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EVALUATION OF ALTERNATIVE GUIDED BUS DESIGNS

RESULTS FOR KINGSTON UPON HULL

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This work was undertaken on a project sponsored by the Engineering and Physical Sciences Research Council.

CONTENTS

ABSTRACT

This paper describes the background and methodology employed in research funded by the EPSRC to assess the traffic management implications of guided bus schemes. One central aim of the project is to demonstrate how simulation tools can be adapted to account for the special features of guided bus schemes and demonstrate their applicability on an actual planned scheme. Traditional bus priority measures are first assessed for their benefits and these are contrasted with those from the planned guided bus scheme. Variations to the planned scheme are also considered.

A sophisticated microsimulation model is used to assess the impact of incorporating guided bus infrastructure into three planned schemes. Two of these are from Leeds and Kingston-upon-Hull and are largely within the existing Road infrastructure, whilst the third is from Chester and is largely segregated from the existing road infrastructure.

This paper deals exclusively with the Kingston-upon-Hull scheme. The network under consideration is due north of Hull city center and contains two main arterials, the Beverley Road and Stoneferry Road, together with a network of connecting roads. The traditional bus priority measures are concentrated on the Beverley Road, which is currently the main bus arterial of the two roads. When the guideways are constructed the intention is that the Stoneferry Road would become a more important bus arterial than it currently is. The planned guided bus scheme exists in four variants: two-way at the kerb; two-way in the median; tidal in the median and an elevated section located in the median. This paper describes the evaluation of the base network; the individual traditional priority measures; the combined traditional priority measures and the four planned guided bus schemes.

1 DESCRIPTION

A schematic of the network considered in this paper is presented in figure 1. The 2.5km section of Beverley Road from the Ennerdale Link Road in the north (point 1) through to the junction with Inglemire lane (north of point 3) is a two lane dual carriageway containing a median which is broken occasionally to allow for turning traffic. South of this point the road reverts to single carriageway, two lanes in each direction for 2kms. The land use surrounding Beverly Road is predominantly residential, with the denser housing towards the southern section of the road, nearest the city centre. The road frontage is a mix of residential and retail or commercial properties. There are extensive sections of peak period operation reserved bus lanes in both directions along the southern section of Beverley Road. Due to the large residential population surrounding this road, there is a high frequency of buses along the road, with all services, when combined, providing a peak hour frequency of 1 bus every 3 minutes.

On the eastern side of the network the main arterial consists of Holwell Road in the north and Stoneferry Road in the south. North of Sutton Road, a 2.2km section of Holwell Road is the main through road for a large residential estate, and contains three roundabouts that feed traffic onto the main road from the minor estate roads. The short ¾km section of Holwell Road south of Sutton Road and most of the 2km length of Stoneferry Road is two lanes, dual carriageway and surrounded by light industrial units and larger industrial estates. There are no explicit facilities for public transport along this arterial, and the combined bus frequency is approximately 1 every 6 minutes along the southern sections of the arterial.

The river Hull between Beverley Road and Holwell & Stoneferry Roads limits the opportunities for vehicles to cross from one to the other. Sutton Road is a primary route joining the two arterials and consists of dual two lane carriageway. Further south is Clough Road and Ferry Lane which contains a swing bridge to allow ships to navigate along the river Hull.

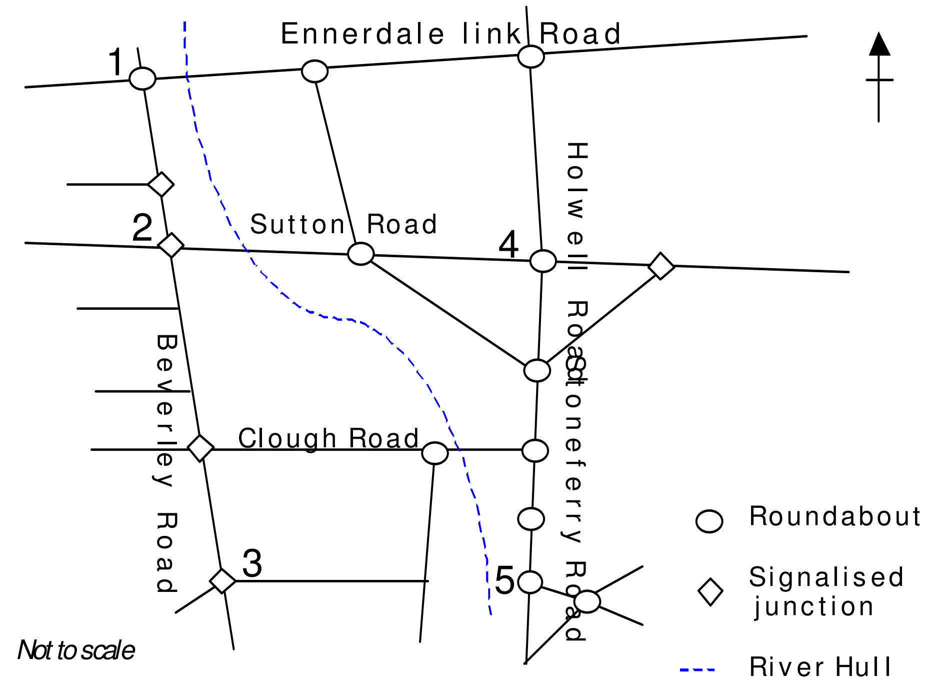

Figure 1 : Schematic of Kingston-upon-Hull network

2 TRADITIONAL PRIORITY MEASURES

There already exists a large degree of public transport priority on the Beverley Road, in the form of extensive stretches of conventional with flow bus lanes in both directions. The additional measures considered in this paper are all directly or indirectly applicable to this arterial.

2.1 Selective vehicle detection

There are four signalised junctions along the length of Beverley Road. Under this measure, each of these junctions will have infrastructure installed in the inbound direction to allow the presence of a bus to be detected and the signals altered so as to eliminate or reduce the delay for buses. As a bus crosses the detector, a prediction of its arrival time at the stop-line will be made, based on the position of the detector and the speed of the bus. If this predicted arrival time is during a green stage then no modification to the signals are required. If the predicted time is just after the end of a green stage, then an extension of the green time is considered to see if this would allow the bus to exit the link. If this is feasible then the extension is made, otherwise a recall is considered. A recall involves an earlier than usual recall of a green stage for the bus, thereby reducing the time the bus spends queuing. A check is made to ensure that no inter-greens are violated during these modifications. A “payback” mechanism exists whereby any shortening or lengthening of stages are compensated for in the subsequent cycle. An extension has the ability to eliminate the entire delay that a bus would normally experience, whilst a recall will only reduce the delay. Due to limitations in the mechanisms available for implementing selective vehicle detection and signal modification, it is necessary to simplify the signal plans for two of the junctions along the Beverley Road. The simplification is to remove the stages allocated for dedicated right turns at the junction.

2.2 Co-ordination for buses

Traditionally, duration of stages at signalised intersections and the offsets between them are derived for a homogenous stream of traffic. This stream of traffic is measured as either as vehicles or passenger car units (PCU's). In reality, however, this arrangement fails to adequately account for the travel characteristics of buses and the fact that they carry much greater numbers of persons per vehicle (or per PCU) than cars. Since buses usually need to stop along a link for passengers to alight or board, they experience a greater journey time than the general stream of traffic. Thus a "green-wave" engineered for the general traffic will not necessarily work for buses. Similarly, an approach that contains a high bus flow may be inadequately represented in the "competition" for green time at the junction, relative to other approaches. The TRANSYT program provides a mechanism to attach different weights and travel characteristics to buses within the traffic stream and thus derive signal settings that are optimised to reduce overall person-hours of travel rather than overall vehicle hours. Only along the Beverley Road are there sufficient numbers of signalised intersections to enable this measure to be implemented.

2.3 Reduced dwell time at stop

A significant proportion of any bus journey is the time spent at bus stops whilst passengers board or alight from the bus. If this time could be reduced then some journey time savings may result. Measures to achieve this include the introduction of bus conductors, separate boarding and alighting doors on buses, an exact fare policy or the greater use of prepaid tickets. In practice the latter of these proposals is the most likely to be considered as practical or acceptable. This measure is not restricted to a particular location but has benefits spread throughout the network. A conservative estimate of the effect of this measure is a 20% reduction in the time to "service" the average passenger.

3 GUIDED BUS SCHEMES

The plans for guided bus within Kingston-upon-Hull primarily apply to the Holwell and Stoneferry Road arterial route. For the purposes of this study, is was envisaged that when the guideway is complete, this arterial will act as the main bus route into the city centre from the residential areas in the north and north-eastern sections of the city and from a proposed Park and Ride site. The Beverley Road currently serves large sections of this residential area and to reflect this change in emphasis, the provision of bus services along Beverley Road are reallocated to the Holwell/Stoneferry Road route and the existing bus lanes along the Beverley Road removed. At a subsequent meeting with Kingston-upon-Hull staff, this was not thought appropriate and a further set of results are reported (see section 8), where Beverly Road maintains its role as a public transport corridor.

The frequency of buses along the guideway routes has been increased to approximately 1 bus every 4 minutes. Passenger arrivals at the bus stops on the guideways has also been increased by approximately 70%, which is inline with quoted evidence from the Leeds Scott Hall Road guided bus scheme. The patronage of bus stops along the Beverley Road has been reduced by 10% in order to represent a slight loss of patronage due to the reduction in service frequency and removal of reserved bus lanes.

The appendix contains diagrams of each of the proposed guided bus options. A detailed discussion of each option is given below.

3.1 Two-way kerb guideway

This scheme is probably the most practical of the four in terms of its operation and construction costs. To the north of the Holwell and Stoneferry Road roundabout a short section of guideway, approximately 300m in length is proposed to allow priority access to the roundabout approach. The conflicting demands between private and guided vehicles are controlled by a set of signals to give absolute priority to the guided buses. After travelling through the roundabout the buses join a second section of inbound guideway 550m in length which terminates with a giveway to the private traffic on the general highway. Travelling outbound, the guideway starts halfway along the relevant link and continues for 150m until a signalised junction with Ferry Lane. The conflicts between traffic on Ferry Lane are controlled by signals that give absolute priority to guided buses. After passing through the junction, the buses join another section of guideway that runs for 250m, to a signalised junction just short of the Holwell and Stoneferry Road roundabout. Once again absolute priority is given to guided buses at this junction. Thereafter the buses travel along the normal highway.

The bus stops in this new scheme have been placed near to the existing kerb side bus stops. This means that they are predominantly within the sections of guideway

3.2 Two-way median guideway

This scheme is perhaps the most complicated of the four and shares some common features with the tidal median scheme described below. From the north a section of median bus lane is proposed to allow buses easy access to the median facilities. A bus lane is proposed in preference to a section of guideway to allow buses to "drift" into the reserved lane anywhere along its length after leaving or passing a bus stop. This manoeuver would not be possible with a guideway which has a fixed entry point. Also land take and enforcement are not thought to be an issue here.

As the bus travels along the reserved lane and approaches the Holwell and Stoneferry Road roundabout, the signals are changed to stop the circulation traffic on the roundabout (on and off traffic at the roundabout can still make their turn) and allow the guided bus to travel through the roundabout. Further south, a similar signaling arrangement operates at the Stoneferry and Clough Road roundabout to allow buses to travel through the roundabout at the junction with Ferry Lane. Beyond this roundabout, the guideway continues for another 150m before it merges with the general traffic at a give-way junction. Travelling northbound, there is a similar arrangement, with guided buses given priority over circulating traffic on the roundabouts. An 120m section of median reserved bus lane is provided to the north of the Holwell and Stoneferry Road roundabout to allow guided buses to better merge with the high speed traffic on the general carriageway.

Provision of bus stop facilities is more problematic with median guideways. Physical access to the center of the carriageway can only be achieved safely by the provision of signalised crossing facilities. These do not currently feature in the plans for the scheme.

3.3 Tidal median guideway

Much of the physical infrastructure for this implementation resembles that for the two-way guideway. Clearly on-street there will need to be an adaptation of the entry and exit points of the guideway so that they are suitable for both directions. North of the Holwell and Stoneferry roundabout there will only need to be one section of bus lane, which would operate in an inbound direction during the morning peak and an outbound direction during the evening peak.

3.4 Elevated guideway

In terms of physical infrastructure this scheme is the most ambitious of the four. The elevated section begins to the north of the Holwell and Stoneferry Road roundabout and continues over that and the Clough Road junction (which is now a signalised junction rather than a roundabout) before returning to ground level, 150m beyond the junction. There is a median reserved bus lane similar to that used in the median guideway schemes along Holwell Road, but signaling is not required since there is no interaction between the roundabout and the guideway.

For obvious reasons there is no provision for bus stops along the elevated sections.

4 BASE CASE MODELLING

A DRACULA microsimulation model of the sub-network was cordoned from the full network supplied by Kingston-upon-Hull City Council. The extent of the network is shown in figure 2.

The initial sub-network contained a number of SATURN buffer nodes that do not possess the sufficient level of information required by the DRACULA microsimulation program. These tended to be concentrated along the Beverley Road. Using information and junction plans provided by Kingston-upon-Hull City Engineers, these buffer nodes were converted into "simulation" nodes (priority, signalised, roundabouts or buffer nodes). The TRANSYT program was then used to produce a set of signal timings. Supplementary information on bus stop location and likely bus stop usage was collected by means of site visits.

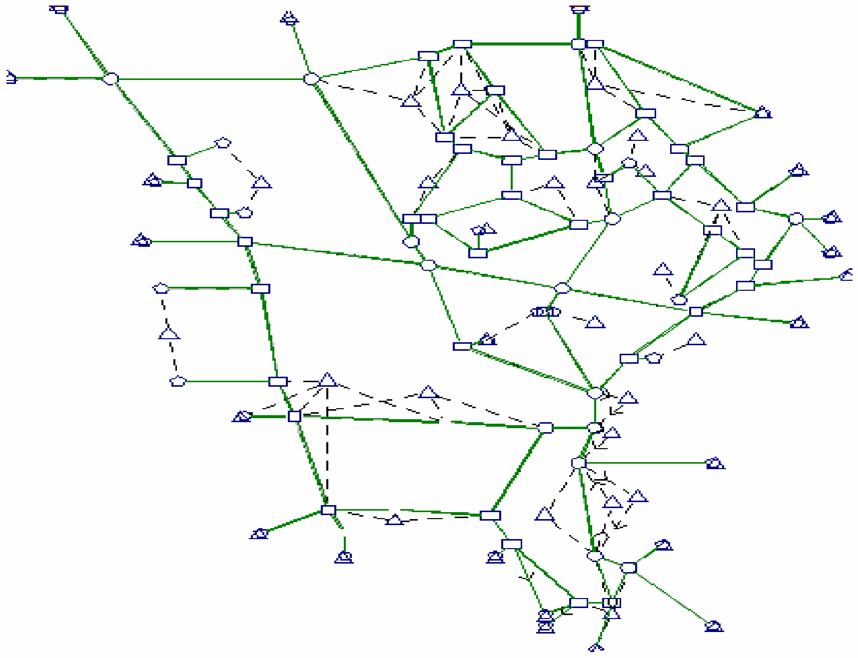

Figure 2 : SATURN sub-network

Kingston-upon-Hull City Council provided an extensive set of 15, two-way, link hourly traffic flow counts for many points within the sub-network. These were used as the primary calibration reference. Initially the mean absolute error between observed flows and assigned flows was 37% in error. By use of the SATASS and SATME2 procedures in SATURN it is possible to adapt a prior OD matrix to better represent a set of observed link flows. Rather than specifying a requirement for exact equality, which is normally difficult to achieve, an upper or lower bound was specified for the flow along a link. To decide which bound was appropriate, the initial assignment was consulted:

- if the assigned flow was more than 110% of the observed flow, an upper bound of 110% of the observed flow was specified;
- if the assigned flow was less than 90% of the observed flow, a lower bound of 90% of the observed flow was specified;
- otherwise no bounds were set.

This procedure produced flows that are, on average, within 16% of the observed. It was hoped that by specifying the bounds as above, a 10% margin would have been achieved. This was not so since, whilst in some cases an improvement was achieved, it was not sufficient to bring the flow to within ±10% of the observed flow. Also, sometimes an upper bound of 110% produced a flow which was less than 90% and since it is not possible to set both an upper and lower bound (or visa-versa) there was no way to resolve this. The scatter plot of observed and modelled flows is given in figure 3. The low to medium flow results are reasonable, with a slight tendency to under predict. The very high observed flow of 2,000 vehicles proved difficult to reproduce.

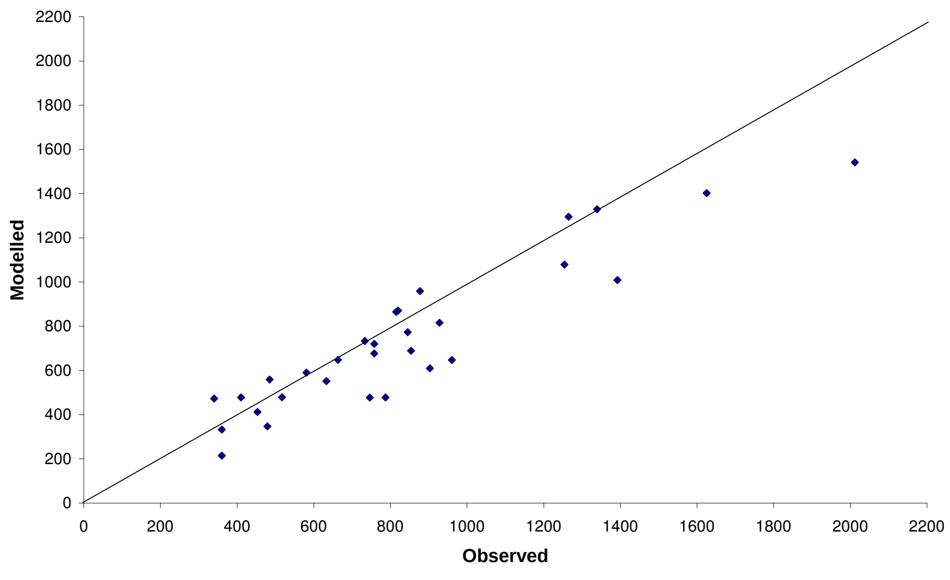

Figure 3: Correspondence between observed and modelled flows

The simulation model contains a random element that determines such features as driver behaviour and bus service operation. This random feature can be used to simulate the variance of behavior within the network by varying the random number seed. The results presented in this section are the aggregation of four such similar runs.

Examining the journey times for private and public vehicles in the network provides further checks on to the validity of the model. Unfortunately no observed journey time measurements are available, but figures reported by the model can be assessed for plausibility. The total network speed is reported as 24.3 km/hour (15.2 mph), which is on the low side for an urban area during the morning peak. Two routes in both directions have been selected for more detailed assessment, one along the Beverley Road and the other along Holwell and Stoneferry Roads. These are reported in table 1 and the starting and ending points for each section are as given in figure 1.

Route	Public vehicles		Private vehicles	
	Journey time (s)	Speed (km/h)	Journey Time (s)	Speed (km/h)
1 to 2	540	11	495	12
2 to 3	363	23	298	27
4 to 5	449	18	314	25
2 to 1	176	34	130	46
3 to 2	292	28	197	41
5 to 4	356	22	298	27

Table 1 : Base network route journey times and speeds

As would be expected, the journey times in the inbound direction in the morning peak are generally greater than in the outbound direction. Also the journey times for public vehicles are greater than those for private vehicles. The speed for buses increases on section 2 to 3 compared to section 1 to 2, since section 2 to 3 has extensive sections of reserved bus lane.

5 GUIDED BUS MODELLING

The microsimulation model contains a great deal of detail relating to the guided bus scheme. The ability to model the journeys of individual vehicles and to re-act in a real-time manner to the presence of vehicles makes this approach much more accurate that more aggregate, average flow models such as TRANSYT and SATURN. This ability is illustrated in figures 4 and 5 which shows how the presence of a bus in the guideway can be used to alter signal settings in order to allow buses to cross a stream of traffic with minimal delay.

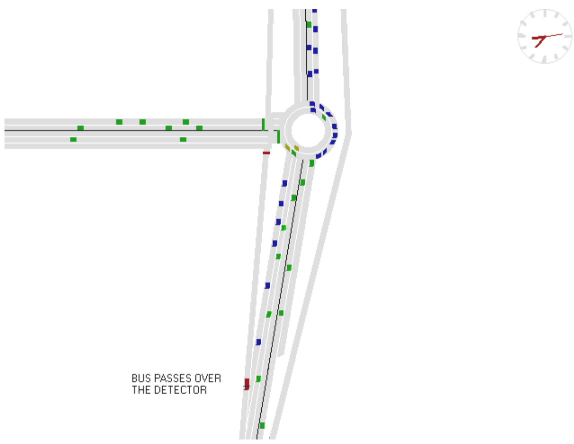

Figure 4 : Guided bus passes over detector

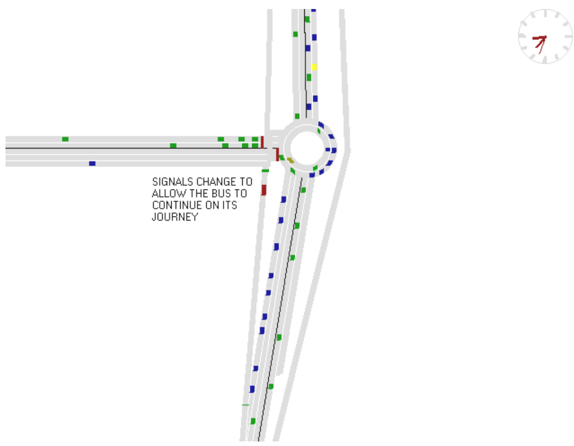

Figure 5 : Signals change for guided bus

In the median scheme it is necessary for buses to travel through a roundabout of circulating traffic. Figure 6 illustrates how this is accomplished.

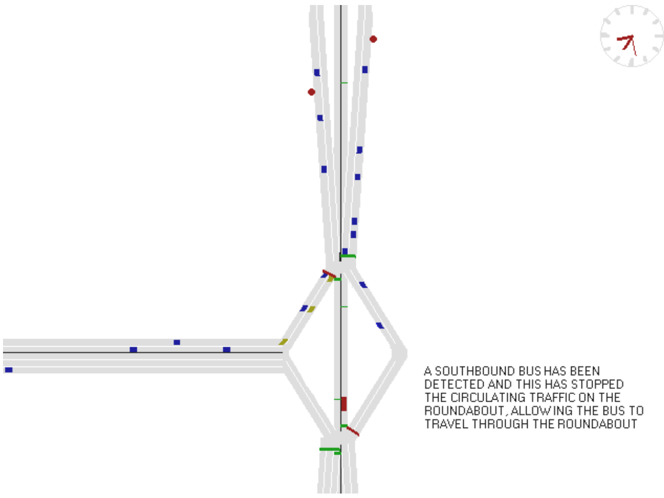

Figure 6 : Guided bus travel through a roundabout

6 MODEL RESULTS

The results of modelling the traditional bus priority measures and the four guided bus options are presented in this section. They may be compared against the base case given in table 1. It should be noted that most situations tested produced a different traffic assignment from that in the base case. This is a result of necessary modifications, such as the change to some signal plans as was the case for selective vehicle detection or additional junctions for the various guided bus schemes. All the results presented in this section are based on four simulation runs per scenario.

6.1 Network Speed

Table 2 gives the total network speed for the nine scenarios under consideration:

Scenario	Base	SVD	RTS	CB	ALL	2-Kerb	2-Med	1-Med	Elev
Speed	24.3	22.9	24.1	21.9	22.2	21.9	19.7	18.5	19.5

Table 2 : Total network speed for each scenario

Key	Base:	Base network	CB:	Signal co-ordination for buses	2-Med:	Two-way median guided bus
	SVD:	Inbound Selective vehicle detection	ALL:	All 3 traditional bus priority measures	1-Med:	One-way median guided bus
	RTS:	Reduced dwell time at stop	2-Kerb:	Two-way kerb guided bus	Elev:	Elevated guideway

The highest average network speed was reported for the base case. The next highest is for the reduced time spent at a bus stop by buses.

6.2 Public Transport Journey times

The journey time for individual buses running in the network are extracted and presented in table 3. For the base and traditional measures, there are a total of 15 buses per run, times by 4 simulation runs, making a total of 60 buses for sections 1 to 2, 2 to 3, 3 to 2 and 2 to 1 on the Beverley Road. There is a lower frequency of 7 buses per run (28 in total) for the sections 4 to 5 and 5 to 4 on Holwell/Stoneferry Road. For the guideway measures there is a reduced number, 10 buses per simulation run for the Beverley Road and an increased number for

Holwell/Stoneferry Road of 15 buses per simulation run. Since the traditional measures are concentrated on the Beverley Road we would expect reduced journey times along section 1 to 2 to 3 and 3 to 2 to 4 (although selective vehicle detection is only enabled in the 1 to 2 to 3, inbound, direction). Conversely, for the guided bus schemes, the removal of bus lanes on Beverley Road should increase the journey times along Beverley Road and the guideway infrastructure decrease them along Holwell/Stoneferry Road. The relevant cells have been lightly shaded in table 3.

	Base	SVD	RTS	CB	ALL	2-Kerb	2-Med	1-Med	Elev
1 to 2	**540**	520	504	500	431	575	636	716	540
2 to 3	**363**	340	336	346	324	376	389	379	376
4 to 5	**449**	443	441	443	476	365	344	329	323
2 to 1	**176**	165	162	161	163	201	203	202	205
3 to 2	**292**	276	270	273	259	305	304	316	304
5 to 4	**356**	304	421	283	293	301	260	256	189

Table 3 : Public transport journey times(s) along six sections

The selective vehicle detection measure has produced mixed results. The section 1 to 2, which contains two junctions equipped for selective vehicle detection, has show a small reduction (-4%) in mean journey time and the section 2 to 3, with a further two equipped junctions, has shown a slightly greater reduction (-6%) in journey time. The reduced time at stop should produce a uniform reduction in all bus journey times, this it has failed to do for the section 5 to 4, with a large increase (+18%). A more detailed inspection of this section shows that the largest increase (56 seconds) occurs in the southern sub-section of the section, which contains two bus stops with laybys. The presence of laybys can introduce a disproportionate largely variance in the journey times reported by buses. Co-ordination for buses gives a reduction in bus journey times on those sections where one is expected (1 to 2, -7%, 2 to 3, -5%, 2 to 1, -8% and 3 to 2, -7%). The section 5 to 4 has seen an unexpectedly large decrease (-21%) in journey times and once again this is attributable to the southern sub-section of this section, although the outcome is the opposite of that seen for the reduced time at bus stop measure. The combined use of all the traditional bus priority measures has given decreases in bus journey times on all sections except for 4 to 5, which is the most congested route and is affected by only one priority measure, reduced time spent at bus stops.

The removal of reserved bus lanes does not appear to have significantly affected the journey times for buses along sections 2 to 3 and 3 to 2 for the guided bus schemes. The introduction of guideway infrastructure has produced reductions in mean journey times along the most congested 4 to 5 section of 84 seconds for a two way kerb guideway (-19%), 105 seconds for a two way median guideway (-23%), 120 for the median guideway (-26%) and 126 seconds for an elevated guideway (-28%). When comparing the performance on the guideway options, it needs to be borne in mind that the journey time for the two way kerb guideway includes an element of time spent at two bus stops in either direction whilst the other three guided schemes do not have any bus stops along the guideway sections. A more detailed study of the performance around the guideway sub-sections shows that a large proportion of the reduction is due to this sub-section, with the mean journey time nearly halving from 170 seconds to typically 90 to 100 seconds. The mean journey time savings on the section 5 to 4 are more modest, a reflection of the fact that this is the counter-peak direction and thus less congested in the base case.

In addition to the mean journey time savings report in table 3, reductions of between 10 and 34 seconds have been recorded in the standard deviation of bus journey times along the routes.

6.3 Private Vehicle Journey times

Information on private vehicle journey times was collected to ensure that the implementation of the traditional measures or the guided bus schemes did not have too great an (adverse) impact on their journey times. The sample sizes for private vehicle journeys along the same routes as for public vehicles are larger and more consistent across all scenarios. The private vehicle journey times and indicative sample sizes for a single run (n) are given in the final column of table 4.

	Base	SVD	RTS	CB	ALL	2-Kerb	2-Med	1-Med	Elev	n
1 to 2	**495**	476	466	451	379	508	516	634	454	800
2 to 3	**298**	186	279	216	207	221	225	212	215	500
4 to 5	**314**	305	336	322	343	414	270	215	333	30
2 to 1	**130**	111	130	148	147	129	130	137	130	300
3 to 2	**197**	218	198	190	190	193	195	268	193	200
5 to 4	**298**	259	348	241	250	247	249	240	265	200

Table 4 : Private transport journey times(s) along six routes

None of the routes have experienced an excessive change in their journey times. The most notable result is the reduced journey time for private vehicles under selective vehicle detection and the combined measures for section 2 to 3. This is the section which required the simplification of the signal plans at two junctions. This simplification has the effect of reducing the amount of lost-time at the junctions and thereby increases the capacity of the junctions. This is illustrated by running four base case scenarios with the signal timings used in the selective vehicle detection measure, and the private vehicle journey time along the section 2 to 3 is 184 seconds in this *alternative* base case. This section also has lower journey times for the guided bus schemes, and this a consequence of the removal of the reserved bus lanes along this section of Beverley Road.

The private vehicle journey time for vehicles travelling on section 4 to 5 is markedly lower for a one-way guideway than that in the other situations. The assigned flow along the critical link that feeds into the junction with Ferry Lane has decreased by 200 vehicles for this guideway option over the base case. This re-assignment of vehicles to other routes may be a result of the more complicated road infrastructure required for this guideway option.

6.4 Environmental measures

Given the microscopic nature of the simulations it is possible to track the behaviour of individual vehicles as they travel through the network. Vehicles may be cruising, idling, accelerating or decelerating. Given pollutant emission and fuel consumption rates for each of these states it is possible to arrive at totals for the simulation. The pollutants measured in these simulations are CO (in kg), NO_x (kg) and HC (kg) and, in addition, fuel consumed (kl).

	Base	SVD	RTS	CB	ALL	2-Kerb	2-Med	1-Med	Elev
CO	**1,256**	1,477	1,270	1,548	1,459	1,461	1,702	1,759	1,696
NO_x	**307**	363	311	382	360	359	423	433	420
HC	**810**	939	818	974	921	931	1,067	1,116	1,062
Fuel	**5,417**	5,758	5,444	5,846	5,686	5,737	6,072	6,300	6,015

Table 5 : Environmental indicators

To a large extent these indicators duplicate the results on network speed presented in table 2. Those cases that show a high mean network speed show low emissions and fuel consumption and those with a low mean network speed show high emissions and fuel consumption. This is to be expected since any congestion in the network is bound to adversely affect the reported mean speed and the amount of pollutants emitted. These statistics are vehicle emissions and a better measure would be pollutants or fuel consumption per person or person-kilometre. To obtain these figures a more precise knowledge of vehicle occupancy rates is required. If these figures were available, then the increased occupancy rates for buses may favour the guideway schemes.

7 REFINEMENTS

The above results were presented to members of the Technical Services Department at Kingston-upon-Hull City Council. The only substantive reservation was the assumed reduction in public transport provision along the Beverley Road. The intent of the guideway construction on Stoneferry/Holwell Road is to enhance the provision for public transport along that arterial, without adversely affecting such provision elsewhere in the City. In light of these comments, a further set of simulations runs were conducted with the reserved lanes, bus frequency and passenger patronage figures restored to the Beverley Road.

Scenario	Base	2-Kerb	2-Med	1-Med	Elev
Speed	24.3	22.0	19.2	19.9	19.1

Table 6 : Total network speed for each scenario

The differences between the corresponding speeds in tables 2 and 6 are minor.

	Base	2-Kerb	2-Med	1-Med	Elev
1 to 2	**540**	611	620	739	674
2 to 3	**363**	366	360	361	355
4 to 5	**449**	358	341	319	312
2 to 1	**176**	181	174	183	183
3 to 2	**292**	288	288	299	291
5 to 4	**356**	287	258	253	174

Table 7 : Public transport journey times(s) along six sections

The expected outcome is that the journey times reported by buses along the sections where the reserved bus lanes have been "re-introduced", sections 2 to 3 and 3 to 2, should be lower in table 7 than in table 3. This is the case. The reported comments on the performance for guideway sections 4 to 5 and 5 to 4 reported earlier are equally valid here. In summary, the two-way kerb guideway has the longest journey time, but this includes bus stop dwell time, whilst the elevated guideway has the shortest journey time.

	Base	2-Kerb	2-Med	1-Med	Elev	n
1 to 2	**495**	527	530	688	628	800
2 to 3	**298**	252	280	243	252	500
4 to 5	**314**	396	276	217	339	30
2 to 1	**130**	135	128	139	135	300
3 to 2	**197**	197	198	269	199	200
5 to 4	**298**	247	245	238	261	200

Table 8 : Private transport journey times(s) along six routes

As would be expected, the journey times for private vehicles reported in table 8 have increased on sections 2 to 3 and 3 to 2, the greatest increase is 55 seconds whilst the smallest is only 1 second.

	Base	2-Kerb	2-Med	1-Med	Elev
CO	**1,256**	1,441	1,755	1,809	1,675
NO_x	**307**	354	436	444	412
HC	**810**	918	1,095	1,148	1,065
Fuel	**5,417**	5,689	6,120	6,446	6,131

Table 9 : Environmental indicators

The environmental indicators have not substantially changed as a result of the changes to the network.

8 CONCLUSIONS

The traditional measures are able to deliver some savings in journey times but these are marginal. None of the proposed measures has a high, visible impact on the highway and this may disadvantage them in the travelling publics' perception, relative to the guided bus schemes.

Although the guideways are short in nature, they have been planned along where the congestion along the route is most severe. This enables the guideway to deliver the most benefit where it is needed the most. The guideway schemes are able to deliver significant journey time savings over this short section of road way, of the order of 1 to 2 minutes per vehicle. This may sound small but the schemes are also able to deliver a more reliable journey time, with the variability in journey times been reduced to a half in some cases. Evidence from the Scott-Hall Road scheme in Leeds suggests that even modest journey time savings (of between 3 to 5 minutes) and increases in reliability can produce significant patronage growth (in excess of 70% over 2½ years).

The scheme that gives the better performance is the elevated guideway with a 2 minute reduction in journey time. This is to be expected given the high degree of segregation envisaged by this option. On the converse side is the inability to provide for passenger boarding or alighting along the guideway. If the guideway is envisaged as an express option only linking the residential district in the north with the city center then this is not a concern.

Of the two median guideway options there is little to chose between them in operation. On this study of the morning peak it would appear that only an inbound guideway is required in order to deliver journey time savings. If a similar result was found in the evening peak, that only outbound buses required priority, then a tidal option would appear to be the more cost effective of the two median provision options.

The kerb guideway appears to perform the worst of the four variants. This is a slightly unfair judgement since the kerb guideway scheme uniquely includes the provision of two bus stops that add a significant and variable element to the journey time of buses along its route.

9 APPENDIX

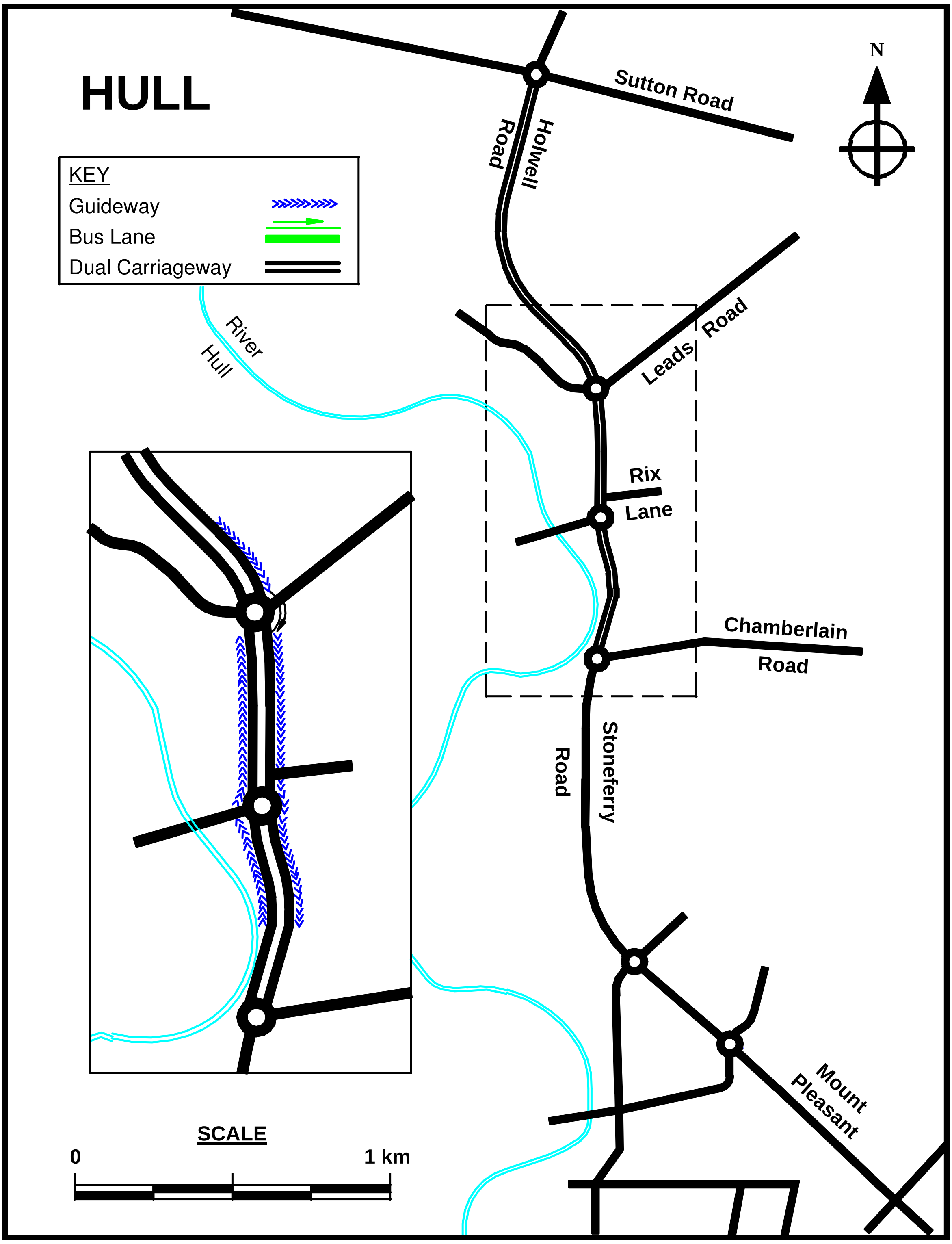

Figure A1 : Two-way kerb guideway

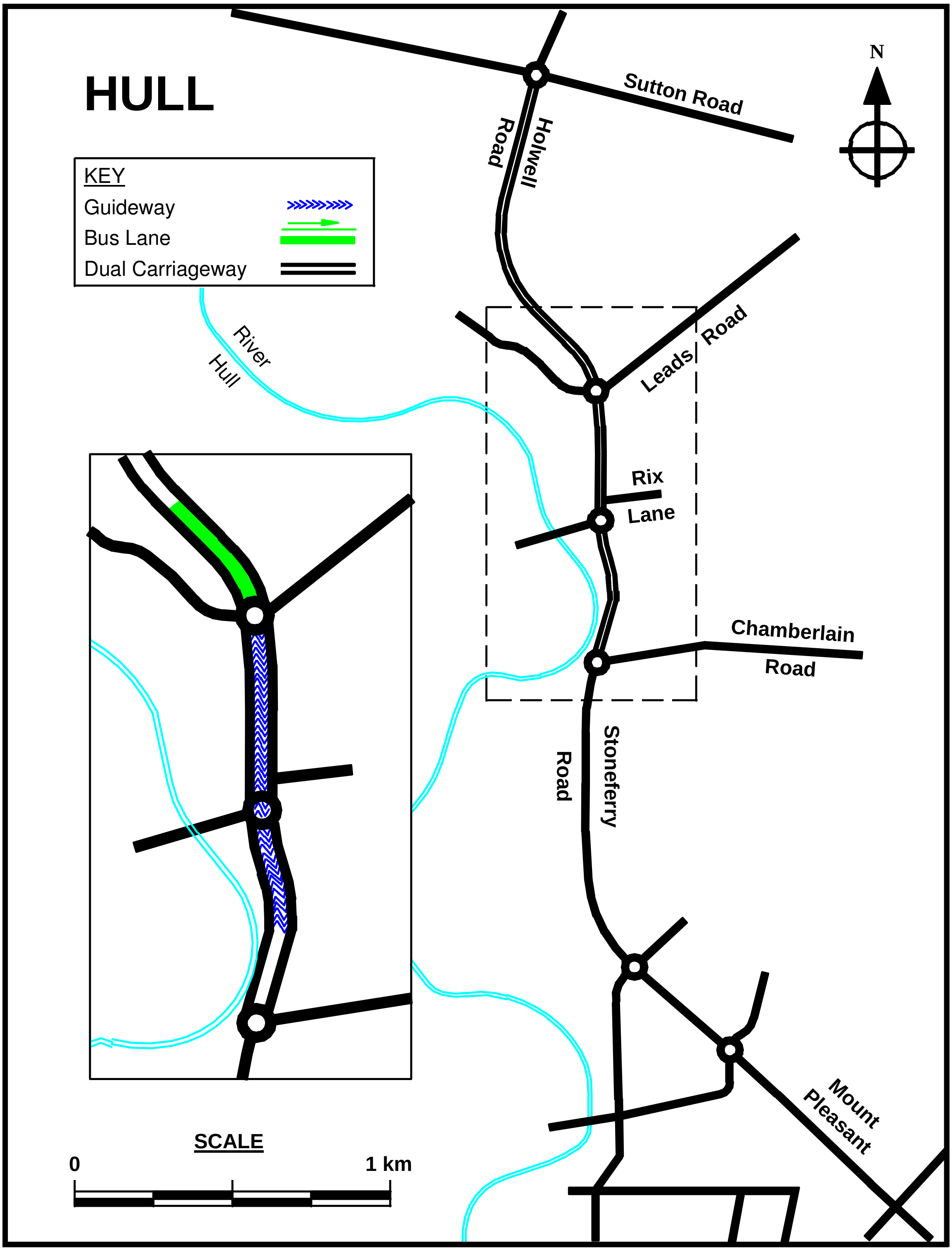

Figure A2 : Two-way median guideway

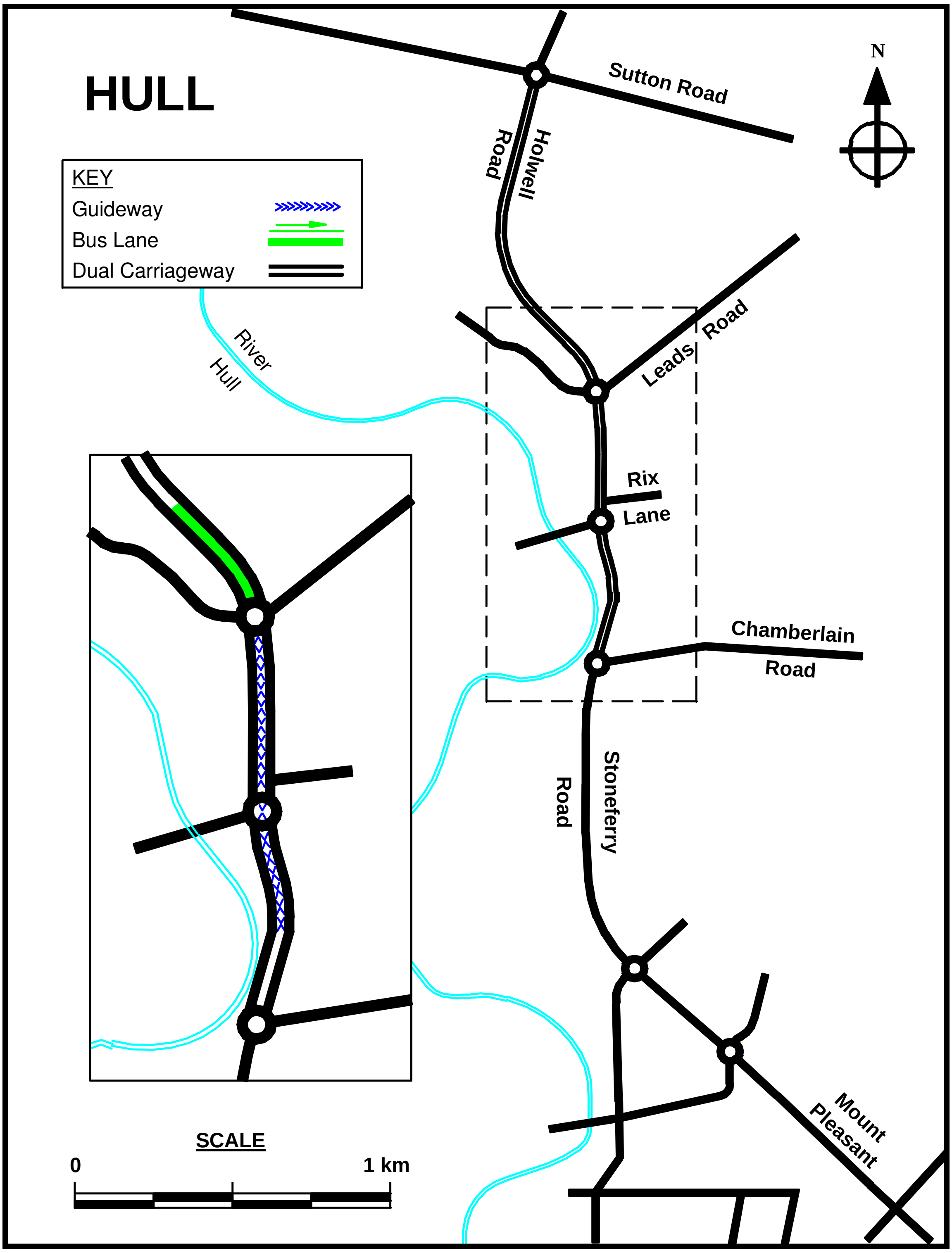

Figure A3 : One-way (Tidal) guideway

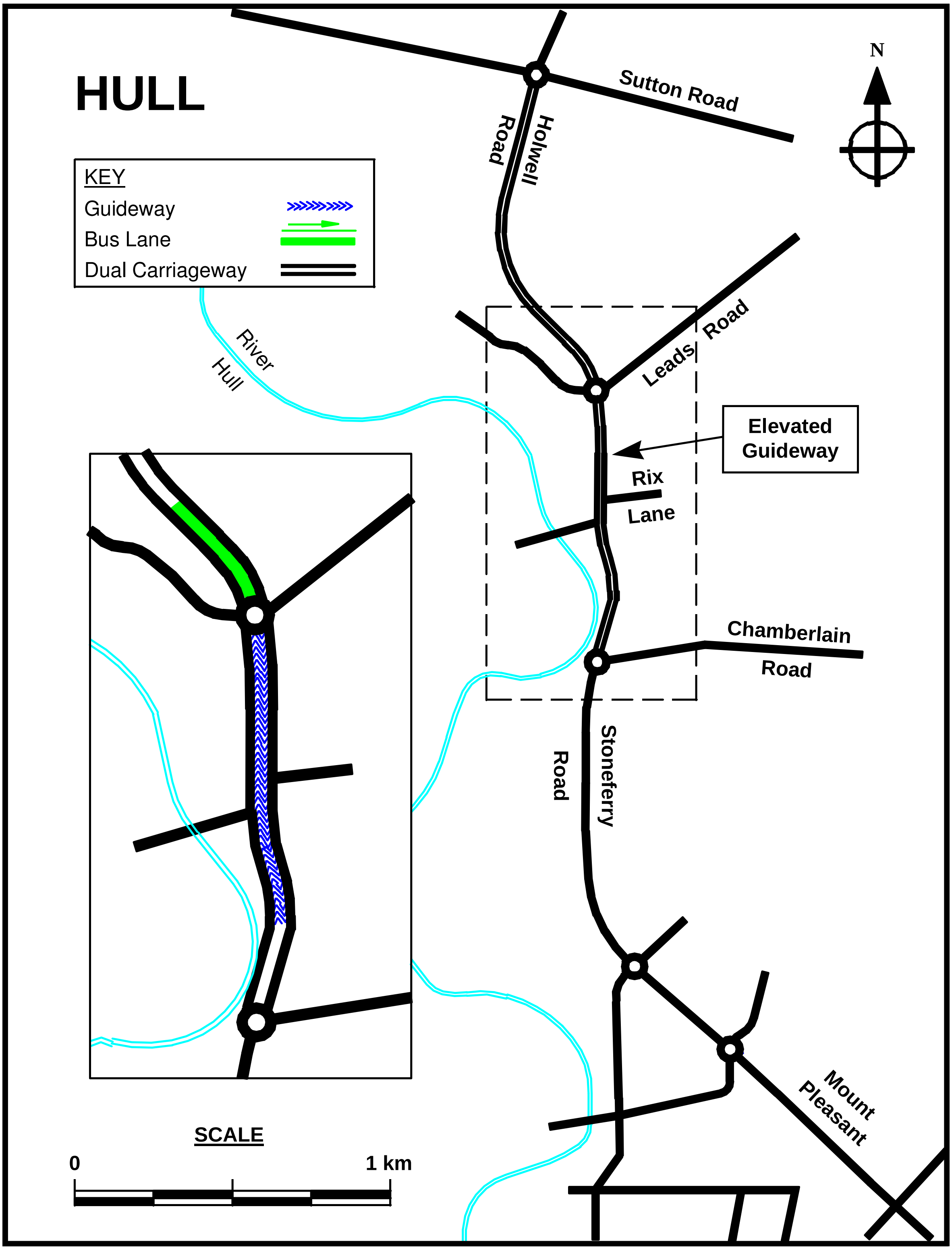

Figure A4 : Elevated guideway