Managed Motorways – All Lanes Running

All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) Analysis and Hazard Assessment

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All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) Analysis and Hazard Assessment

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Abbreviations

APTR	All Purpose Trunk Road
ATM	Active Traffic Management
CDM	Construction (Design and Management)
C'way	Carriageway
D3M	Dual 3-lane Motorway
D4M	Dual 4-lane Motorway
HA	Highways Agency
HGV	Heavy Goods Vehicle
KSI	Killed and Seriously Injured
LBS	Lane Below Signal
LHV	Large Heavy Vehicle
MAC	Managing Agent Contractor
MIDAS	Motorway Incident Detection and Automatic Signalling
MM-DHS	Managed Motorway – Dynamic Hard Shoulder
MM-ALR	Managed Motorway – All Lanes Running
ORR	On Road Resource
PIA	Personal Injury Accidents
PTW	Powered Two Wheeler
TechMAC	Technology Managing Agent Contractor
TO	Traffic Officer
Veh-mile	Vehicle Mile

Executive summary

One of the most significant challenges associated with MM-ALR is the delivery of a design that will be both safe to use from a driver/rider point of view and safe to operate from the view of those that have to work on the road (On Road Resources (ORR)).

This document summarises the results of a number of strands of work intended to provide an understanding of the safety challenges involved and to gain a level of assurance of how MM-ALR would be expected to perform in terms of safety. The safety implications for a number of populations have been considered including those that stop on the hard shoulder and vulnerable road users (such as pedestrians and those that have to work on and maintain the network).

Three distinct elements of work have been undertaken:

- Analysis of accident and casualty data collected from the Dual 3-lane Motorways (which have hard shoulders) and multi-lane All-Purpose Trunk Roads (which do not). The purpose of this analysis is to establish the safety implications of converting the hard shoulder to a running lane without any further mitigation (Referred to as D4M without a hard shoulder in this document).
- Detailed analysis of some of the more significant safety hazards has been undertaken using the accident and casualty data described above. The purpose of this is to ensure that the safety implications of these are as fully understood as possible.
- A Hazard Assessment has been undertaken with respect to the MM-ALR concept. The purpose of this is to understand how the MM-ALR scheme is expected to perform it terms of safety and how it is expected to impact some key populations. The results from this are presented in the Demonstration of Meeting Safety Objective Report[1].

Safety Implications of removing the Hard Shoulder

Analysis of accident and casualty data collected from all the Dual 3-lane Motorways and multi-lane All-Purpose Trunk Roads (APTR) in England indicates that 3-lane APTRs have a rate[2] of Killed and Seriously Injured (KSI) accidents that is approximately 9% higher than that encountered on the D3M network. With regard to KSI casualties, the rate is approximately 5% higher. These rates take into account the impact of MIDAS queue protection and are therefore measured against a baseline of a D3M without MIDAS.

It is estimated that if the whole of the D3M network in England was converted to D4M without a Hard Shoulder and without further mitigation, the increased numbers of Killed and Serious accidents would lead to an additional cost ranging between £24m and £54m per year. Over the typical design life of 30 years this would accumulate to a cost of £720m to £1,620m. If the design life is 60 years this would accumulate to a cost of £1,440m to £3,240m.

[1] http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/Demonstration_of_meeting_safety_objective_report_(Final_23-03-12).pdf

[2] per Million Vehicle Mile

Detailed Accident and Casual Analysis

The main conclusions to draw from the above are that in comparison with D3M links, multi-lane APTR links are characterised by:

- A four to five fold increase in the frequency of vehicle parked in main carriageway accidents.
- An increase in the frequency of accidents involving vehicles leaving the carriageway
- No increase in the frequency of fatigue related accidents
- An increase in frequency of Pedestrian accident
- No increase in the frequency of Debris related accidents
- An increase in the frequency of accidents involving a motorcycle.

It is likely that the frequency of vehicle parked in main carriageway and vehicles leaving the carriageway accidents are related to the loss of the Hard Shoulder. However, it is likely that most of the increase in the frequency of pedestrian accidents is due to different levels of access to the road. The reason for the increase in frequency of Motorcycle accidents is less clear and may be due to a number of factors including differences in geometrical standards between the two types of road.

Hazard Assessment

A hazard assessment has been undertaken. This has involved agreeing the characteristics of a generic D3M link without MIDAS and using this to derive a safety baseline. The features of MM-ALR have then been used to determine whether or not the risk associated with each hazard has gone up, gone down or remained the same. In addition ‘D4M without a hard shoulder’ has also been compared with the safety baseline.

The Hazard Assessment shows that the safety risk is driven by removal of the hard shoulder which leads to an increased frequency of vehicles stopped in a lane, vehicles leaving the carriageway and pedestrians in the road (and closer to traffic). In addition, maintenance activities will be more challenging to mitigate and revised practices will need to be developed and adopted. This assessment assumes that MM-ALR design features promote situational awareness leading to the required level of driver compliance.

The hazard assessment suggests that D4M without a hard shoulder will be less safe than the baseline. MM-ALR (assuming situational awareness can be maintained) is expected to have a level of safety comparable with the safety baseline.
Further information about the results of the hazard assessment can be found in the Demonstration of Meeting Safety Objective Report [5].

1. Introduction

One of the most significant challenges associated with MM-ALR is the delivery of a design that will be both safe to use from a driver/rider point of view and safe to operate from the view of those that have to work on the road (On Road Resources (ORR)).

This document summarises the results of a number of strands of work intended to provide an understanding of the safety challenges involved and to gain a level of assurance of how MM-ALR would be expected to perform in terms of safety. The safety implications for a number of populations have been considered including those that stop on the hard shoulder and vulnerable road users (such as pedestrians and those that have to work on and maintain the network).

2. Document Structure

Section 3 of this document is primarily concerned with understanding what the safety implications would be if the hard shoulder was converted to a running lane without further mitigation. This has been accomplished by reviewing accident and casualty data collected from all the Dual 3-lane Motorways (which have hard shoulders) and multi-lane All-Purpose Trunk Roads (which do not) in England. The implications of applying what is effectively 'D4M without a Hard Shoulder' to two key scenarios is all presented. The first of these scenarios considers what would have happened if the M42 ATM pilot consisted of simply converting the hard shoulder to a running lane. The second scenario considers what would have happened if this approach was adopted on the D3M network as a whole.

Section 4 contains a more detailed analysis of some significant hazards as identified during this work. The purpose of this is to ensure that the safety implications of these are fully understood before moving onto a Hazard Assessment.

Section 5 reports on a Hazard Assessment undertaken with respect to the MM-ALR concept. The purpose of this is to understand how the MM-ALR scheme is expected to perform it terms of safety and how it is expected to impact some key populations. A number of key challenges are identified.

Section 6 contains a summary and conclusions.

3. Implications of converting the Hard Shoulder to a running lane without mitigation

This section is intended to provide an indication of the change in accident and casualty rates that could result should the hard shoulder on existing Dual 3-lane Motorways (D3M) without MIDAS queue protection be converted into a running lane (creating a four lane motorway (D4M) without a hard shoulder and without MIDAS).

In order to accomplish the above an analysis has been carried out on all the D3M links and multi-lane All-Purpose Trunk Roads (APTR) in England. On the latter, hard shoulders are not present and therefore analysis of these links can give an indication of how the accident and casualty rate can change if the Hard Shoulder is converted into a running lane.

The results from the analysis are likely to be a good indication of the rates that will apply to a 3 lane carriageway without a hard shoulder. However, MM-ALR will create a four lane carriageway. Therefore, there will need to be further interpretation of the results regarding the accident rates that will result from a four-lane carriageway (D4M) without a hard shoulder.

3.1. Understanding the impact of MIDAS

It should be emphasised that the purpose of this analysis is to understand the changes that would result from converting a D3M link without MIDAS queue protection into an MM-ALR link.

A representation of the features of both D3M without MIDAS queue protection and MM-ALR (Future Managed Motorway Concept) links is presented in Figure 3.1-1.

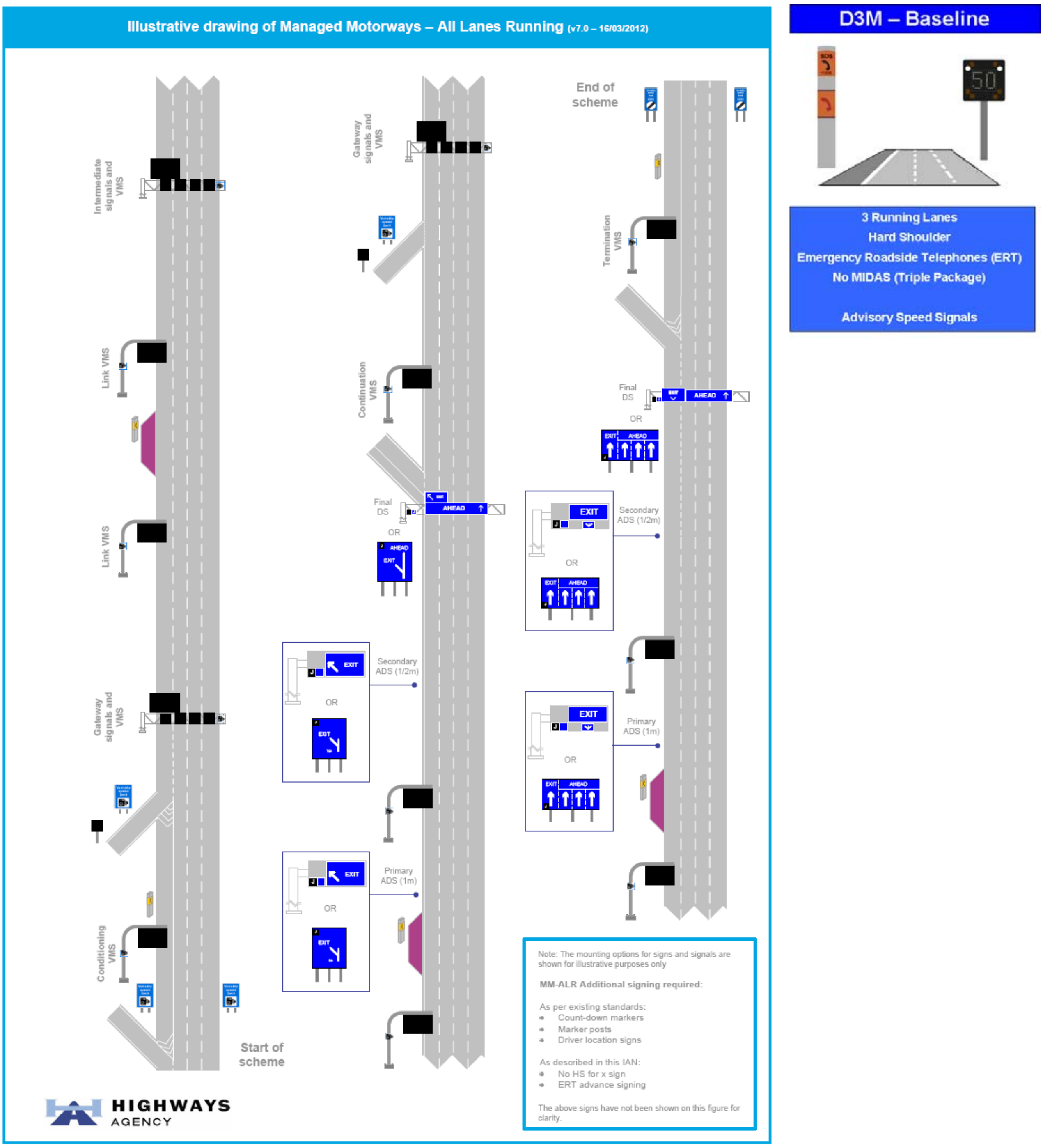


Figure 3.1-1: Main features of D3M and MM-ALR

As noted above the comparison is to be between a D3M link without MIDAS queue protection and an MM-ALR link with appropriate technology and control.

Where MIDAS is installed it has been shown to reduce Personal Injury Accidents (PIA) by an average of 13% and Killed and Seriously Injured (KSI) Accidents by on average between 9 and 10% [1]. When carrying out this analysis, it is therefore necessary to take account of the length (or more correctly the proportion) of the D3M network where MIDAS has been installed.

Using information supplied by the HA (a list of current MIDAS locations), it has been possible to establish that MIDAS is installed on just over 1000km (600 miles) of the

D3M network. The D3M network is 2136 km (1331 miles) long. Therefore, MIDAS is installed on just less than 50% of the D3M network at the time of the analysis for this Report.

Therefore, in overall terms, the accident and casualty statistics for the D3M network as a whole are better than would be expected for the D3M network without any MIDAS installed. The difference is of the order of 6.5% for all PIAs and 5% for KSIs.

3.2. Overall Accident and casualty rates by road type

The Highways Agency is responsible for two types of 'Trunk Road' in England; Trunk Road Motorways and All-purpose Trunk Roads (APTR). In general Motorways have a hard shoulder and APTRs do not. Therefore, by comparing the accident and casualty rates on these two types of road it is possible to indicate what impact removing the hard shoulder will have. I.e. it is possible to compare the rate of accidents and casualties on D3M links with 3 Lane APTR links (that do not have a Hard Shoulder). From this the benefit (or otherwise) of providing the Hard Shoulder can be deduced.

A number of assumptions have been made regarding this comparison:

- Accident and Casualty data has been obtained from all Highways Agency D3M links, dual carriageway APTR links that have two lanes in each direction and dual carriageway APTR links that have 3 lanes in each direction. The decision to split the APTR data into two sets is to compensate for the fact that there are only a limited number of APTR links that have 3 lanes in each direction.
- Accidents and Casualties occurring at Junctions have been excluded from the analysis. This is considered to be reasonable as D3Ms have exclusively grade-separated junctions while APTRs have a mixture of grade-separated and at-grade junctions. (Also the proposed change, the addition of a lane at the expense of the hard shoulder mainly affects the link. It is assumed that slip-roads and junctions would be re-modelled accordingly.)

In addition a number of other constraints are noted:

- In general, flow levels (per lane) on the APTR network are likely to be lower than those on the motorway network. I.e. these links are likely to be operating well within capacity. For this reason the results are presented per million vehicle mile as opposed to 'per mile'.
- In order to carry out this analysis, personal injury accident and casualty data in the national 'STATS19' database have been analysed to determine the frequencies of accidents and casualties. Stats19 injury accident data includes the road class and type where an accident occurred, but does not include the number of lanes at that location. Therefore, this analysis has used the Stats19 dataset that has been 'snapped to' HAPMS (HA Pavement Management System), where each section have data including the road class, type and the number of lanes. Snapping of accidents to sections is routinely done by the HAPMS team each year, and each accident is snapped to the nearest section (and carriageway if possible). There are a few accidents (<5%) that are located too far from any section to be snapped.
- Traffic data used is based on the DfT traffic survey data, more details can be found at http://www.dft.gov.uk/matrix/

- The Stats19 data criteria used for this analysis is as follows:
    - Injury accidents reported to and by the police.
    - Only those accidents snapped to HAPMS sections, July 2010.
    - 2005-2009 validated Stats19 data on 2006 HA network.
    - The accident's Junction detail = 00 (which means that it is not at or within 20 metres of a junction).
    - Lay-by or hard shoulder accidents are those where at least one vehicle in the accident was recorded as on, entering or leaving hard shoulder or lay-by.
    - Casualties in hard shoulder or lay-by accidents are all casualties in these accidents, that is, occupants of the vehicle that was on, entering or leaving hard shoulder or lay-by, occupants of other vehicles and pedestrians.
    - Contributory factor data includes only those accidents which were attended by the police and factors were recorded. Since accidents can have up to 6 factors individual percentages for factors should not be summed.
- The HAPMS criteria used in this analysis is as follows:
    - Used HAPMS dual carriageway sections rather than Stats19 road type.
    - Used HAPMS road class rather than Stats19 road class.
    - Carriageways not specified are not included.
    - Motorways with 3 lanes only
    - Dual A-roads with 2 or 3 lanes only
    - Other motorway and dual A-road number of lane combinations not included.
- DfT traffic criteria used in this analysis is as follows:
    - Dual carriageways only
    - Motorways with 6 lanes only (3 in each direction)
    - Dual A-roads with 4 or 6 lanes only (2 or 3 lanes in each direction)
    - Other motorway and dual A-road number of lane combinations not included (for example, 5 lanes).
- The length of Dual 3-lane APTR is relatively short (98 miles) and hence the number of personal accidents is smaller (but still substantial at 1227 in total) and is expected to be subject to a larger proportion of random variation.

The overall accident and casualty rates (per vehicle mile) by road type are presented in Table 3.2-1.

Table 3.2-1: Summary of accident and casualty data by road type (2005-09) (England only)

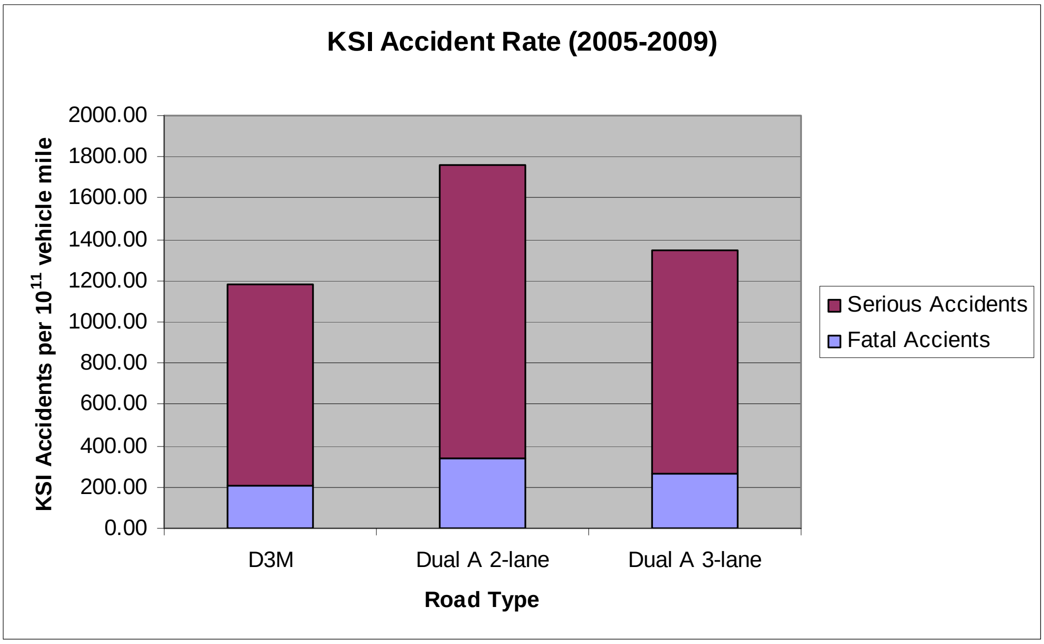
All Accidents and Casualties	All Dual M 3-lane	All Dual A 2-lane	All Dual A 3-lane
Fatal accidents	444	326	35
Serious accidents	2,080	1,355	146
Fatal and Serious Accidents	2,524	1,681	181
Slight accidents	17,357	8,487	1,046
All accidents	19,881	10,168	1,227
Killed	528	361	37
Seriously injured	2,661	1,662	183
Killed and Seriously Injured (KSI Casualties)	3,189	2,023	220
Slightly injured	29,534	13,596	1,700
All casualties	32,723	15,619	1,920
DfT traffic data	**All Dual M 3-lane**	**All Dual A 2-lane**	**All Dual A 3-lane**
Length (miles)	1,331	1,416	98
Traffic (5 year total) (10^{11} veh-mile)	2.13	0.95	0.13
Average AADT	87,685	36,893	74,663
Accident and Casualty rate (per 10^{11} veh-mile)	**All Dual M 3-lane**	**All Dual A 2-lane**	**All Dual A 3-lane**
Fatal accidents	208	342	261
Serious accidents	977	1421	1088
Fatal and Serious Accidents	1185	1763	1349
Slight accidents	8150	8901	7798
All accidents	9335	10664	9147
Killed	248	379	276
Seriously injured	1249	1743	1364
Killed and Seriously Injured (KSI Casualties)	1497	2122	1640
Slightly injured	13868	14259	12674
All casualties	15365	16380	14314

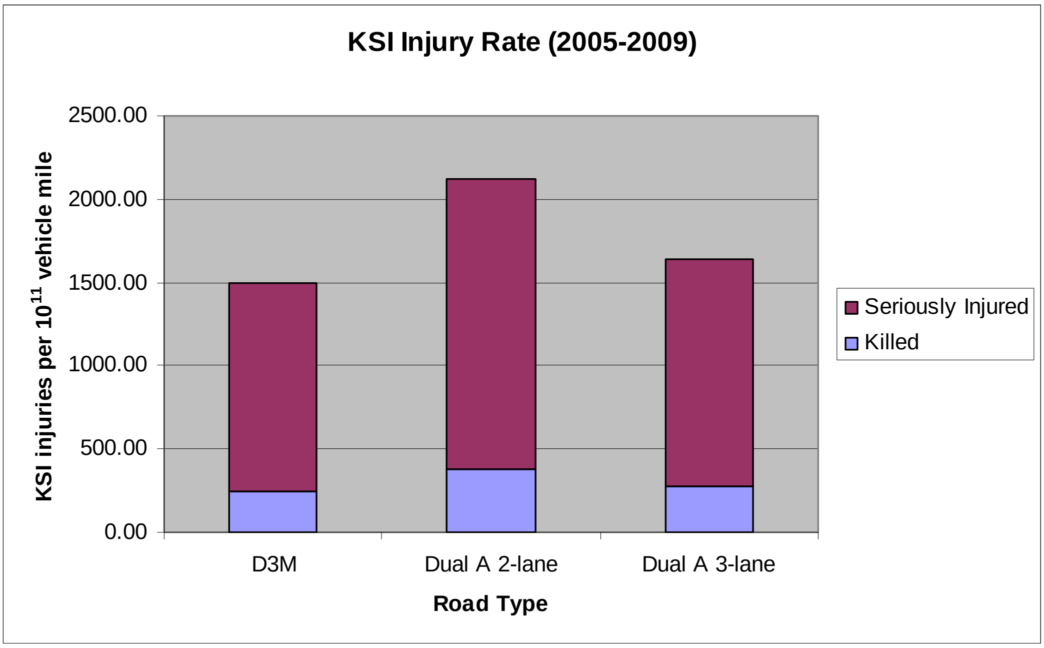
From Table 3.2-1 it can be seen that in overall terms the lowest overall rate of accidents and casualties can be found on 3-lane APTR links (which generally do not have a hard shoulder). This may be as a result of the small sample size for these roads (as noted previously) i.e. that slight accidents/casualties maybe under-represented.

As HA national targets concern fatal and seriously injured accidents and casualties it is concluded that the analysis should be focused on these groups. (These are highlighted in Table 3.2-1 and where relevant in subsequent tables.)

The lowest rates of Fatal and Serious Accidents and Casualties can be found on D3M links. The rates are higher on APTR 3-lane links, and higher still on APTR 2-lane links. This is illustrated in Figure 3.2-1.

Figure 3.2-1: KSI Accident and Injury rates by road type





From this it can be seen that the lowest rate of fatal and serious accidents (KSI accidents) and KSI injuries can be found on D3M links. A Hard Shoulder is present on these links.

Table 3.2-2 compares the rate of accidents and casualties on Dual 2 lane and Dual 3 lane APTR links with D3M links by severity. For example the fatal accident rate on Dual 2 lane APTRs is 63.99% higher than the rate on D3M links.

Table 3.2-2: Comparing APTR accident and casualty rates with those encountered on D3M links

Percentage change in Accident rate (per vehicle mile) with respect to D3M rate	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	100	+63.99	+25.16
Serious accidents	100	+45.50	+11.44
Fatal and Serious Accidents	100	+48.75	+13.86
Slight accidents	100	+9.21	-4.32
Percentage change in Casualty rate (per vehicle mile) with respect to D3M rate			
Killed	100	+52.71	+11.26
Seriously injured	100	+39.50	+9.19
Killed and Seriously Injured (KSI Casualties)	100	+41.69	+9.53
Slightly injured	100	+2.82	-8.61

Of the two possible comparators, Dual 3 lane APTR links are probably the more representative (having the same number of lanes, although the sample size is smaller). This suggests that if the hard shoulder is converted to a running lane there would be an increase in KSI accidents of in the order of 14% and an increase in KSI injuries in the order of 10%. (Strictly, as discussed earlier, this represents removing the Hard Shoulder from D3M links as opposed to converting the hard shoulder to a running lane.)

If the benefit of MIDAS on 50% of D3M is removed (See Section 3.1), then the difference is estimated to be approximately 9% for KSIs accidents (13.86%-5% = 8.86%) and 4.5% for KSI casualties (9.53% -5%[1] = 4.53%).

It should be noted that the comparison does not take into account that APTR links also include lay-bys. Therefore it is necessary to further adjust these figures so that the effect of lay-bys can be removed.

Assuming that Dual 3 lane APTR links is the more representative comparison, the adjusted number of accidents would be obtained from the following formula;

> (Existing rate of Accidents) – (Existing rate of Hard Shoulder/Lay-by accidents) – (Existing rate of stopped in carriageway accidents) + (Recalculated rate of stopped in carriageway accidents)

This equation assumes that all Hard Shoulder and lay-by accidents are removed from the totals and replaced by accidents involving vehicles broken down in the running lane. (As the Hard Shoulder and lay-bys are not present, accidents involving these cannot now occur. However, the number of broken-down in carriageway accidents would be expected to increase.)

[1] A Figure of 5% is used on the assumption that the change in KSI casualties brought about by the implementation of MIDAS is similar to reported change in KSI accidents.

It also assumes that the only vehicles that would be parked in the carriageway would be those that have resulted from a breakdown. That is, casual stops on the carriageway (i.e, within a running lane) would be eliminated as effectively as they are on the Motorway network.

The existing rate of 'Hard Shoulder/Lay-by' accidents/casualties is presented in Section 4.1.

The existing rate of 'Parked in Carriageway' accidents/casualties is presented in Section 4.2.

3.3. Implications if applied on the M42 ATM Pilot

This section considers what may have happened in terms of safety if the M42 ATM Pilot scheme had been replaced by a scheme where the hard shoulder had been converted into a running lane without further mitigation (i.e. D4M without a hard shoulder).

Table 3.3-1 presents 'before' accident and casualty data collected from the M42 ATM Pilot. As before, the accidents and casualties are those that have been recorded more than 20m from a junction, i.e. on the links between junctions.

Table 3.3-1: Link accidents and casualties M42 Junction 3a – 7 before implementation of the M42 ATM Pilot.

	09/06/2000 - 08/06/2003				
PIA Summary	**Year 1**	**Year 2**	**Year 3**	**Total**	**PIA/Million Vehicle mile by severity**
Fatal	0	2	3	5	0.33
Serious	7	9	4	20	1.31
Fatal and Serious	7	11	7	25	1.64
Slight	64	53	44	161	10.55
Total	71	64	51	186	12.19
	09/06/2000 – 08/06/2003				
Casualty Summary	**Year 1**	**Year 2**	**Year 3**	**Total**	**Casualties/Million Vehicle Mile by severity**
Fatal	0	3	3	6	0.39
Serious	9	12	4	25	1.64
Fatal and Serious	9	15	7	31	2.03
Slight	114	77	71	262	17.17
Total	123	92	78	293	19.20

It should be noted that MIDAS was installed in September 2002, towards the end of the period covered by the data. For the purposes of this analysis it is assumed that MIDAS was not installed for the whole period.

Table 3.3-2 presents after accident data collected from the M42 ATM Pilot. As previously, the accidents and casualties are those that have been recorded more than 20m from a junction.

Table 3.3-2: Link accidents and casualties M42 Junction 3a – 7 After implementation of the M42 ATM Pilot.

	01/10/2006 - 30/09/2009				
PIA Summary	**Year 1**	**Year 2**	**Year 3**	**Total**	**PIA/Million Vehicle mile by severity**
Fatal	0	0	0	0	0.00
Serious	3	2	1	6	0.32
Fatal and Serious	3	2	1	6	0.32
Slight	19	33	23	75	4.04
Total	22	35	24	81	4.36
	01/10/2006 - 30/09/2009				
Casualty Summary	**Year 1**	**Year 2**	**Year 3**	**Total**	**Casualties/Million Vehicle Mile by severity**
Fatal	0	0	0	0	0.00
Serious	3	3	1	7	0.38
Fatal and Serious	3	3	1	7	0.38
Slight	45	45	37	127	6.84
Total	48	48	38	134	7.22

It can seen from the above that there were 25 KSI accidents and 31 KSI injuries in the before period (which covers three years). In the after period, also covering three years there were 6 KSI accidents and 7 KSI casualties (all serious with no fatalities). This shows a dramatic change in the numbers KSI which is even more remarkable as during this period there was a 21% increase in the volume of traffic.

As reported in Section 5 of this report, a hazard based assessment has been carried out to determine the risk associated with a number of interventions on the D3M network. This assessment has concluded that D4M without a hard shoulder has of the order of 20% more risk than a D3M without MIDAS.

It is important to recognise that the Hazard analysis represents risk on a scheme which in itself does not equate to accidents (this is due to the semi-quantitative approach adopted in the analysis). However, if it is inferred that this change in risk translates to a change in accidents, then it would suggest that the rate of KSIs accident could increase by of the order of 20%.

Both the data collected from the network and the hazard assessment infer that there would be an increase in KSI accidents. Considering the two, it may be possible to infer that this is of the order of 9 to 20%. However, it would be more appropriate to emphasis the lower figure and possibly consider the inferred figure as an indicative upper limit.

Using data from previous sections and the hazard assessment, and assuming that the traffic flow remains constant, the total KSI accidents and injuries on the links that could result are summarised in Table 3.3-3.

Table 3.3-3: Predicted number of link accidents and casualties M42 Junction 3A to7

	Before (3 year period)	After – based on difference in accident and casualties rates D3M without MIDAS and 3-lane APTRs (9% change in Accidents and Injuries)	After – inferred from Hazard Assessment (20% change in Accidents and Injuries)
KSI Accidents	25	27.2	30
KSI Injuries	31	32.5	37

In order to establish how this translates into monetary terms, DfT data for the valuation of road accidents and casualty costs[1] (June 2009) have been obtained. These are as shown in Table 3.3-4.

Table 3.3-4: Valuation of Accidents and Casualties

Accident/casualty type	Cost per casualty
Fatal	£1,585,510
Serious	£178,160
Slight	£13,740
Average for all Severities	£47,740

Accident Type	Motorways
Fatal	£1,952,830
Serious	£234,010
Slight	£28,500
All injury	£82,680

Using the above, and assuming the same proportions of fatal and serious accidents and casualties as indicated in the 'before' data the cost over three years for these additional accidents and casualties is estimated to be £1.30m, although using the inferred results of the hazard assessment it could be as much as £2.8m.

3.4. Implications if applied across the D3M network

From Table 3.2-1, it can be seen that during a 5 year period there were 444 fatal and 2080 serious accidents on the D3M network. Using the same approach as outlined above, it is estimated that if the whole of this network was converted to D4M without a Hard Shoulder, the increased numbers of fatal and serious would lead to an additional cost ranging between £24m and £54m per year. Over the typical design life of 30 years this would accumulate to a cost of £720m to £1,620m (without discounting). If the design life is 60 years this would accumulate to a cost of £1,440m to £3,240m (without discounting).

The above is based on the KSIs increasing by either 9% or 20% and the proportion of Fatal and Serious accidents remaining constant.

[1] http://www.dft.gov.uk/pgr/statistics/datatablespublications/accidents/

4. Analysis of impact on key hazards and populations

The purpose of this section is to understand in more detail the potential impact of MM-ALR on a number of key hazards and populations. These were identified as requiring more detailed analysis during the Hazard log scoring workshops (See Appendix B). They are listed below:

- Accidents that occur on the Hard Shoulder or are associated with Lay-bys
- Accidents involving a vehicle parked on the main carriageway
- Accidents where the vehicle left the carriageway
- Accidents with the contributory factor 'fatigue'
- Accidents where at least one of the casualties involved was a pedestrian
- Accidents where a vehicles hit an object (debris)
- Accidents involving a motorcyclist

The purpose of this work is to provide more certainty about estimating the numbers of accidents and casualties that would result from conversion of the hard shoulder into a running lane. A more detailed analysis of a selection of APTR links is also presented in order to help verify the results of the above.

It should be noted that due to the difficulty of identifying maintenance and ORR related accidents and casualties on the network (as the numbers involve are small in comparison to the accident types identified above) the impact of MM-ALR on these population are discussed and presented in Section 5.6 using a slightly different dataset which identifies accidents at roadworks involving pedestrians.

4.1. Hard Shoulder / Lay-by Accident and casualty rates by road type

Table 4.1-1 presents the Hard Shoulder and Lay-by Accident and casualty rates (per vehicle mile) by road type.

Table 4.1-1: Hard Shoulder and Lay-by Accident and Casualty rates

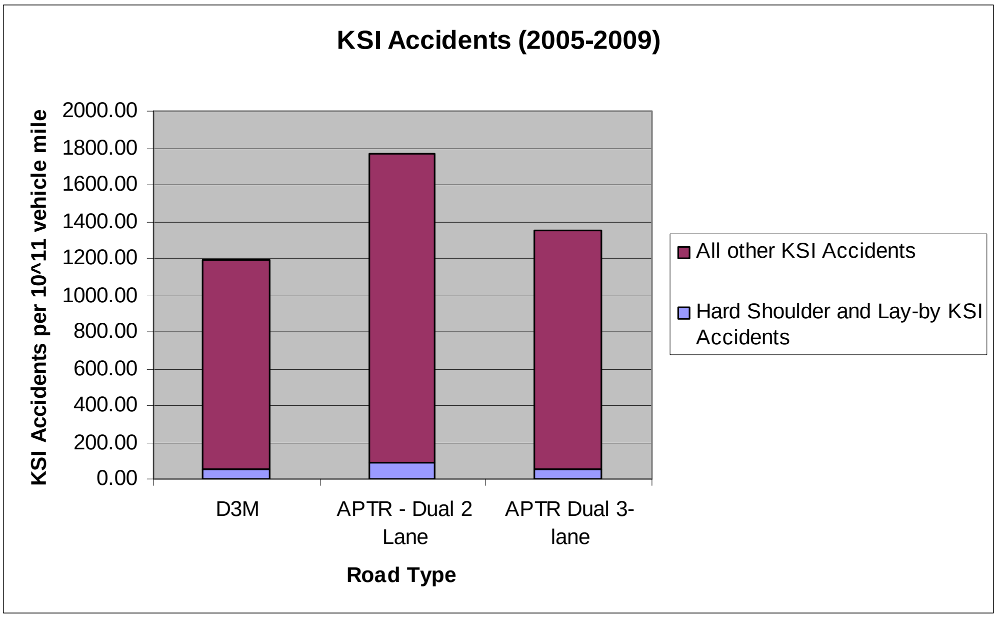
Hard Shoulder and Lay-by Accidents and Casualties	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	36	26	2
Serious accidents	80	62	5
Fatal and Serious accidents	116	88	7
Slight accidents	216	193	25
All accidents	332	281	32
Killed	46	28	2
Seriously injured	114	77	7
Killed and Seriously injured (KSI Casualties)	160	105	9
Slightly injured	414	340	38
All casualties	574	445	47

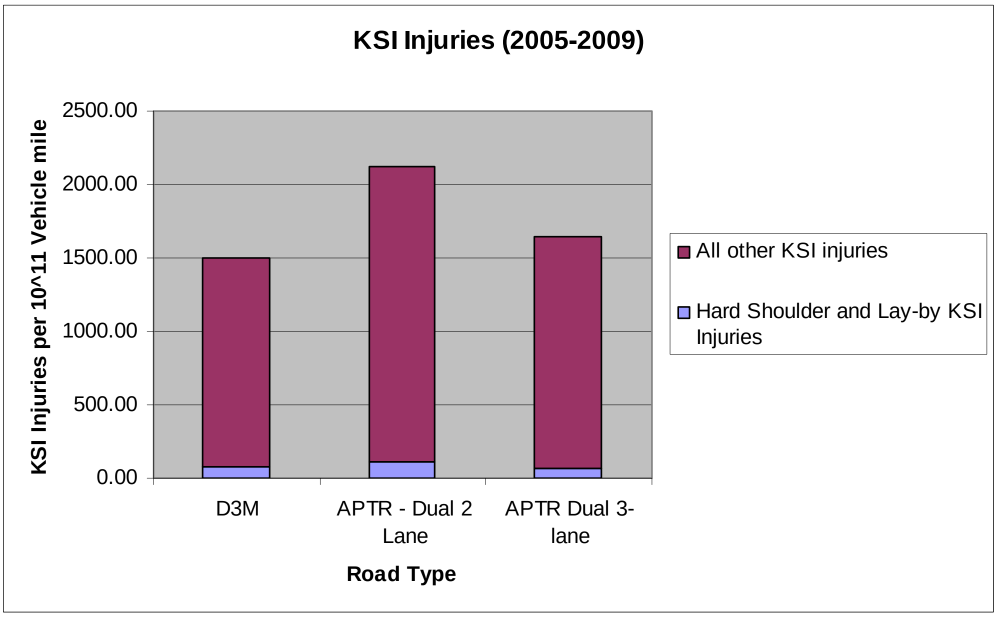
DfT traffic data	Dual M 3-lane	Dual A-2 lane	Dual A-3 lane
Length (miles)	1,331	1,416	98
Traffic (5 year total) (10^{11} veh-mile)	2.12	0.95	0.13
Average AADT	87,685	36,893	74,663
Hard Shoulder and Lay-by Accident and Casualty rate (per 10^{11} veh-mile)	**Dual M 3-lane**	**Dual A 2-lane**	**Dual A 3-lane**
Fatal accidents	16.9	27.3	14.9
Serious accidents	37.7	65.2	37.3
Fatal and Serious accidents	54.6	92.5	52.2
Slight accident	101.7	202.8	186.3
All accidents	156.3	295.3	238.5
	21.7	29.4	14.9
Killed	53.7	80.9	52.2
Seriously injured	75.3	110.4	67.1
Killed and Seriously Injured (KSI Casualties)	194.9	357.3	283.2
Slightly injured	270.2	467.7	350.2
All casualties	16.9	27.3	14.9
Hard Shoulder and Lay-by Accident and Casualty as a proportion of the total	**Dual M 3-lane**	**Dual A 2-lane**	**Dual A 3-lane**
Fatal accidents	8.1%	8.0%	5.7%
Serious accidents	3.8%	4.6%	3.4%
Killed and Seriously injured	4.6%	5.2%	3.9%
Slight accidents	1.2%	2.3%	2.4%
All accidents	1.7%	2.8%	2.6%
Killed	8.7%	7.8%	5.4%
Seriously injured	4.3%	4.6%	3.8%
Killed and Seriously Injured (KSI Casualties)	5.0%	5.2%	4.1%
Slightly injured	1.4%	2.5%	2.2%
All casualties	1.8%	2.8%	2.4%

The main conclusion to be drawn from Table 4.1-1 is that on D3M links Hard Shoulder/ Lay-by accidents account for approximately 8% of fatal accidents, and about 5% of KSI accidents. Similar proportions are experienced on Dual 2 Lane APTRs.

The proportion of total fatal and KSI accidents on Dual 3 Lane APTRs are slightly lower (5.7% and 3.9%). The KSI accident and casualty rates are illustrated in Figure 4.1-1. As Hard Shoulder/ lay-by accidents only account for about 2% of all personal injury accidents, it can be concluded that they have a higher severity than the norm for each road type, which probably comes about as result of large speed differentials (as one vehicle is stationary).

Figure 4.1-1: Hard Shoulder and Lay-by Accident and Casualty rates as a proportion of all accidents and casualties





4.2. Vehicles Parked in Lane Accident and casualty rates by road type

Table 4.2-1 presents vehicle parked in running lane accident and casualty rates (per vehicle mile) by road type.

Table 4.2-1: Vehicle parked in running lane accident and casualty rates

Parked and on main carriageway	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	13	18	4
Serious accidents	28	80	7
Fatal and Serious accidents	41	98	11
Slight accidents	152	255	28
All accidents	193	353	39
Killed	15	20	4
Seriously injured	36	96	10
Killed and Seriously Injured	51	116	14
Slightly injured	291	476	50
All casualties	342	592	64
Traffic (5 year total) (10^8 veh-mile)	2124.3	951.5	134.2
Fatal rate (per 10^{11} veh-mile)	6.1	18.9	29.8
Serious rate (per 10^{11} veh-mile)	13.2	84.1	52.1
Fatal and Serious rate (per 10^{11} veh-mile)	19.3	103	81.9
Slight rate (per 10^{11} veh-mile)	71.6	268	208.6
All accident rate (per 10^{11} veh-mile)	90.9	371	290.5
Killed rate (per 10^{11} veh-mile)	7.1	21	29.8
Seriously injured rate (per 10^{11} veh-mile)	16.9	100.9	74.5
Killed and Seriously Injured rate (per 10^{11} veh-mile)	24	121.9	104.3
Slightly injured rate (per 10^{11} veh-mile)	137	500.3	372.5
All casualty rate (per 10^{11} veh-mile)	161	622.2	476.7
As Percentage of All Accidents and Casualties			
Fatal accidents	2.9%	5.5%	11.4%
Serious accidents	1.3%	5.9%	4.8%
Fatal and Serious accidents	1.6%	5.8%	6.1%
Slight accidents	0.9%	3.0%	2.7%
All accidents	1.0%	3.5%	3.2%
Killed	2.8%	5.5%	10.8%
Seriously injured	1.4%	5.8%	5.5%
Killed and Seriously Injured	1.6%	5.7%	6.4%
Slightly injured	1.0%	3.5%	2.9%
All casualties	1.0%	3.8%	3.3%
By severity			
Fatal accidents	6.7%	5.1%	10.3%
Serious accidents	14.5%	22.7%	17.9%
Fatal and Serious accidents	21.2%	27.8%	28.2%
Slight accidents	78.8%	72.2%	71.8%
All accidents	100.0%	100.0%	100.0%
Killed	4.4%	3.4%	6.3%
Seriously injured	10.5%	16.2%	15.6%
Killed and Seriously Injured	14.9%	19.6%	21.9%
Slightly injured	85.1%	80.4%	78.1%
All casualties	100.0%	100.0%	100.0%

From Table 4.2-1 , it can be seen that vehicle parked in running lane accidents represent a higher proportion of KSI accidents on APTR network than on D3M links. Whereas they represent only 1.6% of KSI accidents on D3M links, they represent about 6% on APTR links. Also, on Dual 3 lane APTR links the severity ratio is high with 10.3% of these accidents involving a fatality.

In terms of rate per vehicle mile, the rate of KSI accidents on Dual 2 lane APTRs is just over 5 times higher than that encountered on D3M links (103 verses 19). The rate of KSI accidents on Dual 3 lane APTRs is just over 4 times higher than that encountered on D3M links (81.9 verses 19.3). These results would be expected as the APTRs do not have hard shoulders so it is far more likely that vehicles, when they forced to stop, will stop in the running lane.

4.3. Vehicle leaves carriageway accident and casualty rates by road type

Table 4.3-1 presents the accident and casualty rates (per vehicle mile) associated with single vehicles that leave the carriageway by road type.

Table 4.3-1: Accident and Casualty rates for vehicles that leave the carriageway

Single vehicle leaving carriageway nearside or nearside and rebounded	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	98	89	8
Serious accidents	419	311	37
Fatal and Serious Accidents	517	400	45
Slight accidents	1876	1492	154
All accidents	2,393	1,892	199
Killed	118	101	9
Seriously injured	548	392	47
Killed and Seriously Injured	666	493	56
Slightly injured	2,880	2,164	220
All casualties	3,546	2,657	276
Traffic (5 year total) (10^8 veh-mile)	2124.3	951.5	134.2
Fatal rate (per 10^{11} veh-mile)	46.1	93.5	59.6
Serious rate (per 10^{11} veh-mile)	197.2	326.8	275.6
Fatal and Serious Rate (per 10^{11} veh-mile)	243.3	420.3	335.2
Slight rate (per 10^{11} veh-mile)	883.1	1568	1147.2
All accident rate (per 10^{11} veh-mile)	1126.5	1988.4	1482.4
Killed rate (per 10^{11} veh-mile)	55.5	106.1	67
Seriously injured rate (per 10^{11} veh-mile)	258	412	350.1
Killed and Seriously Injured rate (per 10^{11} veh-mile)	313.5	518.1	417.1
Slightly injured rate (per 10^{11} veh-mile)	1355.7	2274.2	1638.8
All casualty rate (per 10^{11} veh-mile)	1669.3	2792.4	2055.9

As Percentage of All Accidents and Casualties	Dual M 3-lane	Dual A 2-lane	Dual A 3lane
Fatal accidents	22.1%	27.3%	22.9%
Serious accidents	20.1%	23.0%	25.3%
Fatal and Serious accidents	20.5%	23.8%	24.9%
Slight accidents	10.8%	17.6%	14.7%
All accidents	12.0%	18.6%	16.2%
Killed	22.3%	28.0%	24.3%
Seriously injured	20.6%	23.6%	25.7%
Killed and Seriously Injured	20.9%	24.4%	25.5%
Slightly injured	9.8%	15.9%	12.9%
All casualties	10.8%	17.0%	14.4%
By severity			
Fatal accidents	4.1%	4.7%	4.0%
Serious accidents	17.5%	16.4%	18.6%
Fatal and Serious accidents	21.6%	21.1%	22.6%
Slight accidents	78.4%	78.9%	77.4%
All accidents	100.0%	100.0%	100.0%
Killed	3.3%	3.8%	3.3%
Seriously injured	15.5%	14.8%	17.0%
Killed and Seriously Injured	18.8%	18.6%	20.3%
Slightly injured	81.2%	81.4%	79.7%
All casualties	100.0%	100.0%	100.0%

The main conclusion to be drawn from Table 4.3-1 is that the rate of accidents and casualties is higher on non D3M links. There may be a number of explanations for this that are not solely down to the absence of the Hard Shoulder. For example differences standards and geometry (especially on curves) may influence this rate.

4.4. Accidents with the contributory factor 'fatigue'

Table 4.4-1 presents accident and casualty rates (per vehicle mile) where 'fatigue' has been recorded as one of the contributory factors.

Table 4.4-1: Accidents and Casualties where fatigue was recorded as a factor

Accidents with fatigue as a contributory factor	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	70	27	2
Serious accidents	268	113	6
Fatal and Serious	338	140	8
Slight accidents	1016	414	39
All accidents	1354	554	47
Killed	90	32	2
Seriously injured	357	131	12
Killed and Seriously Injured	447	163	14
Slightly injured	1799	607	53
All casualties	2246	770	67
Traffic (5 year total) (10^8 veh-mile)	2124.3	951.5	134.2
Fatal rate (per 10^{11} veh-mile)	33	28.4	14.9
Serious rate (per 10^{11} veh-mile)	126.2	118.8	44.7
Fatal and Serious rate (per 10^{11} veh-mile)	159.2	147.2	59.6
Slight rate (per 10^{11} veh-mile)	478.3	435.1	290.5
All accident rate (per 10^{11} veh-mile)	637.4	582.2	350.1
Killed rate (per 10^{11} veh-mile)	42.4	33.6	14.9
Seriously injured rate (per 10^{11} veh-mile)	168.1	137.7	89.4
Killed and Seriously injured rate (per 10^{11} veh-mile)	210.5	171.3	104.3
Slightly injured rate (per 10^{11} veh-mile)	846.9	637.9	394.8
All casualty rate (per 10^{11} veh-mile)	1057.3	809.2	499.1

As Percentage of All Accidents and Casualties			
Fatal accidents	15.8%	8.3%	5.7%
Serious accidents	12.9%	8.3%	4.1%
Fatal and Serious accidents	13.4%	8.3%	4.4%
Slight accidents	5.9%	4.9%	3.7%
All accidents	6.8%	5.4%	3.8%
Killed	17.0%	8.9%	5.4%
Seriously injured	13.4%	7.9%	6.6%
Killed and Seriously Injured	14.0%	8.1%	6.4%
Slightly injured	6.1%	4.5%	3.1%
All casualties	6.9%	4.9%	3.5%
By severity			
Fatal accidents	5.2%	4.9%	4.3%
Serious accidents	19.8%	20.4%	12.8%
Fatal and Serious accidents	25.0%	25.3%	17.0%
Slight accidents	75.0%	74.7%	83.0%
All accidents	100.0%	100.0%	100.0%
Killed	4.0%	4.2%	3.0%
Seriously injured	15.9%	17.0%	17.9%
Killed and Seriously Injured	19.9%	21.2%	20.9%
Slightly injured	80.1%	78.8%	79.1%
All casualties	100.0%	100.0%	100.0%

From Table 4.4-1 it can be seen that fatigue was recorded as a factor in 16% of fatal accidents and 13.4% of KSI accidents on D3M links. (It should be noted that up to 6 contributory factors can be recorded for each accident so these figures indicate the proportion that satisfy this condition in some way). The rate for D3M links and Dual 2-lane APTR links are very similar. However the rate for Dual 3-lane APTR links is much lower, possibly due to the size of the dataset.

4.5. Accidents where at least one of the casualties involved was a pedestrian

Table 4.5-1 presents accident and casualty rates (per vehicle mile) where there was at least one pedestrian involved.

Table 4.5-1: Accidents and Casualties involving at least one Pedestrian

Pedestrian accidents	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	60	60	7
Serious accidents	44	72	6
Fatal and Serious accidents	104	132	13
Slight accidents	58	66	7
All accidents	162	198	20
Killed	65	61	7
Seriously injured	61	84	8
Killed and Seriously injured	126	145	15
Slightly injured	145	137	10
All casualties	271	282	25
Traffic (5 year total) (10^8 veh-mile)	2124.3	951.5	134.2
Fatal rate (per 10^{11} veh-mile)	28.2	63.1	52.1
Serious rate (per 10^{11} veh-mile)	20.7	75.7	44.7
Fatal and Serious rate (per 10^{11} veh-mile)	48.9	138.8	96.8
Slight rate (per 10^{11} veh-mile)	27.3	69.4	52.1
All accident rate (per 10^{11} veh-mile)	76.3	208.1	149
Killed rate (per 10^{11} veh-mile)	30.6	64.1	52.1
Seriously injured rate (per 10^{11} veh-mile)	28.7	88.3	59.6
Killed and Seriously rate (per 10^{11} veh-mile)	59.3	152.4	111.7
Slightly injured rate (per 10^{11} veh-mile)	68.3	144	74.5
All casualty rate (per 10^{11} veh-mile)	127.6	296.4	186.2

As Percentage of All Accidents and Casualties			
Fatal accidents	13.5%	18.4%	20.0%
Serious accidents	2.1%	5.3%	4.1%
Fatal and Serious accidents	4.1%	7.9%	7.2%
Slight accidents	0.3%	0.8%	0.7%
All accidents	0.8%	1.9%	1.6%
Killed	12.3%	16.9%	18.9%
Seriously injured	2.3%	5.1%	4.4%
Killed and Seriously Injured	4.0%	7.2%	6.8%
Slightly injured	0.5%	1.0%	0.6%
All casualties	0.8%	1.8%	1.3%

By severity	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	37.0%	30.3%	35.0%
Serious accidents	27.2%	36.4%	30.0%
Fatal and Serious accidents	64.2%	66.7%	65.0%
Slight accidents	35.8%	33.3%	35.0%
All accidents	100.0%	100.0%	100.0%
Killed	24.0%	21.6%	28.0%
Seriously injured	22.5%	29.8%	32.0%
Killed and Seriously Injured	46.5%	51.4%	60.0%
Slightly injured	53.5%	48.6%	40.0%
All casualties	100.0%	100.0%	100.0%

From Table 4.5-1 it can be seen that the pedestrian accident rate on 3-lane APTR links is about double that which would be encountered on D3M links. This is perhaps unsurprising as pedestrian access to the APTR network is not as restricted as it is for the Motorway network.

The following tables show in more detail the pedestrian location and movement associated with each pedestrian accident on the D3M network and on multi-lane APTR links (i.e. 2-lane and 3-lane APTR combined).

Table 4.5-2: Dual 3-lane motorway Pedestrian Accidents by movement and location

Dual 3 lane Motorway / Pedestrian: Movement	Pedestrian: Location						
	In c'way, crossing elsewhere	On footway or verge	On refuge, central island or central reservation	In centre of c'way, not on refuge, island or central reservation	In c'way, not crossing	Unknown or other	Total
Crossing from driver's nearside	21			5		1	27
Crossing from driver's offside	12		1	2			15
Crossing from driver's offside - masked by parked or stationary vehicle	1						1
In c'way, stationary - not crossing (standing or playing)			5	3	27		35
In c'way, stationary - not crossing (standing or playing), masked by parked or stationary vehicle					3	2	5
Walking along in c'way-facing traffic			2	2	5	2	11
Walking along in c'way-back to traffic				2	6	1	9
Unknown or other	6	6	3	5	27	34	81
Total	40	6	11	19	68	40	184

Dual 3 lane Motorway	Pedestrian: Location						
Pedestrian: Movement (Percentage of Total)	**In c'way, crossing elsewhere**	**On footway or verge**	**On refuge, central island or central reservation**	**In centre of c'way, not on refuge, island or central reservation**	**In c'way, not crossing**	**Unknown or other**	**Total**
Crossing from driver's nearside	11.41			2.72		0.54	14.67
Crossing from driver's offside	6.52		0.54	1.09			8.15
Crossing from driver's offside - masked by parked or stationary vehicle	0.54						0.54
In c'way, stationary - not crossing (standing or playing)			2.72	1.63	14.67		19.02
In c'way, stationary - not crossing (standing or playing), masked by parked or stationary vehicle			0.00		1.63	1.09	2.72
Walking along in c'way-facing traffic			1.09	1.09	2.72	1.09	5.98
Walking along in c'way-back to traffic				1.09	3.26	0.54	4.89
Unknown or other	3.26	3.26	1.63	2.72	14.67	18.48	44.02
Total							100

Traffic (5 year total) (10^8 veh-mile)	2124.3

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Dual 3 lane Motorway	**Pedestrian: Location**						
Pedestrian: Movement (per 10^8 veh-mile)	**In c'way, crossing elsewhere**	**On footway or verge**	**On refuge, central island or central reservation**	**In centre of c'way, not on refuge, island or central reservation**	**In c'way, not crossing**	**Unknown or other**	**Total**
Crossing from driver's nearside	0.010			0.002		0.000	0.013
Crossing from driver's offside	0.006		0.000	0.001			0.007
Crossing from driver's offside - masked by parked or stationary vehicle	0.000						0.000
In c'way, stationary - not crossing (standing or playing)			0.002	0.001	0.013		0.016
In c'way, stationary - not crossing (standing or playing), masked by parked or stationary vehicle			0.000		0.001	0.001	0.002
Walking along in c'way-facing traffic			0.001	0.001	0.002	0.001	0.005
Walking along in c'way-back to traffic				0.001	0.003	0.000	0.004
Unknown or other	0.003	0.003	0.001	0.002	0.013	0.016	0.038
Total	0.019	0.003	0.005	0.009	0.032	0.019	0.087

Table 4.5-3 : Multi-lane A-road Pedestrian Accidents by movement and location

Multi lane A-roads	Pedestrian: Location									
Pedestrian: Movement	In c'way crossing on ped crossing facility	In c'way crossing within zig-zag lines at crossing approach	In c'way, crossing elsewhere within 50m of ped crossing	In c'way, crossing elsewhere	On footway or verge	On refuge, central island or central reservation	In centre of c'way, not on refuge, island or central reservation	In c'way, not crossing	Un-known or other	Total
Crossing from driver's nearside	4		4	31		1	7			47
Crossing from driver's nearside-masked by parked or stationary vehicle	1			3			1			5
Crossing from driver's offside	3	1	1	25		3	3			36
Crossing from driver's offside - masked by parked or stationary vehicle				2						2
In c'way, stationary - not crossing (standing or playing)					3		3	32		38
In c'way, stationary - not crossing (standing or playing), masked by parked or stationary vehicle								9		9
Walking along in c'way-facing traffic					2			10		12
Walking along in c'way-back to traffic						1	5	19		25
Unknown or other				7	20	2	1	25	20	75
Total	8	1	5	68	25	7	20	95	20	249

Multi lane A-roads	Pedestrian: Location									
Pedestrian: Movement	**In c'way crossing on ped crossing facility**	**In c'way crossing within zig-zag lines at crossing approach**	**In c'way, crossing elsewhere within 50m of ped crossing**	**In c'way, crossing elsewhere**	**On footway or verge**	**On refuge, central island or central reservation**	**In centre of c'way, not on refuge, island or central reservation**	**In c'way, not crossing**	**Un-known or other**	**Total**
Crossing from driver's nearside	1.61		1.61	12.45		0.40	2.81			18.88
Crossing from driver's nearside-masked by parked or stationary vehicle	0.40			1.20			0.40			2.01
Crossing from driver's offside	1.20	0.40	0.40	10.04		1.20	1.20			14.46
Crossing from driver's offside - masked by parked or stationary vehicle				0.80						0.80
In c'way, stationary - not crossing (standing or playing)					1.20		1.20	12.85		15.26
In c'way, stationary - not crossing (standing or playing), masked by parked or stationary vehicle								3.61		3.61
Walking along in c'way-facing traffic					0.80			4.02		4.82
Walking along in c'way-back to traffic						0.40	2.01	7.63		10.04
Unknown or other				2.81	8.03	0.80	0.40	10.04	8.03	30.12
Total	3.21	0.40	2.01	27.31	10.04	2.81	8.03	38.15	8.03	100.00

Traffic (5 year total) (10^8 veh-mile)	1087

Multi lane A-roads	Pedestrian: Location									
Pedestrian: Movement	In c'way crossing on ped crossing facility	In c'way crossing within zig-zag lines at crossing approach	In c'way, crossing elsewhere within 50m of ped crossing	In c'way, crossing elsewhere	On footway or verge	On refuge, central island or central reservation	In centre of c'way, not on refuge, island or central reservation	In c'way, not crossing	Un-known or other	Total
Crossing from driver's nearside	0.004		0.004	0.029		0.001	0.006			0.043
Crossing from driver's nearside-masked by parked or stationary vehicle	0.001			0.003			0.001			0.005
Crossing from driver's offside	0.003	0.001	0.001	0.023		0.003	0.003			0.033
Crossing from driver's offside - masked by parked or stationary vehicle				0.002						0.002
In c'way, stationary - not crossing (standing or playing)					0.003		0.003	0.029		0.035
In c'way, stationary - not crossing (standing or playing), masked by parked or stationary vehicle								0.008		0.008
Walking along in c'way-facing traffic					0.002			0.009		0.011
Walking along in c'way-back to traffic						0.001	0.005	0.017		0.023
Unknown or other				0.006	0.018	0.002	0.001	0.023	0.018	0.069
Total	0.01	0.00	0.00	0.06	0.02	0.01	0.02	0.09	0.02	0.23

The data presented in Table 4.5-2 and Table 4.5-3 is somewhat limited by a relatively large proportion of unknown pedestrian movements and locations. However, as a general conclusion, with regard to accidents where the pedestrian is walking along the carriageway, the rate of accidents on the APTR network is about 3 times that on the D3M network. Again, this could be a consequence of easier pedestrian access to the APTR network.

4.6. Accidents where a vehicles hit an object (debris)

Table 4.6-1 presents accident and casualty rates (per vehicle mile) where an object on the carriageway was struck.

Table 4.6-1: Accidents and Casualties involving an object on the carriageway

Hit object in carriageway	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	19	8	1
Serious accidents	42	25	
Fatal and Serious accidents	61	33	1
Slight accidents	270	185	18
All accidents	331	218	19
Killed	22	8	1
Seriously injured	55	29	
Killed and Seriously Injured	77	37	1
Slightly injured	494	273	29
All casualties	571	310	30
Traffic (5 year total) (10^8 veh-mile)	2124.3	951.5	134.2
Fatal rate (per 10^{11} veh-mile)	8.9	8.4	7.4
Serious rate (per 10^{11} veh-mile)	19.8	26.3	0
Fatal and Serious rate (per 10^{11} veh-mile)	28.7	34.7	7.4
Slight rate (per 10^{11} veh-mile)	127.1	194.4	134.1
All accident rate (per 10^{11} veh-mile)	155.8	229.1	141.5
Killed rate (per 10^{11} veh-mile)	10.4	8.4	7.4
Seriously injured rate (per 10^{11} veh-mile)	25.9	30.5	0
Killed and Seriously Injured (per 1011 veh-mile)	36.3	38.9	7.4
Slightly injured rate (per 10^{11} veh-mile)	232.5	286.9	216
All casualty rate (per 10^{11} veh-mile)	268.8	325.8	223.5

As Percentage of All Accidents and Casualties			
Fatal accidents	4.3%	2.5%	2.9%
Serious accidents	2.0%	1.8%	0.0%
Fatal and Serious accidents	2.4%	2.0%	0.6%
Slight accidents	1.6%	2.2%	1.7%
All accidents	1.7%	2.1%	1.5%
Killed	4.2%	2.2%	2.7%
Seriously injured	2.1%	1.7%	0.0%
Killed and Seriously Injured	2.4%	1.8%	0.5%
Slightly injured	1.7%	2.0%	1.7%
All casualties	1.7%	2.0%	1.6%

By severity	Dual M 3-lane	Dual A 2-lane	Dual A 3lane
Fatal accidents	5.7%	3.7%	5.3%
Serious accidents	12.7%	11.5%	0.0%
Fatal and Serious accidents	18.4%	15.1%	5.3%
Slight accidents	81.6%	84.9%	94.7%
All accidents	100.0%	100.0%	100.0%
Killed	3.9%	2.6%	3.3%
Seriously injured	9.6%	9.4%	0.0%
Killed and Seriously Injured	13.5%	11.9%	3.3%
Slightly injured	86.5%	88.1%	96.7%
All casualties	100.0%	100.0%	100.0%

The rate of accidents on 2-lane APTR links is slightly higher than that on D3M links. (The rate of KSI injury is virtually the same.) However, the rate on 3-lane APTR links is considerably lower, possibly due to the small sample size. The data suggests that there is no reason to believe that the debris related accident rates on APTR links are substantially worse than those experienced on D3M links.

4.7. Accidents involving Motorcycles

Table 4.7-1 presents accident and casualty rates (per vehicle mile) where a motorcycle (PTW = Powered Two Wheeler) was involved.

Table 4.7-1: Accidents and Casualties involving a Motorcycle (PTW)

PTW accidents	Dual M 3-lane	Dual A 2-lane	Dual A 3-lane
Fatal accidents	39	30	6
Serious accidents	263	216	28
Fatal and Serious accidents	302	246	34
Slight accidents	449	320	47
All accidents	751	566	81
Killed	40	30	6
Seriously injured	277	233	32
Fatal and Serious accidents	317	263	38
Slightly injured	596	434	54
All casualties	913	697	92
(All vehicle type) Traffic (5 year total) (10^8 veh-mile)	2124.3	951.5	134.2
Fatal rate (per 10^{11} veh-mile)	18.4	31.5	44.7
Serious rate (per 10^{11} veh-mile)	123.8	227	208.6
Fatal and Serious rate (per 10^{11} veh-mile)	142.2	258.5	253.3
Slight rate (per 10^{11} veh-mile)	211.4	336.3	350.1
All accident rate (per 10^{11} veh-mile)	353.5	594.8	603.4
Killed rate (per 10^{11} veh-mile)	18.8	31.5	44.7
Seriously injured rate (per 10^{11} veh-mile)	130.4	244.9	238.4
Killed and Seriously injured rate (per 10^{11} veh-mile)	149.2	276.4	283.1
Slightly injured rate (per 10^{11} veh-mile)	280.6	456.1	402.3
All casualty rate (per 10^{11} veh-mile)	429.8	732.5	685.3

As Percentage of All Accidents and Casualties	Dual M 3-lane	Dual A 2-lane	Dual A 3lane
Fatal accidents	8.8%	9.2%	17.1%
Serious accidents	12.6%	15.9%	19.2%
Fatal and Serious accidents	12.0%	14.6%	18.8%
Slight accidents	2.6%	3.8%	4.5%
All accidents	3.8%	5.6%	6.6%
Killed	7.6%	8.3%	16.2%
Seriously injured	10.4%	14.0%	17.5%
Killed and Seriously Injured	9.9%	13.0%	17.3%
Slightly injured	2.0%	3.2%	3.2%
All casualties	2.8%	4.5%	4.8%
By severity			
Fatal accidents	5.2%	5.3%	7.4%
Serious accidents	35.0%	38.2%	34.6%
Fatal and Serious accidents	40.2%	43.5%	42.0%
Slight accidents	59.8%	56.5%	58.0%
All accidents	100.0%	100.0%	100.0%
Killed	4.4%	4.3%	6.5%
Seriously injured	30.3%	33.4%	34.8%
Killed and Seriously Injured	34.7%	37.7%	41.3%
Slightly injured	65.3%	62.3%	58.7%
All casualties	100.0%	100.0%	100.0%

The data suggests that the rate of accidents on multi-lane APTR links is nearly twice that experienced on D3M links. There are a number of possible explanations for this including differing geometric standards on the APTR network and the possibility that the APTR is being used more for leisure trips.

4.8. Summary of Risk profile for Road types

Table 4.8-1 compares the KSI accident rates on D3M links with Dual 2-lane and Dual 3 lane APTR links for the key accident types identified in this report. The top half of the table compares the accident rates. For example, the rate of ‘Fatigue’ related accidents on D3M links is 159.20 (per 10^{11} vehicle mile) while on dual 2 lane APTR links it is 147.2 and on dual 3 lane APTR links it is 59.6. A red triangle pointing upwards means that rate is higher than that encountered on a D3M link. For example, 4 red triangles indicates that the rate is four times higher. Downward pointing green arrows indicates that rate is lower than that encountered on D3M links.

The bottom half of Table 4.8-1 shows the percentage of accidents that fall within each key accident category in comparison with the D3M percentage.

Table 4.8-1: Differences in KSI accidents for selected accident types when compared with D3M links

KSI Accidents	Dual M 3-lane	Dual A 2-lane		Dual A 3-lane	
All	1185.154	1762.936		1349.361	
Hard Shoulder / Lay-bys Accidents	54.606	92.486	▲	52.161	
Vehicle parked on the main carriageway	19.300	103.000	▲▲▲▲▲	81.900	▲▲▲▲
Vehicle left the carriageway	243.300	420.300	▲	335.200	◢
'Fatigue' As a factor	159.200	147.200		59.600	▼▼▼
Pedestrian	48.900	138.800	▲▲	96.800	▲
Debris	28.700	34.700		7.400	▼▼▼▼
Motorcyclist	142.200	258.500	◢	253.300	◢

KSI Accidents	Dual M 3-lane	Dual A 2-lane		Dual A 3-lane	
All - KSI	100.000	148.752		113.855	
Hard Shoulder / Lay-bys Accidents	4.608	7.804	▲	4.401	
Vehicle parked on the main carriageway	1.628	8.691	▲▲▲▲▲	6.910	▲▲▲▲
Vehicle left the carriageway	20.529	35.464	▲	28.283	◢
'Fatigue' As a factor	13.433	12.420		5.029	▼▼▼
Pedestrian	4.126	11.712	▲▲	8.168	▲
Debris	2.422	2.928		0.624	▼▼▼▼
Motorcyclist	11.998	21.812	◢	21.373	◢

The main conclusions to draw from the above are that in comparison with D3M links, APTR links are characterised by:

- A four to five fold increase in the frequency of vehicle parked in main carriageway accidents.
- An increase in the frequency of accidents involving vehicles leaving the carriageway
- No increase in the frequency of fatigue related accidents
- An increase in frequency of Pedestrian accident
- No increase in the frequency of Debris related accidents
- An increase in the frequency of accidents involving a motorcycle.

It is likely that the frequency of vehicle parked in main carriageway and vehicles leaving the carriageway accidents are related to the loss of the Hard Shoulder. However, it is likely that most of the increase in the frequency of pedestrian accidents is due to different levels of access to the road. The reason for the increase in frequency of Motorcycle accidents is less clear and may be due to a number of factors including differences in geometry between these types of road.

4.9. Analysis of data on selected 3-lane APTR links

In order to better understand the impact of the removal of the Hard Shoulder a more detailed analysis has been undertaken on three sections of roads which are known to have three lanes without a hard shoulder or substantial hard strip.

The three specified sections are:-

- A3 – Stoke Interchange to Stratford Bridge
- A23 – M23 Junction 11 to Handcross
- A46 – Junction with A249/B4115 to Junction with A45

The purpose of this analysis is to identify in more detail the types of accident and casualty that would be expected to occur on these roads and whether or not they differ from 3DM links as a whole. This should also help identify areas where further mitigation of risk may be required.

4.10. Analysis of A3 accidents

The A3 is a busy commuter route that runs from the South West of London to Portsmouth. Between the Junction with the M25 and Stratford Bridge the carriageway is three-lanes in each direction. This section is unlit. A summary of the non junction accidents and casualties from the Stoke inter-change (just south of the M25 interchange) and Stratford Bridge is presented in Table 4.10-1.

Table 4.10-1: Summary of non-junction accidents and casualties on the A3 Stoke Interchange to Stratford Bridge

PIA Summary	2005	2006	2007	2008	2009	Total	PIA/100 Million Vehicle Mile by severity
Fatal	3	1		1		5	0.35
Serious	3	2	3	4	1	13	0.91
Slight	30	26	23	16	18	113	7.94
Total	36	29	26	21	19	131	9.21

Casualty Summary	2005	2006	2007	2008	2009	Total	Casualties per 100 Million Vehicle Mile by severity
Fatal	3	1		1		5	0.35
Serious	6	5	6	4	1	22	1.55
Slight	58	39	35	29	30	191	13.43
Total	67	45	41	34	31	218	15.32

PIAs	Fatal	Serious	Slight	Total
Fatigue Related	0	0	9	9
Pedestrian Related	1	0	0	1
Leaving C/W				29
Parked + On C/W	0	0	1	1
Parked in Layby/HS	1	0	5	6
Entering Layby/HS	0	0	0	0
Exiting Layby/HS	0	0	1	1

The frequencies of accidents and casualties are similar to those that would be encountered on a D3M link. Only one of the accidents involved a vehicle parked on the carriageway. Only one other accident involved a pedestrian (who was associated with another parked vehicle although that vehicle was not hit, i.e. the pedestrian was some distance from the parked vehicle).

The 3-lane APTR rate for PIAs involving vehicles parked on the carriageway is 290 per 10^{11} vehicle mile (see Table 4.2-1) The volume of flow during the five year period covered by the accident data is calculated to be $14.22*10^{8}$ vehicle miles. Using these figures, there would be expected to be 4 accidents of this type.

If the D3M rate is used (91 per 10^{11} vehicle mile) there would be expected to be between 1 and 2 accidents.

Although actual numbers are low, they do suggest that vehicle parked in carriageway accidents do not make up a large proportion of the accidents encountered on this link, even though the hard shoulder is not present.

Using data from Table 4.5-2, it would be expected that there would be 2 pedestrian accidents. Again the numbers involved are low.

4.11. Analysis of A23 accidents

The three lane section of the A23 extends 1.8 miles south of M23 Junction 11. It is unusual in that there is only one diverge exit on this section (approximately halfway along the link on the southbound carriageway). It is characterised by being straight and relatively featureless. The section is also lit.

Accident and Casualty Statistics for this section are as presented in Table 4.11-1.

Table 4.11-1: Summary of non-junction accidents and casualties on the A23

PIA Summary	2005	2006	2007	2008	2009	Total	PIA/million Veh Mile by severity
Fatal	0	0	0	0	0	0	0.00
Serious	2	0	0	1	0	3	1.28
Slight	1	4	2	4	2	13	5.55
Total	3	4	2	5	2	16	6.83

Casualty Summary	2005	2006	2007	2008	2009	Total	Casualties per Million Veh Mile by severity
Fatal	0	0	0	0	0	0	0.00
Serious	3	0	0	1	0	4	1.71
Slight	8	5	2	12	2	29	12.39
Total	11	5	2	13	2	33	14.10

PIAs	Fatal	Serious	Slight	Total
Fatigue Related	0	0	1	1
Pedestrian Related	0	0	0	0
Leaving C/W	0	1	5	6
Parked + On C/W	0	0	0	0
Parked in Layby/HS	0	0	0	0
Entering Layby/HS	0	0	0	0
Exiting Layby/HS	0	0	0	0

From the above analysis it can be seen that the rate of accidents and casualties is lower than average. This suggests that a multi-lane APTR without a hard shoulder can perform well as long as the geometry is similar to that associated with D3M links. As can be seen from the data presented above, there have been no pedestrian or 'parked in carriageway' accidents during the 5 year period. It should be noted that based on parked vehicle accident rates recorded for the 3-lane APTR network as a whole, there would be expected to be 1 accident of this type. Based on exposure rates there would be expected to be 0.68 accidents. Therefore, given the expected numbers of accidents, it is not surprising that no accidents of this type have been encountered.

It should be noted that 6 out of the 16 accidents involved a vehicle leaving the carriageway.

4.12. Analysis of A46 accidents

The A46 connects Coventry with the M40 at Junction 15. Between the Junction with A249/B4115 and the Junction with A45 it is an unlit 3-lane APTR. The flow levels are slightly less than those encountered on the A3. It is also characterised by a number of minor accesses and lay-bys at regular intervals.

Table 4.12-1: Summary of non-junction accidents and casualties on the A46

PIA Summary	2005	2006	2007	2008	2009	Total	PIA per million Vehicle Mile by severity
Fatal	1	0	0	1	0	2	0.31
Serious	2	0	0	2	2	6	0.93
Slight	11	12	14	9	12	58	9.01
Total	14	12	14	12	14	66	10.25

Casualty Summary	2005	2006	2007	2008	2009	Total	casualties per million vehicle mile by severity
Fatal	1	0	0	1	0	2	0.31
Serious	3	0	0	2	2	7	1.09
Slight	20	18	28	18	19	103	16.00
Total	24	18	28	21	21	112	17.40

PIAs	Fatal	Serious	Slight	Total
Fatigue Related	0	1	4	5
Pedestrian Related	2	2	1	5
Leaving C/W	0	3	37	40
Parked + On C/W	0	0	4	4
Parked in Layby/HS	0	0	0	0
Entering Layby/HS	0	0	0	0
Exiting Layby/HS	0	0	0	0

The overall frequency of accidents and casualties on this section is slightly higher than that observed on D3M links. Four of the accidents involved vehicles parked on the carriageway and 5 involved pedestrians.

The flow volume during this five year period is 643million vehicle miles. Using the same approach as used previously, there would be expected to be between 2 and 3 vehicle parked in carriageway accidents and about one pedestrian accident.

Examination of the details associated with the accidents involving vehicles parked in the carriageway revealed that three were definitely associated with the lack of a hard shoulder (one was a breakdown, another was a vehicle running out of fuel and the third was a vehicle stopped to assist at a previous accident). Details of the fourth accident were not sufficiently detailed to draw a conclusion. Although the rate of accidents is slightly higher than expected, it is not an order of magnitude higher.

Of more interest is the relatively high frequency of pedestrian accidents and whether or not the lack of a hard shoulder was an influencing factor. Analysis of these accidents indicates that two were suspected suicides, one involved an intoxicated pedestrian and one involved crossing the road. There was a lack of detail on the last accident to draw any conclusions. However, this more detailed analysis (eliminating non-relevant pedestrian accidents) suggests that the frequency of pedestrian accidents is similar to that which would be expected.

4.13. Overall conclusion of the Accident Analysis of selected APTR links

The analysis of the accident and casualty data collected from the three selected APTR links suggests that 3-lane APTR links are capable of performing at a level of safety comparable with D3M links with similar geometry.

5. Risk profile Comparison

The purpose of this part of the work is to compare the risk profile of a number of different scenarios. Each of these progressively adds a certain fundamental change or level of control over the previous scenario.

The scenarios being compared are:

- 3-lane All Purpose Trunk Road
- D3M without MIDAS queue protection – 'the Baseline'
- D3M with MIDAS queue protection
- D4M without a hard shoulder or MIDAS, i.e. a simple conversion of the hard shoulder to a running lane without further mitigation
- D4M without a hard shoulder but with MIDAS fitted
- A generic MM-ALR design with the element as outlined in Figure 3.1-1
- M42 Active Traffic Management Pilot

In order to carry out this work a number of tasks have been carried out:

- Identification of the hazards that are applicable to the scenarios outlined above.
- Definition of what is meant by a 'generic' D3M link without MIDAS
- Assignment of Risk Scores to hazards that are applicable to the 'generic' D3M link without MIDAS (see Appendix C of the Demonstration of meeting the safety objective report for a description of the scoring mechanism used)
- Agreement/verification of the assumptions and Risk Scores applicable to a 'generic' D3M link without MIDAS
- Determination of the change in Risk Score that would result from implementing the various scenarios outlined above

The bulk of the tasks identified above are reported in the Demonstration of meeting the safety objective report [5]. Therefore, the purpose of this section is to provide some supplementary information with regard to a number of key (potentially high scoring) hazards.

These are:

- Driver falls asleep (Fatigue, lapses of concentration etc)
- Pedestrian in running lane live traffic
- Pedestrian walking along the carriageway
- Vehicle stops on the hard shoulder
- Vehicle stops in running lane

5.1. Driver falls asleep (Fatigue, lapses of concentration etc)

From Section 4.4 it has been confirmed that on D3M link it can be seen that Fatigue was recorded as a contributory factor in 16% of fatal accidents and 13.4% of KSI accidents on D3M links. Therefore, the overall level of accidents is similar to that anticipated. A risk score of E09 has been assigned to this hazard within the hazard log which is consistent with the above score.

It is noted that multi-lane APTRs have fatigue rates that are lower then those experienced on D3M links. Therefore, it is not expected that the removal of the hard shoulder will in itself lead to an increase in fatigue related accidents.

5.2. Pedestrian in running lane - live traffic

Section 4.5 provides information on what action the pedestrian was taking before the accident.

The information presented in Section 4.5 suggests that Pedestrians accounts for 4.12% of all KSI accidents on D3M links (104 out of 2524 KSI accidents involved a pedestrian). The risk score for Pedestrian in running lane – live traffic within the Hazard log was calculated as E08.5. This represents about 6% of overall risk.

Section 4.5 also suggests that the rate of accidents on the APTR network is about 3 times that on the D3M network (although this could be a consequence of easier pedestrian access to the APTR network). This gives an indication of the potential change in pedestrian accidents before to after without mitigation.

5.3. Pedestrian walking along the carriageway

Accidents involving pedestrians make up 13.5% of fatal accidents on D3M links. They also account for 4% of KSI accidents. Pedestrian related hazards in their entirety make up 8.5% of the before scheme risk. Therefore the risk is consistent with the data collected from D3M links.

With regard to the specific risk involving pedestrians walking along the carriageway (whether that is the Hard Shoulder or verge), it is estimated that they account for no more than 10% of the total pedestrian risk (based on 20 out of 182 pedestrian accidents associated with pedestrians walking along the carriageway). This would mean that the risk for these hazards should be about 0.8%. (which matches the initial assessment).

With regard to the after risk it is likely that without mitigation there could be an up to 3-fold increase in risk. This corresponds to an index change of 0.5.

5.4. Vehicle stopped on the hard shoulder

From Section 4.1 Hard Shoulder accidents account for about 5% of all KSI casualties on D3M links. The risk score for this hazard within the Hazard log was calculated as S08.0. This represents 2.1% of overall risk (if Events are weighted the same as States).

Consideration could be taken to changing the risk score to 8.5 (representing 6.5% of the scheme risk). However, this hazard is eliminated after MM-ALR is implemented. Therefore, over-representing it in the 'before' case would lead to an over-representation of the benefit (of removing the hazard) in the after case. Therefore the risk score has been kept at S08.0 in the before case.

5.5. Vehicle Stops in running lane

Vehicle stops in running lane is a key hazard within the hazard assessment, and therefore needs to be risk scored as accurately as possible. Refer to "Demonstration of meeting safety objective report" for details of the hazard scoring

5.5.1. Understanding this hazard on dual 3-lane motorways

The associated accident (Vehicle parked in running Lane) represents the following proportions of all accidents and casualties by severity on D3M links:

- 1.6% of all fatal and serious accidents
- 1.6% of all killed and seriously injured casualties

The KSI ratio (the proportion of all personal injury accidents/casualties that are fatal/serious accidents/casualties) for "Vehicle parked in running lane" are:

- Accidents = 0.21
- Casualties = 0.15

In comparison for D3M links:

- Accidents = 0.13
- Casualties = 0.10

That is, "Vehicle parked in running lane" have a higher severity of accident/casualty when compared with the average for D3M links.

The table below provides information about the proportion of these accidents that occur during peak and off peak and the KSI ratios peak and off-peak.

	Proportion (All accidents)	Number of KSI	Proportion of KSI accidents	KSI ratio - Accidents
Peak	0.34	16	0.39	0.24
Off-Peak	0.66	25	0.61	0.19

The key facts obtained from the above analysis are:

- They are more likely to happen off-peak rather than peak
- The KSI ratio off-peak is less than the KSI ratio peak.

5.5.2. Determining the hazard frequency

The frequency of lane closures is used as a proxy to estimate the frequency with which vehicles might be forced to stop suddenly.

The 'number of lane closures per day per motorway mile' is assumed to be 0.22. Therefore the number of lane closures per year = 0.22*365 = 80.3 (Rounded to 80).

Analysis of the Command and Control data for the M4 had identified that the daily profile for the frequency of these causes is as shown in Figure 5.5.2-1.

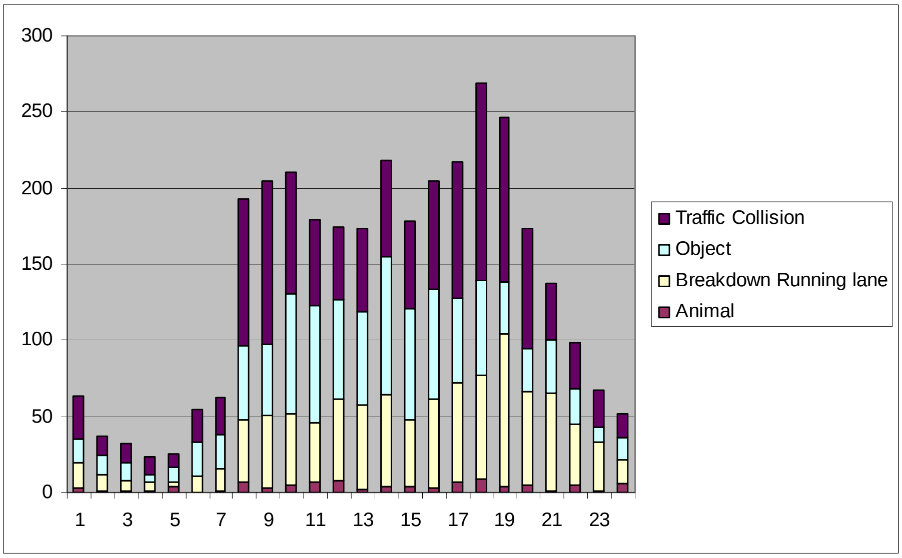


Figure 5.5.2-1: Frequency of causes leading to vehicle parked in carriageway

From this it can be assumed that the Frequency of the underlying hazard is proportional to flow (as the above plot mirrors the flow profile on the M4).

Assuming 60% of the flow during the peak, the frequency of the underlying hazard is:

- Peak: 48
- Off Peak: 32

In terms of Frequency index (see Appendix C), this equates to:

- Peak: 4.68
- Off Peak: 4.51

If however, the hazard is scored as a State, the 'Frequency' is as follows for the off-peak:

Number of occurrences: 32, Assume present for 1 hour each = 32 hours per year which equates to frequency index score closest to 3.5 (between probable and occasional)

5.5.3. Determining the hazard probability

This hazard is not always considered to result in a collision. For example, in the case of a vehicle fault, the vehicle does not usually stop suddenly, so drivers immediately behind have time to react. The following vehicle will be warned by observing vehicle brake lights, which may be supplemented by the use of hazard lights. Assumed to be Occasional (2.0)

As noted above there are more vehicle parked in carriageway accidents off-peak than peak (1.56 as many). Assuming that the frequency is proportional to flow, then it is likely that the hazard probability off peak is higher than that peak: Assuming that it is 1 for peak, the off-peak probability is 2.35 times higher.

However, the probability scores use a logarithmic scale. A score of 1.5 represents 3 times the probability score 1.

Therefore the hazard probability for peak and off peak can be different by 0.5.

Assume:

- Peak probability value of 1.5
- Off Peak Probability value of 2

5.5.4. Determining the hazard severity

This hazard is one of the most common causes of collisions on the motorway where there is a high speed differential.

The KSI ratio off-peak is lower than the KSI ratio peak. However, is still of the same order. Therefore, assume that there is no difference with regard to the hazard severity off peak. Comparing the KSI ratios with D3M accidents as a whole the severity of Vehicle Parked in carriageway accidents is 60% greater. This suggests a higher than average severity index of 1.5, but not 2 (as the difference in severity does not justify this value)

The above calculations suggest the following risk scores for this hazard:

- Peak : E4.68+1.5+1.5 = 7.68
- Off Peak (if hazard is considered an Event) : E4.51+2+1.5 = 8.01
- Off Peak (if hazard is considered a State) : S3.5+2+1.5 = 7.00

Given the difference in score when treating this hazard an Event or State, the decision has been taken to consider this hazard as an Event in all subsequent calculations.

5.5.5. Reality check

The ‘peak’ risk component of this hazard represents 1.01% of the baseline D3M risk and the ‘off-peak’ component 2.16% of the baseline D3M risk. Data from D3M links (see Section 3.4.1 indicates that they combined represent about 1.6% of all KSI accidents. Therefore, the calculated values are slightly higher than reality, but appropriate for use within the hazard log.

5.6. Hazards Affecting Road Workers

There are a number of different types of road workers on the Highways Agency’s network:

- On-road Traffic Officer (TO) patrols
- Managing Agent Contractor (MAC) Incident Support Units
- MAC, Technology Managing Agent Contractor (TechMAC) and NRTS staff (and other contractors) undertaking inspection and maintenance work
- Highways Agency’s own vehicle recovery service.

In addition the Emergency Services and Recovery Organisations work on the Highways Agency’s network.

Every year a number of people die and suffer serious injury while working on the Strategic Road Network. The Highways Agency considers this to be unacceptable and hence has introduced the strategy “Aiming for Zero”. This will be an important consideration in the development of MM-ALR and its impact on road workers. Table 5.6-1 shows the number of pedestrians injured at roadworks on the entire Highways Agency network. This can be compared with the total number of accidents on the D3M network (

Table 5.6-2). The datasets do not entirely match (one covers 2004-2008 and the other 2005-2009), however they suggest that fatal accidents involving road workers account for about 1% of all fatal accidents.

Table 5.6-1: Number of pedestrian accidents and casualties at motorways roadworks, from Accidents on the Network 2008

Road type	Accident severity	Casualty injury	2004	2005	2006	2007	2008	Total
Motorways	fatal accident	fatal injury	1	2	0	1	0	4
		serious injury	1	0	0	0	2	3
		slight injury	0	0	0	0	2	2
	serious accident	serious injury	1	0	2	1	2	6
		slight injury	0	0	0	0	0	0
	slight accident	slight injury	5	2	6	5	4	22

Table 5.6-2 : Number of accidents on the D3M network

All Accidents and Casualties (2005-2009)	Dual M 3-lane
Fatal accidents	444
Serious accidents	2,080
Fatal and Serious Accidents	2,524

Slight accidents	17,357
All accidents	19,881

In the hazard log maintenance related hazards represent at least 5% of the risk – representing the importance that is given to this group. It also takes account of the fact that accidents at roadworks also lead to fatalities and injuries to the general public.

An initial review of road worker related hazards has been undertaken and the results are presented in Table 5.6-3 where the hazards have been grouped by maintenance workers and on-road resources.

Table 5.6-3 : Initial review of road worker related hazards with respect to MM-ALR

Maintenance workers

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
H52	Maintenance workers setting up and taking down work site	State	S08	S08.1	25.892	More robust signalling, and a more controlled environment to protect maintenance workers
H80	Roadworks - short term static	State	S07.5	S07.99	214.06	All roadworks will commence from a rolling road block, so risk will increase.
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08	E07.8	-36.9	More robust signalling and controlled environment
H79	Roadworks - long term static	State	S07.5	S07.5	0	No change in risk
H51	Maintenance workers in carriageway	Event	E06	E06	-2.842	More robust signalling and controlled environment
H101	Unable to set signs and signals to protect incidents	State	S06	S06	-4.263	Small benefit from perception of controlled environment, regardless whether signals set
H34	Incident management - rolling block	Event	E05	E05.2	58.489	Lack of the hard shoulder for stoppages from which to commence incident management – rolling road block required in all circumstances
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S02	S01.9	-20.56	CCTV for operators to confirm incident location
H6	Collision with workers doing	State	S06.5	S00	-100	Effectively eliminated due to lack of hard

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
	maintenance on verge					shoulder. This will not occur without full TM and RRB
H81	Roadworks - short term static on hard shoulder	State	S07.5	S00	Eliminated	No hard shoulder available, so hazard eliminated
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07	S00	Eliminated	No hard shoulder available, so hazard eliminated

On Road Resources

Hazard	**Description**	**Type**	**Before Safety Risk**	**After Safety Risk**	**%age change in Safety Risk**	**Comments**
H11	Driver ignores closed lane(s) signals that are protecting an incident	Event	E08	E07.8	-36.9	More robust and more frequent signalling,- controlled environment perception for motorists.
H95	TO/ISUO in running lane	Event	E08	E07.6	-60.18	More robust and more frequent signalling to protect TO/ISUO
H62	On-road resources work unprotected	State	S07.5	S07.4	-20.56	More robust and more frequent signalling to protect TO/ISUO
H94	TO arrives, but has difficulty containing the scene	Event	E07	E06.9	-20.56	More robust and more frequent signalling to protect TO/ISUO
H99	TOs/emergency services not despatched in a timely manner	Event	E07	E06.8	-36.9	CCTV to inform operators where exactly incident is, to improve despatch time
H96	TOs behave hazardously at an incident	Event	E06.5	E06.5	0	No change expected
H98	TOs/emergency services despatched but cannot reach scene	Event	E06	E06	-4.263	Small benefit derived from signals being set to facilitate TO/emergency services reaching incident
H101	Unable to set signs and signals to protect incidents	State	S06	S06	-4.263	Small benefit from perception of controlled environment, regardless whether signals set
H83	Signals change while TO/ emergency	Event	E06	E05.9	-20.56	CCTV available for operators to check whether there is still

Hazard	Description	Type	Before Safety Risk	After Safety Risk	%age change in Safety Risk	Comments
	services are still on motorway					attendance at incident
H97	TOs/ emergency services go to wrong location (incident)	Event	E06	E05.9	-20.56	CCTV for operators to confirm incident location
H66	Operator fails to set signals to protect incident in timely manner	State	S05.5	S05.4	-20.56	CCTV for operators to confirm incident location
H34	Incident management - rolling block	Event	E05	E05.2	58.489	Lack of the hard shoulder for stoppages from which to commence incident management – rolling road block required in all circumstances
H84	Signals set in wrong place (i.e. are not protecting the incident)	State	S02	S01.9	-20.56	CCTV for operators to confirm incident location
H82	Short duration stops / debris removal by TO / maintenance workers	State	S07	S00	Eliminated	As for H34, rolling road block required in all circumstances

This assessment gives an initial indication of the main impacts of MM-ALR on road worker safety and what the main questions are that need to be answered. Satisfactory mitigations will be needed if the Highways Agency's Aiming for Zero strategy[5] is to be achieved and obligations under the Health and Safety at Work etc Act 1984 and the Construction (Design and Management) regulations (2007) are to be met.

All of the organisations listed above already work on APTR and D3M (without Triple Package) and will be aware of the hazards that result from these environments, and hence will have appropriate procedures for safe working. They will have seen an improvement in safety with the implementation of Managed Motorways schemes through the mandatory intervisible signals and the wider controlled environment that provides good driver compliance. They will also have seen the benefit of Emergency Refuge Areas, in particular the TechMAC, as equipment cabinets can be safely accessed from them, and the Recovery Organisations where they provide a safer environment to attend their customers.

The change to MM-ALR will see the working environment for these road workers migrate more towards an APTR type environment. This will provide some benefit for the TechMAC in particular as the amount of technology will be reduced compared to conventional managed motorways, which will reduce their exposure on the road network. This can be further improved by developing equipment which can be fault diagnosed from remote locations, and also in many cases rectified/repaired remotely. Another key area will be to improve technology reliability so that fewer interventions are required and maintenance can move towards a reliability centred approach rather than one based upon routine inspections and repairs. It is recognised that a fundamental re-appraisal of maintenance is required. A possible starting point for this is to consider that there is no access to the network – then develop and build minimum requirements from there.

It must also be recognised that vehicles are becoming more reliable, so the need for recovery by recovery organisations is reducing. Further reductions in breakdowns could be achieved by encouraging / requiring the general public to pay more attention to their vehicles, in particular to reduce incidents related to running out of fuel.

Even taking account of these changes considerable effort will be required to ensure road workers are suitably protected where MM-ALR is implemented. What maintenance that is required for equipment on the network will need to be accessed from live lanes. MM-ALR is anticipated not to have the same control as the current MM design, therefore it will be important to make sure high levels of driver compliance with speed limits and lane closures are achieved. This will help protect road workers in the carriageway, and on-road resources trying to attend incidents.

5.7. Hazard Risk Assessment Results

All the results from the hazard assessment have been collated into a single spreadsheet based hazard log. This has been used to generate a series of comparisons that have been represented in graphical form. A single graph has been generated showing a comparison between:

- 3-lane All Purpose Trunk Road

[5] Although this hazard assessment and the Aiming for Zero includes vehicle recovery services such as the RAC and AA as roadworkers. The HA has a different level of responsibility to them as road user and not employer.

- D3M without MIDAS queue protection – 'the Baseline'
- D3M with MIDAS queue protection
- D4M without a hard shoulder or MIDAS, i.e. a simple conversion of the hard shoulder to a running lane without further mitigation
- D4M without a hard shoulder but with MIDAS fitted
- A generic MM-ALR design with the element as outlined in Figure 3.1-1
- M42 Active Traffic Management Pilot

In this graph the Baseline score (D3M without MIDAS queue protection) is set at 100.

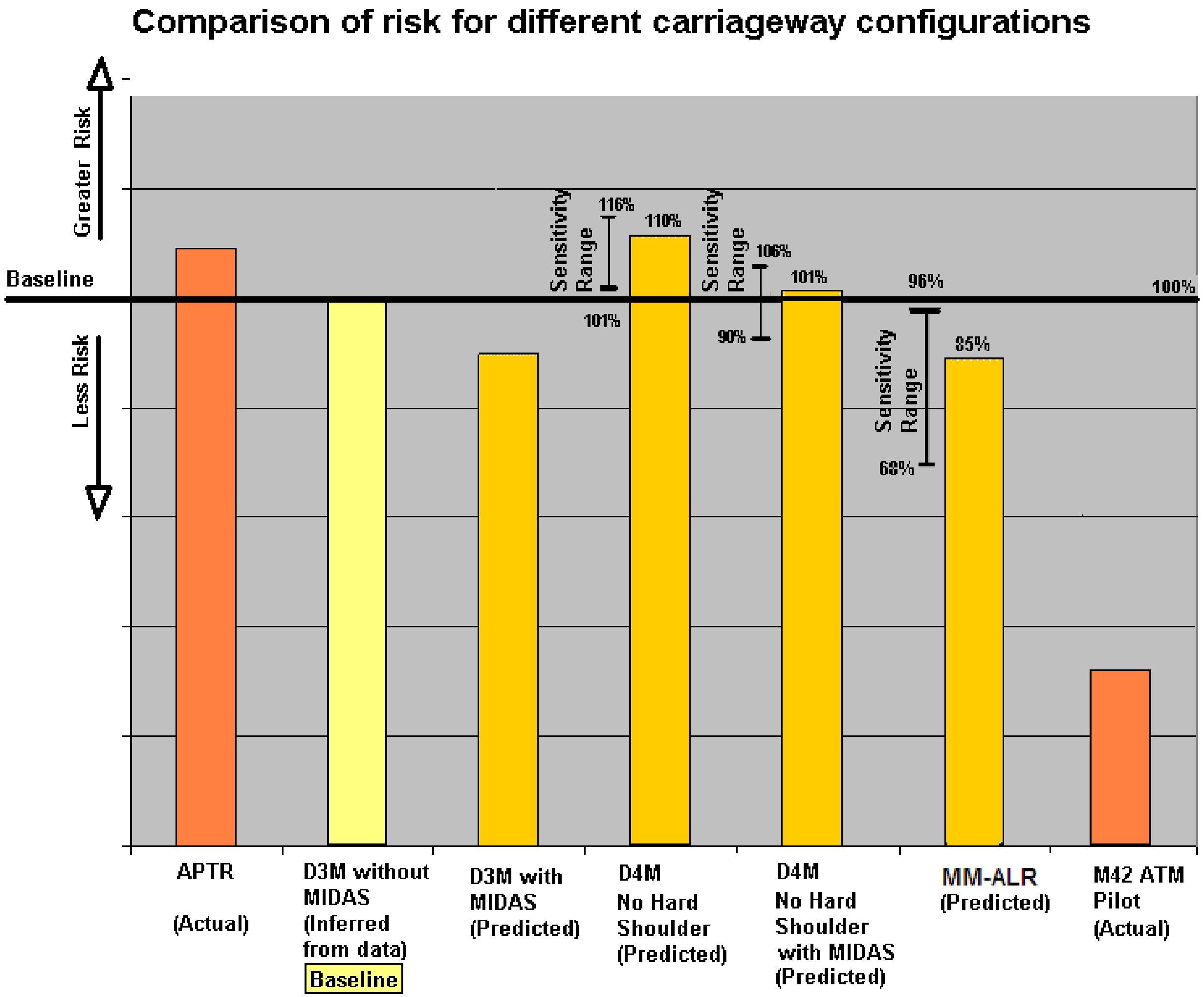
It should be noted, as previously, that with regard to these comparisons the following assumption has been made; that 'risk' in the hazard log corresponds to KSI accidents. This is not strictly true as the hazard log uses a scoring system that is semi-quantitative. However, it should be sufficient for purposes of this comparison to assume that they are equivalent.

How each comparative 'score' has been arrived at is described below:

- **3-lane All Purpose Trunk Road verses the Baseline** – From Section 3.2, if the impact of MIDAS on some sections of D3M is removed from the analysis of all the D3M link accident data, then the difference between the two is estimated to be approximately 9% for KSIs accidents and 5% for KSI injuries.
- **D3M with MIDAS queue protection verses the Baseline** – from MIDAS report [1] KSI accidents are reduced by 10% overall.
- **D4M without a hard shoulder or MIDAS verses the Baseline** – based on the hazard analysis presented in this report
- **D4M without a hard shoulder but with MIDAS fitted verses the Baseline** – as above but with the 10% improvement noted in the MIDAS report [1]
- **A generic MM-ALR design verses the Baseline** – before and after workshops refined by the data presented in this report
- **M42 Active Traffic Management Pilot verses the Baseline –** The KSI accident rate for the D3M network Table 3.2-1 has been compared with the after KSI accident rate for the M42 ATM pilot Table 3.3-2.

In addition, analysis has been undertaken where the weighting of Hazards with respect to Events and states has been undertaken to produce a range of results. In reality, this is a very severe test and it is unlikely that this range of results will actually be achieved.

Figure 5.7-1: Summary of Hazard Assessment (Risk Profiles)



Note: The accident data in this figure (for APTR, D3M and M42 ATM Pilot) refers to accidents not at or within 20m of a Junction

Figure 5.7-1 shows the results if Events and States have equal weighting within the Hazard log. The range of results that would occur if Events are given more weighting and States are given more weighting are shown in the 'range' bars shown on the figure.

The analysis shows that:

- there is a predicted increase in safety risk of the order of 20% when D4M without a hard shoulder is compared with the D3M baseline
- there is a predicted decrease in safety risk of the order of 10% when MM-ALR is compared with the D3M baseline.

Under one condition where Events are given greater weighting than States and the Hazard 'Vehicle stops in Running Lane (off peak)' is treated as an event does the MM-ALR concept show a higher level of risk. This is one extreme combination amongst the 6 tested and is therefore considered to be an unlikely result.

6. Summary and Conclusions

Safety Implications of removing the Hard Shoulder

Analysis of accident and casualty data collected from all the Dual 3-lane Motorways and multi-lane All-Purpose Trunk Roads (APTR) in England indicates that 3-lane APTRs have a rate[6] of Killed and Seriously Injured (KSI) accidents that is approximately 9% higher than that encountered on the D3M network. With regard to KSI casualties, the rate is approximately 5% higher. These rates take into account the impact of MIDAS queue protection and are therefore measured against a baseline of a D3M without MIDAS.

It is estimated that if the whole of this network was converted to D4M without a Hard Shoulder and without further mitigation, the increased numbers of Killed and Serious accidents would lead to an additional cost ranging between £24m and £54m per year. Over the typical design life of 30 years this would accumulate to a cost of £720m to £1,620m (without discounting). If the design life is 60 years this would accumulate to a cost of £1,440m to £3,240m (without discounting).

This suggests that a form of control and driver compliance would be required in order to maintain current levels of safety.

Detailed Accident and Casual Analysis

The main conclusions to draw from the above are that in comparison with D3M links, multi-lane APTR links are characterised by:

- A four to five fold increase in the frequency of vehicle parked in main carriageway accidents.
- An increase in the frequency of accidents involving vehicles leaving the carriageway
- No increase in the frequency of fatigue related accidents
- An increase in frequency of Pedestrian accident
- No increase in the frequency of Debris related accidents
- An increase in the frequency of accidents involving a motorcycle.

It is likely that the frequency of vehicle parked in main carriageway and vehicles leaving the carriageway accidents are related to the loss of the Hard Shoulder. However, it is likely that most of the increase in the frequency of pedestrian accidents is due to different levels of access to the road. The reason for the increase in frequency of Motorcycle accidents is less clear and may be due to a number of factors including differences in geometrical standards between the two types of road.

A number of methods were employed to estimate what the impact would be of removing lay-bys from the APTR data. This was necessary as the MM-ALR concept does not have these features. These techniques have drawn broadly similar conclusions regarding the increase in the number of vehicle stopped in carriageway accidents and casualties.

[6] per Million Vehicle Mile

Hazard Assessment

The Hazard Assessment shows that the safety risk is driven by removal of the hard shoulder which leads to an increased frequency of vehicles stopped in a lane, vehicles leaving the carriageway and pedestrians in the road (and closer to traffic). In addition, maintenance activities will be more challenging to mitigate and revised practices will need to be developed and adopted. This assessment assumes that MM-ALR design features promote situational awareness leading to the required level of driver compliance.

The hazard assessment suggests that D4M without a hard shoulder will be less safe than the baseline, MM-ALR (assuming situational awareness can be maintained) is expected to have a level of safety comparable with the safety baseline.

The change to MM-ALR will see the working environment for these road workers migrate more towards an APTR type environment. This will provide some benefit for the TechMAC in particular as the amount of technology will be reduced compared to managed motorways dynamic hard shoulder, which will reduce their exposure on the road network. This can be further improved by developing equipment which can be fault diagnosed from remote, and also in many cases rectified/repaired from remote. Another key area will be to improve technology reliability so that fewer interventions are required and maintenance can move towards a reliability centred approach rather than one based upon routine inspections and repairs. All these areas will need to be explored during the development of the MM-ALR concept.

Even taking account of these changes considerable effort will be required to ensure road workers are suitably protected where MM-ALR is implemented. What maintenance that is required for equipment on the network will need to be accessed from live lanes. MM-ALR is anticipated not to have the same control as the current MM design, therefore it will be important to make sure high levels of driver compliance with speed limits and lane closures are achieved. This will help protect road workers in the carriageway, and on-road resources trying to attend incidents.

Appendix A – Hazard Descriptions and Applicability

Hazard	Original Description	Revised Description / Applicability
H1	Abnormal loads - escortable	Abnormal loads - escortable
H2	**Abnormal loads - notifiable**	Abnormal loads - notifiable
H3	Aborting or pausing LBS1 sequence half way	
H4	Blanking of one gantry when LBS1 open to traffic indicates sudden local closure of LBS1	
H5	Closing sequence overtakes vehicles in LBS1, requiring them to move out of LBS1 unnecessarily	
H6	Collision with workers doing maintenance from the verge	Collision with workers doing maintenance on verge
H7	Conflicting signs and signals set	Conflicting signs and signals set
H8	**Debris in running lane**	**Debris in running lane (being hit or causing unsafe manoeuvre)**
H9	Driver changes mind about entering ERA	Driver changes mind about entering ERA
H10	**Driver falls asleep**	**Driver Fatigued - unable to perceive hazards effectively**
H11	**Driver ignores closed lane(s) signals that are protecting an incident**	**Driver ignores closed lane(s) signals that are protecting an incident**
H12	Driver ignores traffic management protecting a maintenance site	Driver ignores traffic management protecting a maintenance site
H13	**Driver loses control of vehicle**	**Driver loses control of vehicle**
H14	Driver mistakes ERA for exit slip	Driver mistakes ERA for exit slip
H15	Driver observance of red X changes on rest of network	
H16	Driver on LBS1 fails to exit and continues on LBS1 through junction	
H17	Driver stays on LBS1 when it is closing	
H18	Drivers assume that LBS1 is open immediately after section	
H19	Drivers assume they can use LBS1 on rest of network	
H20	Drivers enter LBS1 too early when LBS1 being opened	
H21	Emergency services driving at	Emergency services driving at speed

Hazard	Original Description	Revised Description / Applicability
	speed down the hard shoulder (LBS1)	down the hard shoulder (LBS1)
H22	Emergency staff -TO etc on foot at scene of an incident	Emergency staff -TO etc on foot at scene of an incident
H23	Escorted convoys	Escorted convoys
H24	Excessive lane changing caused by use of LBS1for hard shoulder running	Excessive lane changing caused by availability of an additional lane
H25	Excessive lane merging required when lanes are closed	Excessive lane merging required when lanes are closed
H26	Excessive opening and closing of LBS1	
H27	Excessively slow moving vehicle in running lane (excluding hard shoulder LBS1)	Excessively slow moving vehicle in running lane
H28	Extreme weather conditions lead to a pile-up	Extreme weather conditions lead to a pile-up
H29	Generic underlying causes for hazards	Generic underlying causes for hazards
H30	Group of vehicles drive too fast (in relation to set/not set speed limit)	Group of vehicles drive too fast (in relation to set/not set speed limit)
H31	HADECS flash unit misaligned affecting drivers on opposite carriageway	HADECS flash unit misaligned affecting drivers on opposite carriageway
H32	Health deterioration of vehicle occupant	Health deterioration of vehicle occupant
H33	HGV-LGV-Bus exits ERA when LBS1 is open	HGV-LGV-Bus exits ERA
H34	Incident management - rolling block	Incident management - rolling block
H35	Incident occurs in opened section of LBS1 during opening sequence	Incident occurs in opened section of LBS1 during opening sequence
H36	Incidents or congestion caused in other lanes or carriageway due to rubber necking	Incidents or congestion caused in other lanes or carriageway due to rubber necking
H37	**Individual vehicle is driven too fast**	**Individual vehicle is driven too fast**
H38	Infrastructure collapse	Infrastructure collapse
H39	Infrastructure collapse due to additional load on LBS1	Infrastructure collapse due to additional load on LBS1
H40	Lane closure signals are set in wrong lane following an incident due to operator error	Lane closure signals are set in wrong lane following an incident due to operator error
H41	Lane diverts into lane with incident due to technical failure	Lane diverts into lane with incident due to technical failure
H42	Lane(s) closed, but driver unable to leave lane and stops	Lane(s) closed, but driver unable to leave lane and stops
H43	Large vehicle does not completely enter hardshoulder -LBS1when stopping	Large vehicle does not completely clear the running lane when stopping on Hard Shoulder (D3M) or Verge (MM-ALR)
H44	LBS1 closed too early	
H45	LBS1 closed too late	

Hazard	Original Description	Revised Description / Applicability
H46	LBS1 opened before required	
H47	LBS1 opened too late (after traffic flow has broken down)	
H48	Legal-illegal pedestrian(s) in path of vehicles in ERA	Legal-illegal pedestrian(s) in path of vehicles in ERA
H49	LGVs, HGVs or other wide vehicles avoid using LBS1 due to narrowing effect of red studs	
H50	Limping vehicles in LBS1 (when open)	Limping vehicles in LBS1 (when open)
H51	Maintenance workers in carriageway	Maintenance workers in carriageway
H52	Maintenance workers setting up and taking down work site	**Maintenance workers setting up and taking down work site**
H53	MIDAS queue protection does not operate for a significant queue	MIDAS queue protection does not operate for a significant queue
H54	**Motorcycles filter through traffic**	**Motorcycles filter through traffic**
H55	Motorcycle stopped in LBS1 when closed	Motorcycle stopped next to running lanes (D3M = Hard Shoulder, MM-ALR = verge)
H56	Motorcycle stopped on LBS1 as LBS1 opens	
H57	Motorcycle uses LBS1 to pass slow moving or stationary traffic	Motorcycle uses Lane 1 to pass slow moving or stationary traffic
H58	Motorcyclist cross wind buffering	Motorcyclist cross wind buffering
H59	Motorcyclist falls off crossing line on entry to ERA	Motorcyclist falls off crossing line on entry to ERA
H60	Motorcyclists crossing line between hard shoulder (LBS1) and LBS2	Motorcyclists crosses rumble strips
H61	Object in LBS1 causes impediment to traffic - causes drivers to take avoiding action when opening	Object in LBS1 causes impediment to traffic - causes drivers to take avoiding action when opening
H62	On-road resources work unprotected	On-road resources work unprotected
H63	Opening sequence is faster than the traffic	Opening sequence is faster than the traffic
H64	Operator closes LBS1 following an incident on main carriageway, diverting traffic toward incident	Operator closes LBS1 following an incident on main carriageway, diverting traffic toward incident
H65	Operator fails to remove signals after an incident	Operator fails to remove signals after an incident
H66	Operator fails to set signals to protect incident in timely manner	Operator fails to set signals to protect incident in timely manner
H67	**Pedestrian in running lane - live traffic**	**Pedestrian in running lane - live traffic**
H68	**Pedestrian on slip road**	**Pedestrian on slip road**
H69	Pedestrians in a running lane - stationary-slow moving traffic	Pedestrians in a running lane - stationary-slow moving traffic
H70	Pedestrians on hard shoulder (LBS1) when LBS1 is closed (adjacent to a parked vehicle)	Pedestrians on hard shoulder adjacent to a parked vehicle (D3M = Hard Shoulder) (MM2 = verge).
H71	Pedestrians on LBS1 while opening	

Hazard	Original Description	Revised Description / Applicability
	LBS1	
H72	Pedestrians walking along the hard shoulder/LBS1 (when LBS1 is closed)	Pedestrians walking along the hard shoulder (Applies to D3M only)
H73	Pedestrians walking on verge when LBS1 is open	Pedestrians walking on verge
H74	Person on off-side of vehicle in ERA	Person on off-side of vehicle in ERA
H75	Power failure of several/all gantries during LBS1 running effectively indicates sudden closure of LBS1	
H76	**Rapid change of general vehicle speed**	**Rapid change of general vehicle speed**
H77	Reduced visibility due to weather conditions	Reduced visibility due to weather conditions
H78	Road Traffic Collision in live lane pushes one or more vehicles into a maintenance site	Road Traffic Collision in live lane pushes one or more vehicles into a maintenance site
H79	Roadworks - long term static	Roadworks - long term static
H80	Roadworks - short term static	Roadworks - short term static
H81	Roadworks - short term static on hard shoulder/LBS1	Roadworks - short term static on hard shoulder
H82	Short duration stops / debris removal by TO / maintenance workers	Short duration stops / debris removal by TO / maintenance workers
H83	Signals change while TO/ emergency services are still on motorway	Signals change while TO/ emergency services are still on motorway
H84	Signals set in wrong place (i.e. are not protecting the incident)	Signals set in wrong place (i.e. are not protecting the incident)
H85	Significant incursion of passing vehicle into ERA	Significant incursion of passing vehicle into ERA
H86	Slow traffic in LBS2 passed by faster traffic on LBS1	
H87	Speed differential between emergency services and general traffic	Speed differential between emergency services and general traffic
H88	Stationary traffic backed up onto motorway at exit	Stationary traffic backed up onto motorway at exit
H89	**Sudden weaving at exit point**	**Sudden weaving at exit point**
H90	System failure - signs or signals incorrectly indicate that lanes with static roadworks are open	System failure - signs or signals incorrectly indicate that lanes with static roadworks are open
H91	**Tail gating**	**Tail gating**
H92	Terrorism of system	Terrorism of system
H93	The driver loses control and enters the maintenance site	The driver loses control and enters the maintenance site
H94	TO arrives, but has difficulty containing the scene	TO arrives, but has difficulty containing the scene
H95	**TO/ISUO in running lane**	**TO/ISUO in running lane**

Hazard	Original Description	Revised Description / Applicability
H96	TOs behave hazardously at an incident	TOs behave hazardously at an incident
H97	TOs/ emergency services go to wrong location (incident)	TOs/ emergency services go to wrong location (incident)
H98	TOs/emergency services despatched but cannot reach scene	TOs/emergency services despatched but cannot reach scene
H99	TOs/emergency services not despatched in a timely manner	TOs/emergency services not despatched in a timely manner
H100	Unable to remove settings of signs or signals after incidents	Unable to remove settings of signs or signals after incidents
H101	Unable to set signs and signals to protect incidents	Unable to set signs and signals to protect incidents
H102	Undertaking	Undertaking
H103	**Unsafe lane changing**	**Unsafe lane changing**
H104	Unsafe lane changing in the slip road (both off and on slips)	Unsafe lane changing in the slip road (both off and on slips)
H105	Vandalism of equipment	Vandalism of equipment
H106	Vandalism or sabotage directed at injuring members of the public or Managed Motorway staff	Vandalism or sabotage directed at injuring members of the public or Managed Motorway staff
H107	Vehicle accelerates into LBS1 immediately after last red X	
H108	Vehicle decelerates suddenly in response to signals	Vehicle decelerates suddenly in response to signals
H109	**Vehicle drifts off carriageway**	**Vehicle drifts off carriageway (i.e. leaving the carriageway as a result of Road Environment)**
H110	Vehicle drifts out of lane	**Vehicle drifts out of lane**
H111	Vehicle drives down LBS1 when closed	Vehicle drives down LBS1 when closed
H112	**Vehicle enters main carriageway unsafely**	**Vehicle enters main carriageway unsafely**
H113	Vehicle exits ERA when LBS1 is open to traffic	Vehicle exits ERA when LBS1 is open to traffic
H114	Vehicle in ERA obtrudes onto LBS1	Vehicle in ERA / Verge obtrudes onto LBS1 (D3M) or Lane 1 (MM-ALR)
H115	Vehicle in lane adjacent to hard shoulder (LBS1) straddles hard shoulder (LBS1)	
H116	Vehicle misjudges entry to ERA	Vehicle misjudges entry to ERA
H117	Vehicle not fully in control when trying to stop on LBS1	Vehicle not fully in control when trying to stop on Hard Shoulder (D3M) or Verge (MM-ALR)
H118	**Vehicle on the main carriageway decelerates suddenly**	Vehicle on the main carriageway decelerates suddenly
H119	Vehicle recovered from ERA when LBS1 is open	Vehicle recovered from ERA
H120	**Vehicle rejoins running lane**	**Vehicle rejoins running lane**
H121	**Vehicle reversing along exit slip**	**Vehicle reversing along exit slip**

Hazard	Original Description	Revised Description / Applicability
H122	Vehicle reversing back to exit slip	Vehicle reversing back to exit slip
H123	Vehicle reversing up entry slip	Vehicle reversing up entry slip
H124	Vehicle reversing up the hard shoulder (LBS1)	Vehicle reversing up Hardshoulder (D3M) or LBS1 (MM-ALR)
H125	**Vehicle stopped on LBS1 as LBS1 opens**	**Vehicle stopped on LBS1 as LBS1 opens**
H126	Vehicle stopped on slip road (off or on slip)	Vehicle stopped on slip road (off or on slip)
H127	Vehicle stopped on the hard shoulder (LBS1) when it is closed	**Vehicle stopped on Hard Shoulder (D3M) or verge (MM-ALR)**
H128	Vehicle stops in LBS1 when LBS1 open	Vehicle stops in LBS1 when LBS1 open
H129	**Vehicle stops in running lane**	**Vehicle stops in running lane - Peak**
H130	Vehicle stops/attempts to stop on the central reserve	Vehicle stops/attempts to stop on the central reserve
H131	Vehicle suddenly decelerates at end of on slip road	Vehicle suddenly decelerates at end of on slip road
H132	Vehicle suddenly decelerates while on off-slip	Vehicle suddenly decelerates while on off-slip
H133	Vehicle travelling in wrong direction	Vehicle travelling in wrong direction
H134	Vehicles with trailer / caravans travelling too fast	Vehicles with trailer / caravans travelling too fast
H135	**Vehicle stops in running lane (off-peak)**	**Vehicle Stops in Running Lane - Off Peak (Event)**

Appendix B – Attendees of Workshops

1st ‘Before’ scoring workshop attendees

Ryszard Gorell - Mouchel
Mara Makoni - Mouchel
Lucy Kinder - Mouchel
Andy Harmer - Mouchel
Nigel Waters Paul Hollywell – Mott Macdonald
Rachel.Murdock – Mott Macdonald

1st ‘After’ scoring workshop attendees, including:

Lucy Wickham – Mouchel
Ryszard Gorell - Mouchel
Alex Kappeler – Arthur D Little
Adam Simpson – IBI Group
Alex Bywaters – Highways Agency
Brian Barton – Highways Agency
Andrew Page-Dove – Highways Agency
Peter Greenslade – DeLoitte
Helen Parkyns – IBI Group
Cyril Diels - TRL

1st Verification workshop 1st February 2012 attendees

Andrew Alcorn, Highways Agency
Max Brown, Highways Agency
Martin Lynch, Highways Agency
Brian Barton, Highways Agency
Andrew Page-Dove, Highways Agency
Mike Wilson, Highways Agency
Alex Bywaters, Highways Agency
Lucy Wickham, Mouchel
Ryszard Gorell, Mouchel
Helen Parkyns, IBI Group
Adam Simpson, IBI Group
Sarah Garland, Highways Agency
Iain Candlish, WSP (CDM Co-ordinator)

2nd Verification workshop 29th February 2012 attendees

Andrew Alcorn, Highways Agency
Martin Lynch, Highways Agency (in part)
Malcolm Wilkinson, Highways Agency
Alex Bywaters, Highways Agency
Gareth Tyler, IBI Group
Lucy Wickham, Mouchel
Ryszard Gorell, Mouchel

Appendix C - References

1 MIDAS Automatic Queue Protection: Full Report on Safety and Congestion Relief Benefits (Summersgill, Fletcher and Mustard) TRL Unpublished Report UPR T/099/05

2 TRL report PR/SE/586 "Accidents alongside high-speed dual carriageways"

3 Working Paper No. 42690/WP/0059

M42 Active Traffic Management Pilot Project Review of 'Safe Haven Layby Frequency and Specification' Issue A – 10th July 2007

4 Accidents on the Network 2008, Highways Agency

5 Demonstration of meeting safety objective report

http://www.highways.gov.uk/knowledge_compendium/assets/documents/Portfolio/Demonstration_of_meeting_safety_objective_report_(Final_23-03-12).pdf