HIGHWAYS AGENCY

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Managed Motorways – All Lanes Running

Evaluation of the provision of Refuge Areas

MMFD-ERA-030- Final Issue

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Executive Summary

Refuge Areas are an integral part of the design of a Managed Motorway scheme. They have evolved since their first deployment on the ATM Pilot scheme on the M42. The latest design, Managed Motorways All Lane Running (MM-ALR) proposes further 'stretching' their provision in order to provide an efficient and cost effective solution that remains able to achieve the required level of safety.

It is suggested and evidenced in this document that decreasing the frequency of refuge area spacing will not have a significantly detrimental affect on traffic flow, overall safety level or incident numbers. Evidence largely supports the view that the majority of drivers will still be able to find refuge in a genuine emergency, provided that illegal / non-emergency stops in refuge areas are successfully managed. A refuge area is defined in IAN 161 as a place (or facility) where drivers can stop in an emergency. Appropriate refuge areas are:

- a motorway service area
- a hard shoulder on an exit slip/link road
- a hard shoulder within a junction (lane drop/lane gain only)
- a bespoke facility, such as an emergency refuge area (ERA)

It is further recommended and evidenced that the design of bespoke ERAs may be adapted / relaxed, so long as the 'ethos' associated with their provision remains consistent with current arrangements. It concludes that the length of an ERA should remain the same as that specified in IAN 111/09 [1] for the lower frequency MM-ALR arrangement. It is considered that the width can be specified as 4.0m. This is consistent with the minimum width allowable in IAN111/09, with a Departure from Standard. Changing this width would remove the need for Departures and is consistent with the fact that no degradation in ERA performance has been noted as a result of adoption of these departures on implemented schemes. The disassociation of ERAs from adjacent gantry locations will minimise the need for costly retaining structures and allow the optimisation of refuge locations on a scheme.

It is expected that there will be less vehicle stoppages due to the permanent removal of the Hard Shoulder. However, there will be additional stops in the running lane which will lead to greater risk; this is assessed as being within the bounds of acceptability when compared against the agreed safety baseline. Control provided through MM-ALR features, will contribute to the mitigation and management of this risk. It is expected that the overall risk of the MM-ALR design will be lower than that on dual 3-lane Motorway without MIDAS (the agreed baseline).

Capability to create an emergency lane (any lane on the motorway) and management of traffic through the use of signs and signals to enable access for emergency vehicles or maintenance workers can be provided. Any planned work will be undertaken using temporary traffic management and at reduced mandatory speeds as is currently the case on managed motorways. The absence of a hard shoulder in the MM-ALR scenario will make the issues associated with maintenance more challenging and work to satisfactorily resolve this is currently on-going.

The proposed design changes are based on experience of designing and operating managed motorways for over five years. This experience and detailed assessment has demonstrated that increasing the spacing between refuge areas is not expected to have a significant detrimental impact on road users. The changes in the design of ERAs on Managed Motorway schemes is summarised in the table overleaf:

Design consideration	M42 ATM Pilot	IAN 111 Design	IAN 111 Stretch	MM-ALR	CALR on Shorter Links
Driver Behaviour	High compliance with signals, due to enforcement and fixed HS CCTV provision – perception of a highly controlled environment.	High compliance with signals, due to enforcement and fixed HS CCTV provision – perception of a controlled environment.	High compliance with signals, due to enforcement and fixed HS CCTV provision – perception of a controlled environment.	Less infrastructure and enforcement. Perception of a controlled environment retained as a key design mitigation requirement.	Use of all lanes without a hard shoulder, therefore driver perception that stopping is not an acceptable option.
ERA Spacing	ERAs co-located with gantries, nominally at 500m spacing	ERAs co-located with gantries, nominally at 800m spacing	ERAs co-located with gantries. Nominal spacing potentially greater than 1000m	Spacing up to 2500m	CALR for short links – no ERAs specified.
ERA Design					
Location / Placement of ERA	ERAs co-located with gantries	ERAs co-located with gantries	ERAs co-located with gantries	ERAs placed where most economic for design / construction + mid link	CALR for short links – no ERAs specified.
Number of Emergency Stops	2 Breakdowns (1 ERA stop, 1 hard shoulder stop). Data from Monitoring results.	Anticipated similar number to M42 evidence.	Anticipated similar number to M42 evidence.	Anticipated minimum i.e. 25% of all stops currently occurring	Anticipated minimum i.e. 25% of all stops currently occurring
Number of Comfort Stops	60 Comfort stops per day per 14.395 km (majority in ERAs) Data from Monitoring results.	Anticipated similar number to M42 evidence.	Anticipated similar number to M42 evidence.	Minimum comfort stops anticipated within ALR section.	Minimum comfort stops within CALR section

Design consideration	M42 ATM Pilot	IAN 111 Design	IAN 111 Stretch	MM-ALR	CALR on Shorter Links
Incident Rate / Distribution					
Maintenance Style / Location	ERAs available for maintainers. HS closures are possible.	ERAs available for maintainers. HS closures are possible.	ERAs available for maintainers. HS closures are possible.	ERAs available at nominal 2500m spacing - alternative solution required to facilitate safe maintenance. Potential use of rolling road blocks (RRB) and maintenance hard standings (MHS).	No ERAs available for maintenance– alternative solution required to facilitate safe maintenance. Potential use of RRBs and MHS.
Journey Time Impact	Journey time benefits due to homogenisation of traffic by VMSL, and reduction of congestion seed points	Journey time benefits due to homogenisation of traffic by VMSL, and reduction of congestion seed points	Journey time benefits due to homogenisation of traffic by VMSL, and reduction of congestion seed points	Journey time benefits due to homogenisation of traffic by VMSL, and reduction of congestion seed points	Permanent hard shoulder running, therefore less congestion, and improved journey time
Safety with respect to Baseline	Safety benefits of 60% approx	Safety benefits of 30%	Safety benefits of 25%	Safety benefits of 15%	Hard shoulder incidents eliminated, however incidents in running lanes increased calculated safety benefit of 5%

1. Purpose

This evaluation presents the three key issues regarding refuge areas and particularly the deployment of bespoke Emergency Refuge Areas (ERAs) on the configuration of Managed Motorways – All Lanes Running. For the purposes of this document it is referred to as MM-ALR.

These issues are:

- The spacing of refuge areas
- The design of ERAs
- The maintenance requirements of the motorway.

The evaluation is structured as follows:

Section 2 - presents background information on the use of ERAs on Managed Motorways schemes, why aspects of ERAs are being evaluated, the safety requirements associated with ERAs and the design philosophy for MM-ALR.

Section 3 - presents supporting information from a literature review which has been used to inform this evaluation.

Section 4 – presents an assessment of refuge area spacing

Section 5 - presents an assessment of ERA design characteristics

Section 6 – describes the maintenance challenges associated with MM-ALR.

Section 7 - References

Appendix A – provides details of relevant background information

2. Background

The M42 ATM Pilot scheme was the first deployment of Managed Motorways in the UK. It featured a high concentration of infrastructure including the provision of bespoke Emergency Refuge Areas at a nominal spacing of 500m.

Monitoring of the M42 scheme post implementation indicated that a variety of benefits accrued as a result of the operation of the scheme. These benefits included incident and accident rate and severity improvements as well as congestion / journey time improvements. As a result, the scheme safety objective has been exceeded by a significant margin.

Detailed monitoring of hard shoulder and ERA activity was undertaken soon after implementation of the ATM Pilot and presented in project document reference 42690DOC/0056 [2]. This work was based on analysis of CCTV images which coincided with a section of the Pilot scheme on which ERAs are located at a nominal spacing of 800m. This monitoring indicated that a wider spacing of ERAs did not compromise the expected use or usefulness of the ERAs.

This monitoring gave confidence in the design guidance for Managed Motorways (IAN111/09) which states that 'ERAs form an integral part of the Managed Motorways - Hard Shoulder Running design and will be spaced between 600m and 1000m inter-junction'. Since the issue of IAN111/09 further work has been undertaken on the design of Managed Motorways resulting in an updated concept referred to as 'MM-ALR'. This work has also been informed by the formal publication of the 3 year monitoring results from the M24 ATM Pilot This review and analysis has suggested that the level of infrastructure, including the placement and frequency of ERAs may be altered / relaxed without having a detrimental impact on the safe operation of a scheme. The development of the MM-ALR concept was also precipitated by the need to demonstrate value for money in the current economic climate, an evolving view of the acceptable level of safety risk and tolerability of risk on a MM scheme. The basic design for MM-ALR is shown in Figure 2.1.

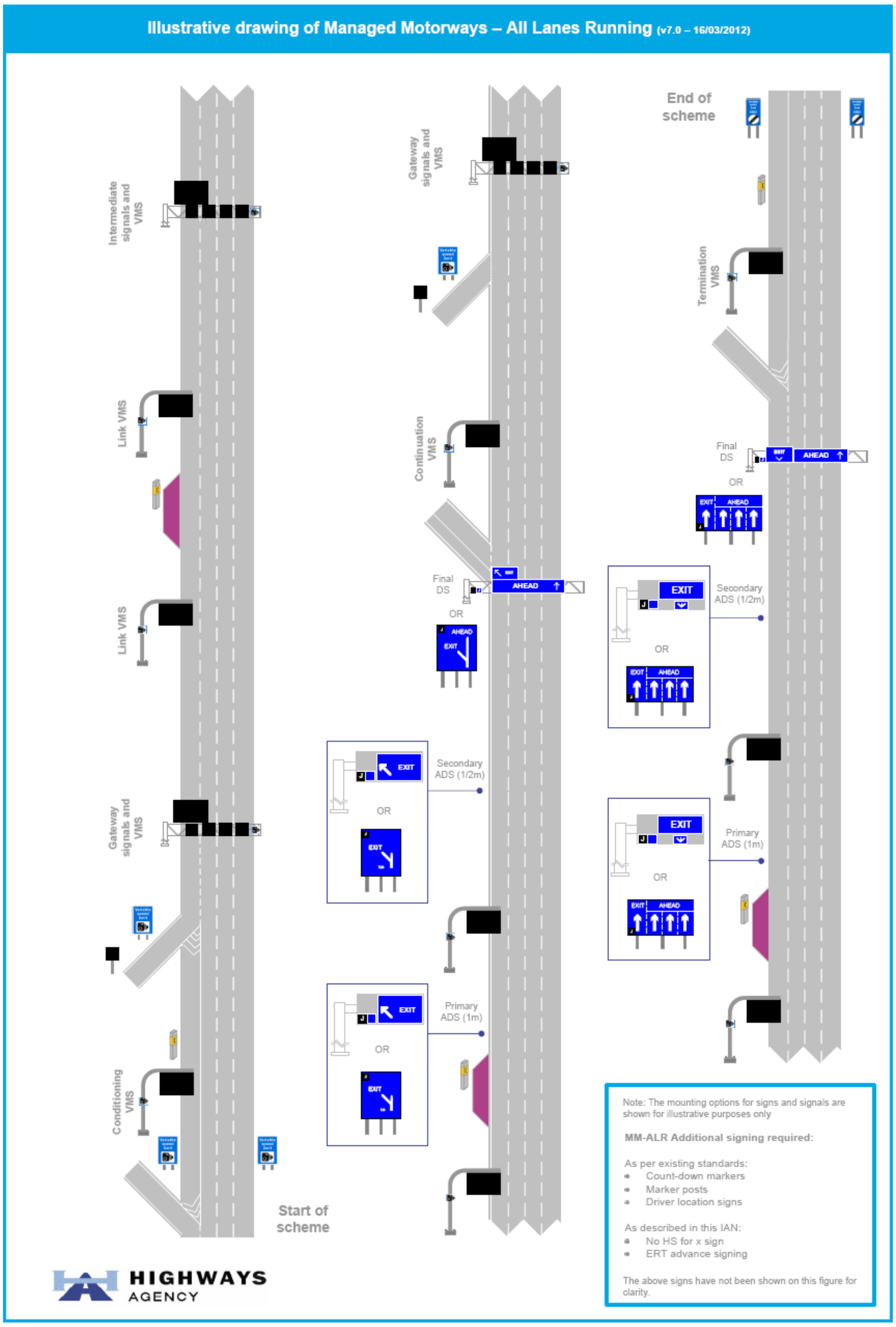


Figure 2.1: MM-ALR

MM-ALR incorporates refuge areas at less frequent intervals i.e. a greater spacing, than has been specified previously. A refuge area is defined in IAN 161 as a place (or facility) where drivers can stop in an emergency.

Appropriate refuge areas are:
- a motorway service area
- a hard shoulder on an exit slip/link road
- a hard shoulder within a junction (lane drop/lane gain only)
- a bespoke facility, such as an emergency refuge area (ERA)

MM-ALR also differs from previously designed and implemented MM schemes in the following respects that are relevant to the frequency, design and use of refuge areas:

- Vehicles will be travelling at a maximum speed of 70mph i.e. in off peak times, when the motorway is free from congestion and there will be no standard restriction of speed to 60mph when Lane 1 is in operation as a running lane.
- The hard shoulder will be permanently converted to a running lane, along with the ability to dynamically control mandatory speed limits. This removes the complex operating regime of opening and closing the hard shoulder and generates significant capital and operational cost savings.
- Refuge area will not be co-located adjacent to gantries or cantilever signs; Refuge areas are expected to be up to approximately 2500m apart.
- There will be areas of the verge where it will be possible for motorists to stop their vehicles in cases of emergency breakdowns, when there is no refuge area provided in the vicinity.
- Where an emergency refuge area is provided, ERTs will also be provided.
- Refuge areas are to be used for breakdowns and genuine emergencies only. It is assumed that no comfort stops will be taken in refuge areas.
- Cabinets and other equipment will be placed in the location where optimum benefit can be gained by maintainers.

It should be noted that the MM-ALR design philosophy makes best use of the existing layout of the road. Refuge areas may either be bespoke facilities (an ERA) or converted from an existing facility, for example a wide load bay. A motorway service area (MSA), the hard shoulder on an exit slip road, or intra-junction, may all be considered to provide a refuge area. Therefore, ERAs form part of a wider strategy of refuge areas providing places of refuge at regular intervals.

2.2 Safety Requirements

The safe operation of MM-ALR is dependant on a number of safety requirements, which have already been identified and captured during the development of the concept. The safety requirements that are relevant to refuge areas are as follows.

- Winter treatment must include refuge areas.

- Comprehensive Closed Circuit Television (CCTV) camera coverage (Pan Tilt Zoom (PTZ)) shall be provided on the carriageway (including refuge areas). Comprehensive is defined as the ability of operators to see up to 95% of the total scheme area and be able to interpret the images correctly (It is noted that it is sometimes impractical to provide 100% CCTV coverage eg: signs or bridges may obscure part of the view. 95% coverage including all areas of special interest would be acceptable.

2.3 The selection of a refuge area maximum spacing of 2500m for MM-ALR

In carrying out the review of the features of MM (including the spacing of refuge areas) it is necessary to make a number of assumptions about the MM design. These assumptions are then tested using a systematic approach in order to determine the likely safety performance of MM-ALR. This systematic approach is based on the analysis of the hazards that will be impacted by the concept. It is not true to say that the hazard analysis derives an optimum refuge area spacing; balancing the requirements of safety and value management. It is however correct to say that the safety analysis determines whether a particular combination of design features will be acceptably safe.

Initially, the MM-ALR concept was evaluated based on a design that did not have refuge areas. This safety evaluation suggested that the design was close to achieving an acceptable level of safety. However, given this result and other considerations such as operability of the concept and reputational considerations for the HA, it has now been concluded that refuge areas should form part of the design.

The selection of an initial assumption of a maximum spacing of 2500m is consistent with the Highway Agency’s Technical Document TD69/07 “The location and layout of Lay-bys and Rest Areas”. This document states that for All Purpose Trunk Road Dual Carriageways the maximum spacing for lay-bys is 2500m. This represented a starting point for the analysis and also enables comparisons to be made with the safety performance of existing multi-lane All-Purpose Trunk Roads (APTR) [7].

3. Supporting Information / Literature Review

In moving from the design solution in IAN 111 /09 to MM-ALR, a number of studies and reviews have been completed which are relevant to refuge areas and the frequency of their provision. These progressively support the view that refuge areas can be located at a reduced frequency. These studies are listed below and described in more detail in Appendix A. A detailed assessment of the implications of a wider refuge area spacing (i.e. 2500m apart) is described in Section 4.

- IAN 111 - ERAs should be placed between 600 and 1000m inter-junction, and co-located with gantries

- M42 ATM Review of Safe Haven Lay-by Frequency and Specification – As the distance between ERAs is increased, the carriageway blockage rate levels off, indicating that below a certain frequency, however this is changed, the blockage rate will largely remain stable; i.e. the blockage rate for ERAs at 2500m is unlikely to be much higher than that for 1500m.

- M42 ATM CCTV monitoring – suggested that the underlying assumptions about the rate at which vehicles are able to make it to an ERA were conservative, suggesting that the distance between ERAs could be extended.

- Birmingham Box Phase 3 Managed Motorways – The breakdown rate for the Bromford Viaduct, part of this scheme, is particularly low (well below the National Average), indicating that when necessary, or when a location is deemed undesirable for motorists to stop, it is possible for vehicles to continue to a place perceived to be more safe to stop.

- CALR for Shorter Links [6] – There are currently hard shoulder discontinuities on the UK Motorway Network of up to 2000m, with no obvious safety disbenefits.

- Lay-bys Standard, DMRB Volume 6, Section 3 [4] – It is recommended that lay-bys are placed at a distance of 2500m on dual carriageways.

4. Refuge area spacing and location

4.1 Introduction

As noted previously, the MM-ALR concept incorporates refuge areas at a maximum spacing of 2500m. When compared with existing managed motorway schemes, this is a reduced frequency of refuge area provision. However, this spacing is consistent with lay-by provisions on the all-purpose trunk road (APTR) network.

This section supports the view that, utilising a 2500m frequency of refuge areas on the MM-ALR Concept is considered to be acceptably safe. This is evidenced by:

- The good safety performance of existing Managed Motorways schemes,
- The likelihood of a reduce vehicle stopping rate on MM-ALR (as drivers of broken-down vehicles are, to an extent, able to choose where they stop, and that without a hard shoulder discretionary (illegal stops) are eliminated),
- The safety performance of 3-lane APTRs (which, although worse than 3 lane motorways, are comparable).
- A detailed hazard log based assessment.

The following is also considered:

- Evidence of the safety performance of Managed Motorways schemes
- The safety performance of roads with similar characteristics to MM-ALR.
- Implications of providing refuge areas at a spacing at 2500m
- Overall safety performance of the MM-ALR concept with refuge areas at a spacing at 2500m
- Impact on carriageway blockages.
- Other issues including, driver behaviour and cost implications of less frequent refuge area provision that are not associated with other managed motorway features such as gantries.

4.2 Evidence of the Safety Performance of Managed Motorways schemes

The safety performance of the M42 Managed Motorways (MM) Pilot has been reported in the document “M42 MM Monitoring and Evaluation three year safety review”[3].

It reports that there has been a substantial (55.7%) reduction in the number of Personal Injury Accidents (PIA) and a reduction in the severity of accidents during the first 36 months of MM operation.

An analysis within this report indicates that the improvement is not uniform across all hazards. The report suggests that the frequency of Rear-end Shunt PIAs is reduced by 50%, the frequency of Single Vehicle PIAs is reduced by 80% while the frequency of Side Impact PIAs remains at approximately the same level. The Rear-end Shunt PIAs reduction is particularly relevant to this analysis, as it is this type of accident that is likely to result from vehicles stopped in the carriageway.

The key implication from the above is that the MM concept is very safe and there is considerable scope for a 'value engineering' review of MM features. These include permanent use of the hard shoulder as a running lane and the increased spacing of refuge areas.

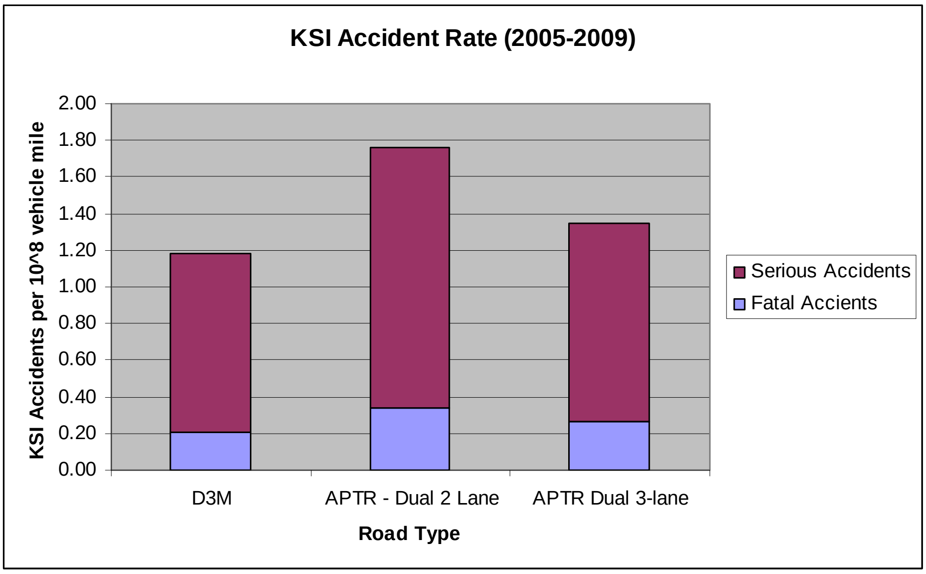
4.3 The safety performance of roads with similar characteristics to MM-ALR

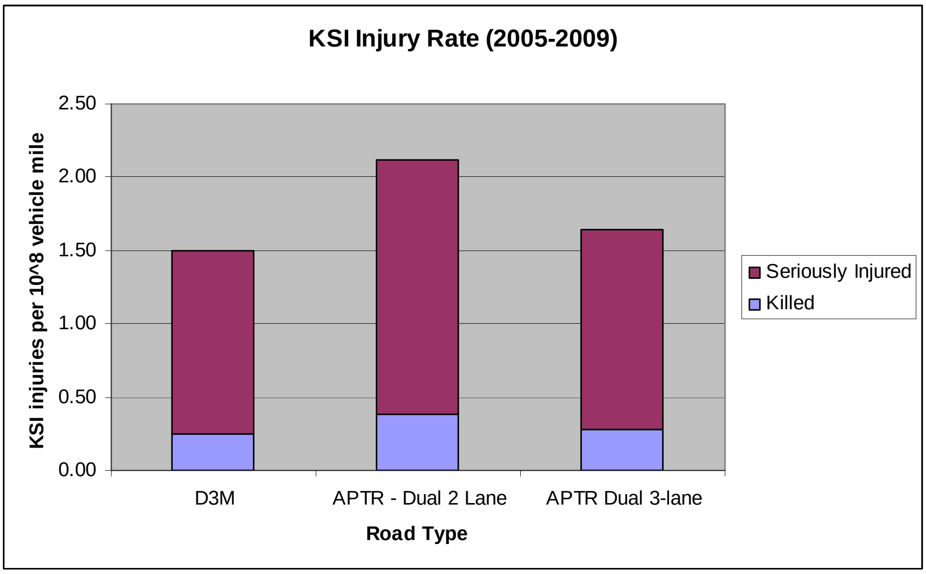
In order to inform the likely safety performance of the proposed MM-ALR design with refuge areas at 2500m intervals, an analysis was undertaken of the accident and casualty rates on the Highways Agency road network[7].

The analysis concentrated on links between junctions and covered Dual 3-lane motorways and multi lane All Purpose Trunk Roads (APTR) (i.e with 2 or 3 lanes in each direction). The 3-lane APTRs were considered to be of most relevance to the MM-ALR concept as they do not have hard shoulders and lay-by spacing similar to the MM-ALR concept.

The analysis shows that the lowest rates of Fatal and Serious Accidents and Casualties can be found on D3M links. (Rate is measured per vehicle mile). The rates are higher on APTR 3-lane links, and higher still on APTR 2-lane links. This is illustrated in the figures below

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. However the rate on APTR Dual 3-lane is only slightly higher than that on D3M.

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.

A more detailed analysis has also 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 implication of 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. There are differences in the type of accident and casualties on these roads. It is also noted that Vehicles parked in the carriageway accidents are higher.

4.4 Implications of providing Refuge Areas at a maximum spacing of 2500m

Appendix A of this document presents a number of items of research and evidence that are relevant to the provision of refuge areas at a spacing of 2500m adjacent to four permanent running lanes. The main points to note are as follows:

- The vehicle breakdown rate varies considerably depending upon location. It is particularly important to note the evidence from the Bromford Viaduct supports the view that many drivers are able to nurse a broken down vehicle up to a few Km distance before stopping (in carriageway locations where drivers perhaps perceive themselves to be vulnerable).

- On dual 3-lane motorways, discretionary stops (comfort stops and vehicle checks on the hard shoulder, i.e. illegal stops) outnumber breakdowns by between 8 and 10 times.

  As they are typically 3 to 5 minutes long, typically only 50% of the time vehicles are stopped on the hard shoulder are as a result of vehicle breakdowns. The implication of converting the hard shoulder to a running lane is that the majority of stops that currently occur on the hard shoulder will be eliminated and the exposure to risk on the Hard Shoulder is reduced by 50% (thus reducing risk by 50%).

Drawing together the data from the various sources presented in Appendix A, it is possible to determine the relative vehicle stopping rates for a standard Dual 3lane motorway (D3M) and MM-ALR based on the following assumptions.

1. The two-way flow is of the order of 130,000 vehicles per day (0.13 million vehicles - typical of the values that would warrant use of an extra lane at peak.)
2. That the breakdown rate is 12 per million vehicle mile
3. That breakdowns are typically of one hour duration and that breakdowns account for 50% of time exposure (if discretionary stops are still present)
4. That discretionary stoppages (comfort stops, vehicle checks) happen 9 times more often than breakdowns
5. For the MM-ALR concept there will be no discretionary stops on the carriageway
6. For MM-ALR that there will be minimal discretionary stops in the refuge areas (However given the experience of the M42 Pilot, mitigation maybe required to prevent the use of the refuge area for comfort stops: eg: more forceful signage, penalties for improper use etc). This assumption should be tested through a sensitivity analysis in order to determine the level of confidence in it and the levels of compliance that would lead to concern.
7. That in a breakdown emergency 50% of drivers will be able to get their vehicles to a place of safety (takes into account previous work on proportion of broken-down vehicles that can be driven a short distance).

Using the above assumptions, for D3M:

- The number of breakdowns per day = 12*0.13 = 1.56 per day per motorway mile (i.e. 0.79 per day per carriageway)

- Time that broken-down vehicle is on Hard Shoulder = 1.56 hours per day per motorway mile

- The number of discretionary stops is = 12*0.13*9 = 14.0 per day per motorway mile

- Total time stoppages on Hard Shoulder per day = 3.12 hours per day per motorway mile

For MM-ALR:

- The number of breakdowns per day = 12*0.13 = 1.56 per day per motorway mile (i.e. 0.79 per carriageway)

- However if it is assumed that 50% of drivers will be able to get their vehicles to a place of safety then the rate is 0.79 per day per motorway mile (i.e. 0.4 per carriageway)

- Time that broken-down vehicle is on the carriageway per day = 0.79 hours per day per motorway mile.

- Assumption: Minimal discretionary stops in refuge area

In summary:

- For dual 3-lane motorways, the total vehicle stoppage time (on the hard shoulder) is estimated to be 3.12 hours per day per motorway mile.

- For the MM-ALR concept, the total vehicle stoppage time (outside refuge areas) is estimated to be 0.79 hours per day per motorway mile. This is based on discretionary stops being eliminated and 50% of broken-down vehicle stopping in a refuge area.

With regard to the last point, these vehicles (i.e. ones which the driver has been unable to reach a refuge area) would either have to stop on the carriageway or the verge. During the peak, the traffic would be managed and as such there is little difference to existing MM schemes (which, as noted before, already have a good safety record).
There will however, be an increased exposure to potential risk off-peak which will, to an extent, be mitigated through CCTV surveillance and the setting of signals and mandatory speed limits, once the stopped vehicle is identified.

4.5 Overall safety performance of the MM-ALR concept with Refuge Areas at a spacing of 2500m

The main points to be drawn from the previous sections are that:
- Multi-lane roads without a hard shoulder but with lay-bys can perform at a similar safety level to Dual 3-lane motorways. These roads are similar to the MM concept but without control.
- Evidence from the M42 ATM pilot indicates that a substantial reduction in accidents and casualties can be achieved where mitigation is added to create a ‘controlled environment’.

A hazard based assessment of the performance of the MM-ALR concept has been undertaken. The results suggest that the concept is able to operate with a level of safety that is comparable or better than a standard dual 3 –lane motorway without MIDAS.

This is because the substantial benefits obtained from appropriate control (As evidenced from the M42 ATM pilot) out-weight the elevated risk (as evidenced from the APTR study).

4.6 Carriageway blockages

Consideration of the above literature review, and looking at the mean number of blockages expected, if the ERA spacing was to be increased, there would not be a commensurate increase in the number of blockages. This is due to the likelihood that vehicles can travel under their own power with 50% of vehicle breakdowns likely to be able to travel a mile to reach a refuge area. However, if refuge areas were to be removed completely, it is likely that the number of live lane blockages will commensurately increase. Note that this calculation is based on a prevailing flat topography and schemes will need to assess the impact of extensive sectiond with gradients > 2%.

4.7 Other issues

This sub-section covers other issues related to the reduced frequency of refuge areas and the decision to disassociate refuge areas with other MM features such as gantries.

4.7.1 Driver behaviour

Increasing the spacing of refuge areas is anticipated to have a number of effects on driver behaviour.

The use of refuge areas for emergency purposes only will be encouraged by appropriate signing and driver education messages. The objective therefore is that their reduced frequency will lead them to be used for illegal / inappropriate purposes more sparingly. Secondly, since they are more scarce, they become less prominent within the scheme. In an emergency, if a driver misses a refuge area that they could have used there is an increased chance of a blockage on the carriageway.

For the above reasons, and since refuge areas are now not expected to be co-located with other MM features such as gantries, it becomes more important to alert the general public to their location and use both in advance (through education eg: literature, publications and web-based information) and within the scheme through the use of advance signing (to assist drivers in their location) and signing to emphasis that their use is for an emergency only.

In order to deter road users from crossing the carriageway, it is considered that the requirement to place refuge areas opposite each other should be retained. It may be possible to introduce a degree of flexibility around this, within certain longitudinal parameters without loosing the essence of the ethos. It remains a requirement to provide emergency roadside telephones at refuge areas and these ERTs will also be required to be placed opposite each other for the same fundamental reason – to deter carriageway crossings by road users.

4.7.2 Cost

It is thought that the disassociation of refuge areas from gantries will have a positive cost impact. Currently costly designs are necessitated by the mandatory guidance for refuge areas to be placed generally downstream of a gantry (geotechnical and geometric constraints etc can result in significant retaining structures being required). This suggests that the placement of refuge areas is currently according to the location from which the greatest operational benefit from the gantry will be realised. By rationalising refuge areas and locating these where the lowest cost solution is legitimised, savings can be made on a significant item of capital infrastructure.

5. ERA Design

There is a relevant public perception of refuge areas on Managed Motorways schemes (ERAs) that has been developed over time. It is therefore considered not to be advantageous to fundamentally change their appearance. It is suggested that the baseline for consideration of the refuge area design be drawn from information contained in the Highway Code, public consultations for MM schemes and other relevant Standards. The information reproduced below is contained within the Highway Code:

> *"You MUST NOT use the hard shoulder for overtaking. In areas where an Active Traffic Management (ATM) Scheme is in force, the hard shoulder may be used as a running lane. You will know when you can use this because a speed limit sign will be shown above all open lanes, including the hard shoulder. A red cross or blank sign above the hard shoulder means that you MUST NOT drive on the hard shoulder except in an emergency or breakdown. Emergency refuge areas have also been built into these areas for use in cases of emergency or breakdown."*

Further information about Emergency Refuge Areas[1] is provided in a number of other documents. The increased spacing of refuge areas is likely to lead to an increase in the frequency of their individual use.

The presence of an ERT in an emergency refuge area is also considered to be a fundamental provision. It is however worthy of note that in the simulation undertaken of the MM-ALR concept at TRL in 2011,ERTs were not included and no participants commented on their absence from the simulation.

Safety analysis work clearly demonstrates the risks associated with safe entry and exit from a refuge area. Therefore the location of a refuge area must seek to maximise sightlines and visibility and not compromise access / egress to them. The provision of CCTV can assist the RCC operators in the management of ERAs through general surveillance and active intervention when observed or considered necessary.

It is considered that the length of refuge area (100m) should be preserved, as prescribed in IAN 111. This was based on a TD 69/07 Type B layout, with entry / exit taper lengths reversed to maximise the length of acceleration of a vehicle in re-joining the motorway. The length and operation of the refuge area design was rigorously tested in a simulation at the test track at the Fire Service College in Moreton-in-Marsh and in practice on the schemes implemented to date.
It has met with the acceptance and 'approval' of stakeholders and the length can accommodate all the parties involved in vehicle remediation / recovery (including HGVs). A similar argument follows for the width of refuge areas.

[1] Highway Code Supplementary Notes - Addendum

IAN 111/09 prescribes a width of 4.6m with an allowable departure to a reduced width of 4.0m. In practice the 4.0m width has been accepted as an allowable departure on a number of schemes and no degradation in performance has been reported or observed. It is therefore considered reasonable to prescribe a width of 4.0m as an acceptable relaxation in standard for the MM-ALR design, which must be recorded in the Design Strategy Report (DSR). This width is greater than the width of a standard hard shoulder provision and will still contribute to the enhanced safety of operatives and motorists whilst within a refuge area. In areas where the road gradient is > 2% and the % of HGVs is higher than average, a risk based safety review is recommended given that the speed under MM-ALR is likely to be 70mph.

The below table summarises the key points made in this section, with regards to the significant areas that would be impacted by any refuge area redesign.

Implication	Result of re-design of Refuge Area
Legal	No legal implications have currently been identified pertinent to the Variable Speed Limit Regulations. This statement is made on the basis that the ethos of the refuge area provision will remain unchanged and the information currently contained within the Highway Code will remain valid and applicable to the MM-ALR design. The exception to this, which may result in the need to review the wording in the Highway Code, is inclusion of the sentence which reads 'Features include sensors to alert the control office when a vehicle has entered'. Inclusion of ERA loops is not included within the MM-ALR concept. Exclusion of this feature would have no bearing or impact on a driver's perception or use of a refuge area facility. DfT legal advice is to be sought regarding the status of ERAs and any related requirements for Statutory Instruments on MM-ALR schemes
Safety	Shortening of refuge areas presents potential safety issues regarding the exit and entry of vehicles.
Emergency Services access	Emergency services vehicles are typically longer than the majority of vehicles using the motorways, hence if refuge areas were to be shortened then this could prove to be problematic for the safe entry and exit of emergency services. It is unlikely however that, in the event of an incident, emergency services would use refuge areas, since an appropriate lane closure would be implemented.
Recovery Operators	Refuge areas must remain wide enough and long enough to enable recovery operators to assist vehicles, so the refuge area can be cleared as quickly as possible. If recovery time is compromised, this could affect the blockage rate on the mainline, which is undesirable.
Driver Behaviour	Changing the design of refuge areas significantly could result in confusion for motorists seeking a safe place of refuge in the event of a breakdown or emergency. This must be tempered with appropriate directional and information signing to guide motorists where to stop in such a situation. The design should be reinforced, and public information disseminated to deter motorists from stopping within refuge areas for comfort breaks.

The working assumption is that refuge areas will be disassociated from gantries (see section 4.7). This allows placement to optimise their location and maximise Stopping Sight Distances (SSDs), which will assist in facilitating the safe exit and entry of vehicles and use by vehicle recovery organisations and the Emergency Services.

It is suggested that the inclusion of refuge area technology e.g. CCTV and loops is assessed on a case by case basis, according to SSDs and other infrastructure in the vicinity. Refuge area loops are considered less important, provided that provision is made (eg: a fixed sign stating that motorists should contact the RCC via ERT prior to refuge area exit) to facilitate effective mitigation of the hazards associated with the exit from a refuge area. Specific refuge area CCTV cameras are also no longer specified as a requirement. Comprehensive CCTV PTZ coverage of the carriageway, including coverage of refuge areas (except MSAs), will however be included. Provision of CCTV images relies on an operator or an automated system to react and respond in cases where a need is identified. RCC operators do not and will not be monitoring these CCTV images on a permanent basis. The facility does exist to enable the images to be viewed when carriageway conditions alert an operator to a potential intervention requirement.

6. Maintenance Requirements

The aspiration of the Highways Agency is to take forward initiatives to remove the need for workers to be on the live carriageway (aiming for zero). Designers should be cognisant of this and seek to have a positive influence on this goal in their scheme design activities and processes.

As part of the MM-ALR design, there is an overall reduction in infrastructure of around 50% when compared to an IAN111 design. This will reduce the requirement for maintenance activities, although work undertaken to assess the impact of maintenance does indicate a greater requirement for temporary traffic management activities. This is primarily due to the deletion of the hard shoulder, which has been used extensively as a platform from which to set out and undertake maintenance activities. To minimise the impact of lane closures on network performance, the majority of maintenance is expected to be undertaken outside peak periods and will mainly be restricted to night time and weekends. It is currently anticipated that without suitable mitigation, the overall risk to maintenance workers will be increased. There is a significant amount of work being undertaken within the MM-ALR maintenance workstream to assess and quantify this and to identify suitable and sufficient mitigation to ensure that risks to maintenance workers are managed successfully to be ‘as low as reasonably practicable’. This is being achieved through consideration of the elimination and reduction of maintenance activities where practicable.

All maintenance activities within a MM-ALR scheme must be carried out in a safe manner and are generally expected to be undertaken from either a designated area for maintenance or from a lane closure under traffic management. In exceptional circumstances, maintenance hard standings (MHS) may be considered on MM-ALR schemes, where sufficient evidence of their benefits (operational, safety and cost) can be demonstrated.

7. References

[1]	Interim Advice Note 111/09, Managed Motorway Implementation Guidance, Hard Shoulder Running
[2]	M42 ATM Pilot, ATM safety monitoring: First set of 4-lane MVSL results
[3]	M42 MM Monitoring and Evaluation, Three Year Safety Review, HCG, January 2011
[4]	DMRB TD 69/07 The Location and Layout of Lay-Bys and Rest Areas
[5]	Review of Safe Haven Lay-by Frequency and Specification 42690/WP/0059
[6]	Evaluating Controlled All Lane Running (CALR) as a design solution for shorter Managed Motorways
[7]	All-Purpose Trunk Roads (APTR)/Dual 3-lane Motorway (D3M) Analysis and Hazard Assessment, 1039092/ATA/035

Appendix A – Literature Review

This appendix contains information about a number of studies that are relevant to this evaluation, particularly in terms of the discussion of refuge area spacing presented in Section 4. These papers consider in particular, two parameters that are relevant to refuge area spacing: The frequency of breakdowns and how long a vehicle can travel before stopping following a breakdown.

A1 Interim Advice Note 111/09

The passage below has been extracted from IAN 111/09. It is contained within a 'black box'; indicating that this is mandatory and must be adhered to when designing IAN 111 compliant MM schemes. It describes the initial design and spacing of ERA for use on Schemes post the M42 ATM Pilot.

"ERAs form an integral part of the MM-HSR design and will be spaced between 600m and 1000m inter-junction (i.e. between junctions). The average frequency must be no greater than 800m.

They are to be co-located with gantries and located downstream of the gantry (See Appendix D Drawing 005). This arrangement is to enable drivers to associate gantries with an ERA beyond it. It also enables signs for the ERA ("Emergency Refuge Area - SOS") to be mounted on the gantry leg (See Appendix D Drawing 007) ERA signs will need to be authorised by the NetServ Safe Road Design Team.

If local conditions (topology, SSD) dictate that it is impractical to locate the ERA downstream of the gantry, the ERA may be located upstream of the gantry (See Appendix C Drawing 006). Each ERA will have an ERT and the vehicle restraint system provided at the ERA will have a gap to allow access to the ERT and adjacent equipment such as the CEC."[2]

A2 Safe Haven Lay-By Frequency and Specification – Oscar Faber

This report calculated the number of blockages caused by broken down vehicles in the carriageway (i.e. those that could not move to an area of safety), that would consequently cause disruption to the traffic flows.

The formula for the number of blockages is based around the following three findings / assumptions:

- Up to half of breakdowns are able to travel under their own power for at least <u>one mile</u>
- Up to 25% of breakdowns are able to enter a lay-by unpowered

[2] IAN 111/09 Section 10

- Up to 25% of breakdowns are unable to enter a lay-by and block the carriageway.

The paper noted the following with regard to evidence from the network:

"up to 50% of drivers in breaking down vehicles can travel under power for at least a mile, then we may assume that 50% of breakdowns will travel to the nearest safe haven or exit in an ATM scheme."

The underlying analysis from this paper was used to inform the paper described below.

A3 M42 ATM Review of 'Safe Haven Lay-by Frequency and Specification' – Cambridge Consultants

This document considered the implications of changing the frequency of ERAs. The analysis was based on the Operational Regime of the M42 ATM Pilot. Specifically, it reviewed the regime where the hard shoulder is open to traffic and travelling with a Variable Mandatory Speed Limit (VMSL) of 60mph.

Table 1: Results of applying 'Blockages' model to a variety of ERA frequencies at 60mph

ERA Frequency (m)	Proportion of vehicles not reaching ERA	Peak period blockages per km per month
500	30.6%	3.49
600	33.9%	3.86
700	36.2%	4.12
800	37.9%	4.32
900	39.2%	4.47
1000	40.3%	4.60
1100	41.2%	4.70
1200	41.9%	4.78

The results from this model suggested that as the refuge area frequency increases, the number of blockages tends towards a limit. This is due to the ability of a vehicle to coast a certain distance at a specific speed,

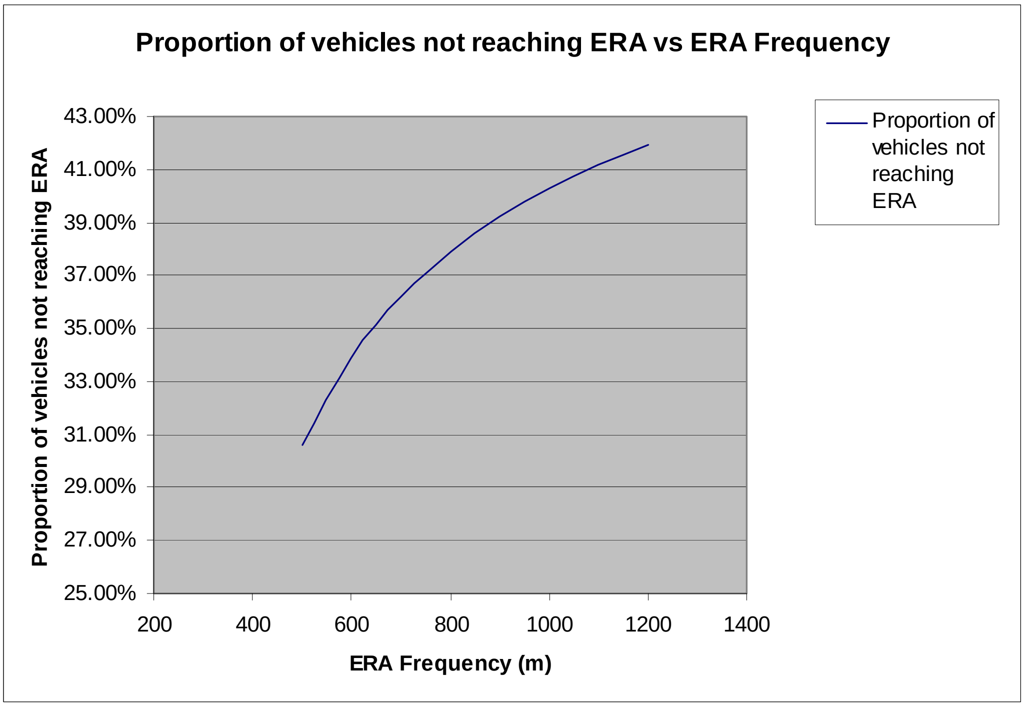


Figure 1: Graph of Proportion of vehicles not reaching and ERA vs ERA Frequency

A4 M42 ATM CCTV monitoring

ERA spacing on Managed Motorways (2009 - unpublished)

This report analysed CCTV footage of ERA and hard shoulder activity for a section of the M42 ATM Pilot where the spacing is approximately 800m.

The main conclusions to be drawn from this analysis are a follows:

- There is good evidence that the breakdown rate happening on the M42 ATM pilot is much less than that used in the model developed in the Oscar Faber report (reference A2 above). Analysis carried out for Through Junction Running also suggests that the frequency of breakdowns is much less than expected.
- There is some evidence supporting the view that approximately 35% of breaking down vehicles will not be able to make it to an ERA. However, it seems that this rate could apply to ERA spacings that are closer to 800m than the 500m used in the model.
- The combination of the above two bullet points suggests that blockage frequencies for ERAs at 800m spacing will be comparable or lower than those originally modelled for ERA spacings of 500m. The overall risk is therefore likely to be comparable to that that was originally used in the Safety Case for the ATM Pilot.

A5 Evaluating Controlled All Lane Running (CALR) as a design solution for shorter Managed Motorways links

This paper, issued by the Highways Agency in 2010, details the suitability of link lengths for the application of CALR (Controlled All Lane Running) on English motorways. It was noted that this intervention is not new and at several locations, due to geometrical constraints, hard shoulder discontinuities for distances up to 2000m are already in existence (eg: on the M48 Severn Bridge where only a hard strip is present). Other locations of hard shoulder discontinuities of 600m and 800m include the stretch of motorway between Junction 7 and 8 of the M6, and in the proximity of Junction 4 on the M5, respectively. The paper concludes that the expected increase in risk when deploying CALR over short sections is increased by 2-5% where no additional mitigation is introduced.

A6 Birmingham Box Phase 3 Managed Motorway - M6 Bromford Viaduct (J5 to J6) Breakdown Statistical Analysis Note

This report details the breakdown rates experienced on the stretch of motorway between J5 and 6, known as the Bromford Viaduct.

Table 2: The number of breakdowns per day for Bromford works versus the baseline

Data Source	Breakdowns per Day	Live Lane Stops Only	Hard Shoulder
Bromford Hard Shoulder Works (2008)[a]	0.87	✓	✗
RAC Breakdowns on Bromford (2008)[a,b]	1.03	✗	✓
Bromford Breakdowns C&C Logs (2008)[a,c]	1.53	✗	✓
National Average Roadworks (2007)[a]	3.50	✗	✓

a M6 Bromford Breakdown Analysis Note (total over AM and PM peaks – 8hrs)
b Using adjusted figures
c Total over 24hrs, although the majority are observed to be during AM and PM peaks

Table 3: Evidence from Other Roadworks

All Purpose Trunk Roads	Breakdowns per Day
M25 J2-30[a]	0.87
Light Vehicle Breakdown Rate[b]	1.03
Heavy vehicle breakdown Rate[b]	1.53

a Dartford recovery statistics (no hard shoulder available)
b Cole and Evans "Incidents and recover procedures in major roadworks"

Analysis carried out for Bromford viaduct to determine number of breakdowns using different sources of data. This has been scaled as indicated to obtain a rate per million vehicle mile.

Data Source	Breakdowns per day AM and PM peaks (8 hrs)
Bromford Roadworks (2008) - live lane stopped	**0.87**
M4 J1 to J2 Elevated section	**0.76**
Bromford breakdowns C&C logs (2008)**	**1.53**
M42 HSR60 Safety Monitoring (2008)	**2.22**
RAC Breakdowns on Bromford (2008) - corrected	**1.03**
A38M RAC Stopping Rates - corrected	**0.99**
BBMM Phase 2 BDV Recovery (2010)	**2.85**
National Average Roadworks (2007)	**3.50**

Length in miles	**3.75**
AADT (million vehicles)	**0.11**
Proportion of AADT flow during peak (inferred from flow data)	**0.55**
Vehicle flow Bromford during peak (million vehicle mile)	**0.23**

Data Source	Breakdowns per million vehicle mile
Bromford Roadworks (2008) - live lane stopped	**3.83**
M4 J1 to J2 Elevated section	**3.35**
Bromford breakdowns C&C logs (2008)**	**6.74**
M42 HSR60 Safety Monitoring (2008)	**9.79**
RAC Breakdowns on Bromford (2008) - corrected	**4.54**
A38M RAC Stopping Rates - corrected	**4.36**
BBMM Phase 2 BDV Recovery (2010)	**12.56**
National Average Roadworks (2007)	**15.43**

Table 4: Analysis of breakdown rates

The relevance sources of data suggest a breakdown rate significantly below the national average.
This indicates that location can influence the breakdown rate, according to whether this is seen as a desirable place to stop by the public. To summarise:

- The vehicle breakdown rate varies considerably depending upon location
- Using the summation of all the data the vehicle breakdown rate is likely to be between 4 and 15 per million per vehicle mile. But it is still likely that it is at the higher end of the range. This document assumes that it is 12 per million vehicle mile.
- On D3, discretionary stops (comfort stops and vehicle checks on the hard shoulder) outnumber breakdowns by between 8 and 10 times. They are typically 3 to 5 minutes long
- 50% of the time vehicles are stopped on the hard shoulder are as a result of vehicle breakdowns.

A7 Accidents Alongside High Speed Dual Carriageways – Transport Research Laboratory (TRL)

This report investigated accident rates and stopping rates on dual carriageway roads and on the hard shoulder of motorways.

This report concluded that most stops on the Hard shoulder were discretionary, but 50% of the time was spent by broken-down vehicles, which means that 50% of exposure could, in theory, be avoided if these discretionary stops could be avoided. There was a clustering of broken-down vehicles around emergency phones suggesting that many drivers were capable of 'choosing' in a limited way where to break-down.

Distribution of vehicle stops did not appear to be greatly influenced by cross-section, except that elevated sections and bridge parapets tended to be avoided.

Other key finding are:

- On D3, discretionary stops (comfort stops and vehicle checks on the hard shoulder) outnumber breakdowns by between 8 and 10 times. They are typically 3 to 5 minutes long
- 50% of the time vehicles are stopped on the hard shoulder are as a result of vehicle breakdowns.

A8 Lay-Bys Standard, DMRB Volume 6 Section 3, updated in 2007

This guidance recommends that lay-bys are placed at a distance of 2500m on dual carriageways for all Annual Average Daily Traffic (AADT) flows, and at a spacing of between 2000m and 5000m on single carriageways for high AADT flows.