’*,
http://www.garden.force9.co.uk/OBahn.htm.

TRL (2003). ‘*Audit of the Cambridge Rapid Transit proposal*’.
http://www.dft.gov.uk/stellent/groups/dft_foi/documents/page/dft_foi_035513.pdf

Buses International Association (2004). ‘*British busways attract worldwide attention’*.
http://www.busesintl.com/July_2002.htm.

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