Evaluating Congestion Caused by Abnormal Loads
Final Report

by Nicholas Taylor, Tim Rees, Philip Sanger, Kate Alexander and David Savage

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by Nicholas Taylor, Tim Rees, Philip Sanger, Kate Alexander and David Savage (TRL Limited)

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Evaluating Congestion Caused by Abnormal Loads

Client: 
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(Mr. Andrew Cook)

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Executive summary

E.1 Congestion on Britain’s roads is an increasing problem and in recent years traffic volumes have increased to such an extent that parts of the network are often operating close to capacity. The Department for Transport (DfT) and the Highways Agency (HA) are committed to reducing traffic congestion by better management of the road network. The movement of large and heavy Abnormal Loads through the road network can cause additional delays to other traffic. As part of its commitment the Highways Agency is considering alternative modes of transport of the largest and heaviest loads.

E.2 Each year the Abnormal Loads Team of the Highways Agency issues 300-400 Special Order\(^1\) permits for the movement of Abnormal Indivisible Loads (AILs) by road, and also authorises 700-800 VR1\(^2\) wide loads. Lesser movements are covered by other STGO\(^3\) and C&U\(^4\) regulations. Delays caused by Abnormal Loads could be reduced by a better understanding of how they are related to the types of load and the conditions under which they are moved. Movements also involve operational and administrative work by the police and local authorities, such as escorting, road closure and temporary removal of street furniture, and wider costs of maintaining or assessing road structures for their ability to carry the loads. Finally, there may be impacts on safety, and the natural and human environment.

E.3 Alternative modes for large and heavy loads, such as rail and water have their own issues of capacity, accessibility, investment and cost. This project aims to gain a better understanding of the congestion and other impacts caused by the movement of Abnormal Loads and surrounding issues. This will assist the Highways Agency in deciding whether and when to permit the largest and heaviest Abnormal Loads to travel by road, and to promote alternative methods of transporting Abnormal Loads, in particular by water.

E.4 The Final Report summarises the results of a project which has performed a Literature Review related to Abnormal Loads and related issues, conducted a Consultation of Stakeholders and Experts, monitored a number of Abnormal Load movements on the road, analysed the traces of loads in MIDAS\(^5\), and has developed a detailed spreadsheet Model to enable congestion delays and costs caused by Abnormal Loads to be estimated as a function of route, day and time of travel, and load characteristics such as speed and take-up of lanes. A separate Modelling Report describes the model and also examines other factors which it would be appropriate to include as part of the cost model. Statistics of AIL movements and results of monitoring and modelling are given in the main Final Report. A shorter Summary Report details the main non-technical issues and conclusions.

E.5 A Literature Review at the start of the project has identified about 50 sources covering the subject areas of cost of road transportation, environmental impacts, intermodality, water transport and regulation. However, no information is available about the impact of AILs in modern road conditions. The Review has identified some sources on the important secondary impacts of ordinary freight traffic besides congestion, including accidents, noise, pollution, climate change and infrastructure damage.

E.6 The Model’s results for congestion costs will contribute to the Highways Agency’s assessment of Abnormal Load applications. Other types of externality cost are recognised, and some estimates are made. Detailed estimation of externalities for Abnormal Loads would require significant additional research, as no data specific to them are currently available. An estimated externality cost per mile could be input into the model to form part of the overall cost, but based on the Review and estimates the effect in cost terms is small and would be unlikely to affect routing decisions.

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1. Vehicles over 6.1m wide, or over 30m long (rigid), or over 150,000kgs.
2. Vehicle Regulations 1: loads exceeding 5.0m (16’4") up to 6.1m (20’) wide not covered by Special Order.
4. The Road Vehicles (Construction and Use) Regulations 1986 (SI 1078) – loads up to 4.3 metres wide and 27.4 metres long.
5. The Highways Agency’s Motorway Incident Detection and Automatic Signalling system.
E.7 Fourteen Abnormal Load moves (excluding last-minute cancellations) have been observed on the road, and nearly 60 moves have been monitored on motorway sections of their routes using MIDAS detector data. This is somewhat fewer than was originally planned, caused by a lack of moves taking place. Sections covered by MIDAS are limited to certain motorways, and therefore may not be representative of all motorways, nor of other types of road including single carriageways, which can be studied only by direct observation or modelling.

E.8 Although the basic principles of modelling queuing and delay are simple, a more complex approach is needed to account for the motion of Abnormal Loads and the possibility of traffic overtaking. Modelling requires some care because results can be very sensitive to some inputs such as lane take-up and speed of load, and also to traffic behaviour including any diversion. Theoretical examples to illustrate this are given. Queuing and delay are also sensitive to ambient demand, which can vary from hour to hour and day to day. Applying accurate average demand figures is labour intensive because large databases of hourly counts or average daily flows have to be consulted.

E.9 A mathematical model, which takes account of the unique circumstances of each Abnormal Load movement, has been developed and implemented in a spreadsheet. The model takes account of variations by day of week and time of day, and allows the optimum timing of a move to be estimated, as well as the timing of breaks. Given realistic data, it can produce a description of an AIL’s effect on traffic which corresponds with observation.

E.10 Specific conclusions concerning modelling are:

- The model’s estimate of congestion cost is specific to the load’s size, speed and route, and ambient traffic flows, so its results can contribute to the decision-making process. It calculates queuing and delays from traffic and queuing theory, and does not depend on statistical results from monitoring, except to calibrate certain values such as passing speeds and capacities;

- The model depends on the data put into it being realistic, which includes correctly identifying the independent sections of the route, making realistic assumptions about diversion, and inputting accurate time-dependent ambient traffic volumes. Experience suggests that use of ADTs where TRADS data are unavailable, even if correct for the day of travel, may reduce accuracy, but is unlikely to affect conclusions about the general magnitude of congestion impact;

- Congestion caused by a load is most sensitive to its speed, width or lane-take, and the effective capacity of passing lanes, and ambient traffic volume where this is comparable to normal road capacity;

- Congestion costs are highly variable. Calculations from moves monitored using MIDAS range from virtually zero, to £1600/mile on one motorway section. However, it is estimated that £100/mile is exceeded on only 8% of motorway load-miles. These results are not necessarily representative of all motorways, and not representative of other road types, but may indicate likely magnitudes. The variability of cost not only reflects the familiar way in which delays to individual vehicles vary with place and time, eg between peak periods near cities and night-time on rural roads, but is also magnified by the fact that the heavier the traffic the more vehicles are affected by the Abnormal Load and any queuing it causes;

- Directly observed moves, which used a range of road types, are estimated to have average costs intermediate within the range of MIDAS results. The average delay caused by the most disruptive loads is estimated to be in the range 15-25 minutes per vehicle affected;

- Traffic can incur measurable delay even when appearing to flow freely at 30-50 mph, when the presence of a ‘queue’ may not be obvious to an observer;

- Diversion may be important only on certain routes, depending on local conditions;

- Empty transfer can be modelled in a similar way to loaded moves, with the appropriate route and vehicle characteristic data, but empty mileage is strongly case-dependent. Since empty

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6 Average Daily Traffic counts
7 The Highways Agency’s TRaffic and Accident Data Statistics database
transfer is likely to be less disruptive than a loaded move, it should be considered whether the expense of modelling and approval procedure is justifiable.

- There are no data on externality costs specific to Abnormal Loads, but some figures are estimated which indicate that they are unlikely to be sufficient to affect decisions;
- The Literature Review has concluded that there is no other current or relevant research.

E.11 When estimating costs of transport by water, it must be kept in mind that water transport can also involve substantial road segments, but that water costs are less directly dependent on distance than road transport and involve a large, sometimes dominant, component of intermodal transshipment costs, especially craneage, although roll-on-roll-off operation can reduce this. Water costs can also be affected by infrastructure operations such as dredging and civil works, and the impact of these costs will depend on whether they are ‘one off’ or can be shared among several moves.

E.12 Consultation of members of the Expert Panel and other Stakeholders has aired issues of escorting practice and fair comparison between road and water modes, as well as giving members of the Expert Panel the opportunity to influence the course of the project and in particular the monitoring of Abnormal Loads. Bearing in mind that Water Preference is government policy, Stakeholders have pointed to certain costs and operational factors which tend to make water options uncompetitive, as well as several unfair disadvantages compared to road, and have pointed out the potential for developing new road/water interchanges.
Abstract

Congestion on Britain’s roads is an increasing problem and in recent years traffic volumes have increased to such an extent that parts of the network are often operating close to capacity. The Department for Transport (DfT) and the Highways Agency (HA) are committed to reducing traffic congestion by better management of the road network. As part of this commitment alternative modes of transport of large or heavy Abnormal Indivisible Loads (AIL) are being considered. The report summarises the results of a project which has performed a Literature Review related to Abnormal Loads and related issues, conducted a Consultation of Stakeholders and Experts, monitored a number of Abnormal Load movements on the road, and has developed a detailed spreadsheet model to enable congestion delays and costs caused by Abnormal Loads to be estimated as a function of route, day and time of travel. The report includes details of the impacts of heavy and wide load movements, and recommendations from consultation for improved water transport facilities.
1 Introduction

1.1 Congestion on Britain’s roads is an increasing problem and in recent years traffic volumes have increased to such an extent that parts of the network are often operating close to capacity. The Department for Transport (DfT) and the Highways Agency (HA) are committed to reducing traffic congestion by better management of the road network. The movement of large and heavy Abnormal Loads through the road network can cause additional delays to other traffic. As part of its commitment the Highways Agency is considering alternative modes of transport of the largest and heaviest loads.

1.2 Each year the Abnormal Loads Team of the Highways Agency issues 300-400 Special Order permits for the movement of Abnormal Indivisible Loads (AILs) by road, and also authorises 700-800 VR1 wide loads, while lesser movements are covered by other STGO and C&U regulations (see Executive Summary footnotes and Section 3 for definitions). Delays caused by Abnormal Loads could be reduced by a better understanding of how they are related to the types of load and the conditions under which they are moved. Movements also involve operational and administrative work by the police and local authorities, such as escorting, road closure and temporary removal of street furniture, and wider costs of maintaining or assessing road structures for their ability to carry the loads. Finally, there may be impacts on safety, and the natural and human environment.

1.3 Alternative modes for large and heavy loads, such as rail and water (and potentially even air – see References), have their own issues of capacity, accessibility, investment and cost. This project aims to gain a better understanding of the congestion and other impacts caused by the movement of Abnormal Loads and the issues surrounding them. This will assist the Highways Agency in deciding whether and when to permit the largest and heaviest Abnormal Loads to travel by road, and to promote alternative methods of transporting Abnormal Loads, in particular by water.

1.4 This Final Report summarises the results of a project which has performed a Literature Review related to Abnormal Loads and related issues, conducted a Consultation of Stakeholders and Experts, monitored a number of Abnormal Load movements on the road, analysed the traces of loads on motorways using MIDAS, and developed a detailed Spreadsheet Model to enable congestion delays and costs caused by Abnormal Loads to be estimated as a function of route, day and time of travel, and load characteristics such as speed and take-up of lanes.

2 Approach to the project

2.1 In Phase 1 a Literature Review (Sanger 2003) was conducted covering all modes and their economic and environmental impacts, and a Feasibility Report (Taylor and Rees 2004) produced, primarily concerned with methodology for monitoring and measuring road movements.

2.2 In Phase 2 a consultation was conducted of a number of Stakeholders, some of whom are also members of the Expert Panel set up to advise the Highways Agency directly. This was mainly done by face-to-face meetings, but with some written submissions also.

2.3 In the final Phase 3 of the project, there were three main activities conducted simultaneously: live monitoring of selected loads, collection and analysis of data from MIDAS detectors, and development of the mathematical and spreadsheet model.

2.4 A separate Modelling Report (Taylor 2006) describes the mathematics embodied in the spreadsheet model. It uses an example of an actual move to illustrate the relationship between observed, modelled and MIDAS-derived queue measurements.

2.5 The Model’s results for congestion costs will contribute to the Highways Agency’s assessment of Abnormal Load applications. Other externality costs are identified, but their estimation for Abnormal Loads would require significant additional research, as no data specific to Abnormal Loads are currently available. In the absence of such research, estimated externality costs per mile can be input into the model to form part of the overall cost.
2.6 This Final Report summarises the above and includes statistics of load movements, the principal results of monitoring, MIDAS analysis and modelling, and the results of some sensitivity tests. A shorter Summary Report details the main non-technical issues and conclusions.

3 The nature and extent of Abnormal Load traffic

3.1 Abnormal Loads fall into several categories (Highways Agency 2005). Those exceeding 6.1m (20’) wide, or 30m long (rigid), or 150,000kgs, require a Special Order (SO) permit from the Highways Agency, of which 300-400 are issued every year. Agency guidelines state that it can take up to 8 weeks’ to process the application, and early contact at the planning stage is encouraged.

3.2 Other wide loads exceeding 5.0m (164”) up to 6.1m (20’) wide are required to be authorised under VR1, about 700-800 authorisations being made every year. Each SO and VR1 authorisation can cover a number of identical moves. Lesser loads are classified under other STGO or C&U regulations. For full definitions see footnotes in the Executive Summary.

3.3 The Special Order specifies the route and special cautions and manoeuvres in detail. It is normally valid for 6 months. SO transports over 150,000kgs are limited to 12 mph, and large slow loads usually require a police escort for all or part of their journey, to close roads and direct traffic, though the police are increasingly charging for this service.

3.4 Since January 2004, more routine escorting is being undertaken by the hauliers themselves or private escort companies. A self-escorting Code of Practice has been developed and circulated.

3.5 SO loads include wide heavy objects like electricity transformers, castings, industrial distillation columns and bridge sections (see Figures 1-3), but can also include lighter loads which are long, like wind turbine blades or girders. A number of factors influence the volume of movements, such as the number of power stations being renewed or dismantled, and the shipping of parts between facilities specialising in one particular operation such as casting or painting. Over the long term the number of loads seems to be relatively constant despite changes in industry.

Figure 1. Two-locomotive girder-frame transporter carrying electricity transformer (SO)
Figure 2. Boxed distillation column on separate rear-steerable trailers (SO)

Figure 3. Long articulated flatbed transporter with casting, negotiating roundabout (SO)

3.5 VR1 wide loads can be shorter, lighter and quicker (see Figure 4). Some narrower or lighter parts such as bridge or wind turbine sections may not qualify for SO or VR1 but are still of interest because of their potential effect on other traffic (see Figure 5).

Figure 4. Short articulated transporter carrying dump truck (VR1)
3.6 The Regulations have developed over the years in the historical context of standard road and lane widths. Single carriageway road widths used to be specified as 20ft, 22ft and 24ft. The current standard lane width, derived from the old wider road standard, is 12ft (3.65m). There is no firm opinion of how wide a load can be accommodated in one lane, in the sense that passing traffic can use all remaining lanes. Loads are sometimes able to overhang the verge or hard shoulder slightly. From monitoring experience, the borderline appears to be in the range 3.8-4.5m, but actual lane occupation can depend on the type of vehicle, the shape of the load and the practice of the police or private escorts (see also later in Section 6).

3.7 The government pursues a Water Preference policy to minimise disruption. Water transport is used or considered for some types of load, especially where water access to facilities is straightforward. Power stations, for example, tend to be sited near sources of cooling water and have slipways installed at the time of their construction. Water transport may be the mode of choice where there is a regular stream of traffic, for example waste of which London alone produces at least 850,000 tonnes per annum.

3.8 The profile of water transport has been raised by two recent developments. April 2004 saw the official launch at the Houses of Parliament of the unpowered seagoing pontoon Terra Marique\(^8\), which carried a decommissioned Concorde airliner to Torness, Scotland, and thence to the Museum of Flight at East Fortune (see Figure 6)\(^9\). The Terra Marique can accommodate the powered waterway barge Inland Navigator with its load, or up to 1200 tonnes of cargo evenly distributed (maximum indivisible load 400 tonnes). The vessels were funded by DfT and are operated by Robert Wynn and Sons Ltd. More recently, completed 40m wings for the Airbus A380 ‘super-jumbo’ airliner, unveiled on 18 January 2005, have been transported by barge from British Aerospace’s Broughton plant via the River Dee to Mostyn in Wales, for shipping to the assembly plant at Toulouse.

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\(^8\) Latin for ‘by land and sea’
3.10 Annual statistics of Special Order and VR1 authorisations have been obtained up to mid 2004 (VR1s were available from January 2004 only, and have been extrapolated from the 6 months’ data to one year). The distance distributions of SO and VR1 moves are shown in Figures 7 and 8 respectively. They are remarkably similar, presumably being determined by the locations of manufacturing or other source facilities and ports, utilities or other destination sites.
Figure 8. Annual distribution of distances of VR1 approvals (extrapolated from 6 months’ data)

3.11 Figure 9 (see over) shows the annual distributions of Special Order load dimensions and weight, taking into account the number of moves allowed for by each authorisation (it is not known whether all these moves were actually performed). Figure 10 shows the corresponding annual distributions for VR1 authorisations, which are restricted to width in the range exceeding 5.0m up to 6.1m, and also tend to be slightly shorter and lighter. Average statistics are not particularly meaningful because of the breadth of the distributions, but the average SO weight (per move) is 98 tonnes, and VR1 weight (per authorisation) 72 tonnes.
Figure 9. Distribution of dimensions of annual Special Order moves.
Figure 10. Distribution of dimensions of annual VR1 approvals (extrapolated from 6 months’ data)
4 Literature Review

4.1 The Literature Review (Sanger 2003) embraces 50 documents covering topics including: costs of transporting loads by road, environmental and socioeconomic effects of Abnormal Load transportation, intermodal transport, potential of waterways, and regulation and guidance.

4.2 For this particular project, the documents of most interest are concerned with modelling and environmental impact. There are also important documents relating to policy, which echo issues raised in the Consultation, especially the government’s report *Waterways for Tomorrow* (2000) and the Fourth Report from the House of Commons Environment, Transport and Rural Affairs Select Committee (2001).

4.3 No up-to-date information was found on the effect of Abnormal Loads. The last study which monitored the congestion effect of Abnormal Load movements was that by TRL (Dunn 1967). Since then, the nature of roads has changed considerably with the expansion of motorways and dual carriageways, and the speed of many AIL moves has increased with the introduction of more powerful locomotives and sophisticated trailer and suspension systems.

4.4 Work by DfT highlighted how sensitive delay and delay-cost can be to ambient traffic demand, the speed of the load, and the section length over which a queue builds up without relief.

4.5 Some data are available on the externality costs of general road, rail and water freight, including accidents and environmental impacts. When DfT figures are extrapolated to AILs (assuming one AIL is equivalent to 10 HGVs) an estimated externality cost of £3/mile is arrived at (as detailed in Appendix I to the Modelling Report). However, no data are available which relate specifically to Abnormal Loads, and this figure does not take account of externality costs of any queuing or diversion associated with the loads. These issues are considered in more detail later in Section 8.

5 Consultation

5.1 The Expert Panel set up to oversee the project, and to advise the Highways Agency directly, includes Stakeholders drawn from several interest groups, including:

- Water authorities and associations
- Road hauliers and their representative organisations
- Utilities and their representative organisations
- The Association of Chief Police Officers (ACPO)
- Local authorities
- National government

5.2 The Consultation involved members of the Expert Panel and other Stakeholders. Views aired were in many cases frank, and there are some differences of substance or emphasis between those whose main interests lie respectively with road and water transport.

5.3 Those concerned with road argue that costs of planning, surveys, fees, craneage, and special civil works (eg to strengthen landings), as well as some actual transport costs including those of road journeys to landings, tend to make water options uncompetitive. Some hauliers also complain that the government’s Water Preferred Policy can lead to extra cost and delay in planning routes and obtaining authorisations. Conversely, they point out that the regulations governing some road moves are very complex and appear to be based on dimensions in imperial units established years ago.

5.4 Those concerned with water argue that water facilities have suffered from a lack of investment and integration over many years, especially compared to roads. They criticise in particular the divided responsibility for waterways and the levying of waterway tolls. A further obstacle is lack of confidence that safe water depths will be maintained in canals and navigations, to ensure that destinations can actually be reached. Water Preference is government policy, but it is argued that action is needed if water facilities are to be ready for a future in which road movement may become increasingly costly, and environmental constraints increasingly severe. Opportunities may also exist
for developing new road/water interchanges to take advantage of the modern road network, for example between the River Thames and the M25 motorway near Chertsey.

5.5 Some see the costs of water transport, combined with the perceived positive subsidisation of the road network, as putting water transport at a major competitive disadvantage. The following quotation may sum up this perception: “At present, where [operators] seek to move Abnormal Loads by inland waterway in competition with road hauliers, [they] are faced with a whole range of costs that, rather than reflecting the intrinsic costs of using each mode, are a direct result of a lack of investment in waterway infrastructure and a set of government policies that .. effectively demonstrate a preference for road transport”\textsuperscript{10}.

5.6 The police are concerned mainly with the practical issues of escorting and safety. They are content with self-escorting by hauliers or their contractors provided there are no major safety issues, but consider that conferring any additional powers to replicate those of the police could cause difficulties. The police wish in particular to remain involved in any traffic management duties related to AILs, though some forces now carry these out on a contract basis.

5.7 Local authorities take the view that most AIL movements are well planned, but are concerned that route planning does not place enough emphasis on the restrictions and impacts on local authority roads, a situation which if true should improve with the introduction of the ESDAL\textsuperscript{11} on-line planning and notification facility.

6 Issues and costs in road movement

6.1 This section summarises issues affecting road transport of Abnormal Loads, and represents an updated summary of issues addressed in the Feasibility Report.

6.2 \textbf{Timing} - The cost, in terms of delay and congestion to other road users, of moving an Abnormal Load by road is sensitive to the day and time of day of the move (see later in Section 13). Some moves are made overnight, but some police forces require that a large, slow load move only during daylight hours for reasons of safety, particularly on high-speed roads, and they may be prepared to escort only at certain times. Hauliers do however have some freedom in deciding when to travel, a common strategy being to divide the journey between a Saturday and a Sunday, even starting on Friday if the journey is very long. One reason why they do this is to allow slack for contingencies. Early morning starts on a Saturday or Sunday are common, and enable several hours’ travel before the peak, which tends to occur near the middle of the day at the weekend. If moving on a weekday, a small-hours or late morning start is more likely in order to avoid the morning peak. Season is also a factor: daylight hours are much longer in summer, and peaks are lower during the school holidays, though holiday traffic is best avoided. For these reasons, a model needs to be very flexible in the way it allows timings to be varied.

6.3 \textbf{Width} - Large transporters including girder-frame types typically occupy two lanes (see eg Figures 1 and 2). Smaller transporters, including rigid flat-bed types capable of carrying loads over 200 tonnes, may be able to fit into one lane, except when manoeuvring (see eg Figure 3). This can make a critical difference to delays on busy roads or if single carriageway roads have to be closed to traffic moving in the opposite direction. While there is no agreement about the dimensions at which loads start to create special problems for other traffic, the self-escorting Code of Practice gives guidance about widths above which the police are likely to require that the load be escorted: 4.1m on local roads and 4.6m on motorways. Among the moves observed (see later in Section 9), loads up to 4.5m wide were able to run in one lane for much of the time.

6.4 \textbf{Speed} – Special Order loads over 150,000kgs are limited to 12 mph, but many people involved in the actual moves consider that this is unrealistically low and needs reviewing. Girder-frame transporters are not physically able to move quicker than about 14 mph. However, other types

\textsuperscript{10} From consultation response by Commercial Boat Operators Association

\textsuperscript{11} See later in Section 6
of transporter are capable of moving considerably quicker, theoretically even when carrying a 200 tonne load. The speed of a load can have as critical an impact as lane-take on delay to other traffic. Raising the speed could reduce congestion costs considerably but could have implications for safety, depending on whether vehicles have adequate braking, and the dynamic loading on bridges would need to be assessed.

6.5 **Traffic flow** - Day-to-day variability, and the rapid change in demand at certain times, especially in the morning peak, are such that the ambient demand on a road section can never be known precisely in advance, only estimated. This can be critical in some cases where demand is close to or exceeds the capacity remaining when the load is present. As will be seen later in Section 11, queuing and delay tend to occur on a few critical sections rather than uniformly along a load’s route.

6.6 **Stopping** - The largest loads are severely limited as to where they can stop, and there is no inventory of suitable stopping places or of sizes which public service areas can handle, and not all motorway service area owners are willing to accommodate Abnormal Loads. Hauliers rely on their experience when planning stops, either overnight, or for short periods to let queuing traffic pass or provide a ‘comfort stop’ for crew.

6.7 **Police and escorting practice** – The largest and slowest-moving loads observed, as well as most night-time moves, were all escorted by the police, so it was not possible to compare police and private escorting practice with similar loads under identical conditions. However, a heavy load carried by a flatbed transporter was able to travel briskly in daylight, under private escort alone. One reason for caution with girder-frames is that they are wide and low-slung, so more likely to conflict with other vehicles and street furniture, and are less manoeuvrable as a result of having two locomotives and up to three drivers. However, the impression was got that the police were particularly cautious and had a strong influence on passing traffic, thanks to their visible presence and blue flashing lights, and their practice of possessing lane 2 well behind a wide load. Passing drivers tended to slow down more than they might otherwise have done, to 30 or even 20 mph, which could reduce effective passing capacity. Currently only the police are allowed to close roads and direct traffic, though self-escorting vehicles can influencing traffic by positioning the vehicle in the road. Since 1 January 2004, when the police have been needed they have been more likely to levy charges. The police tend to impose a fee based on the number of cars or officers with a minimum four hour contract, typically around £880 per ‘slot’, or about £2K per ‘day’ of 9 working hours (figures based on Consultation). A major move may spread over 2 days, so police fees could amount to £2-4K.

6.8 **Whole-journey costs including infrastructure** - These costs will be wide-ranging, but can be in the region of £10-40K for the heaviest loads, depending on load type and distance travelled, not including bridge assessment (detailed assessments can cost £20-30K) and street furniture removal or overhead cable protection costs (typically £2.5K, sometimes more) if necessary. The need for specialist trailers with two or more tractors to carry the heaviest loads increases the cost. Removal and replacement of street furniture must be carried out by the responsible authority and may be achieved ‘while you wait’ or require temporary road closure, depending on the circumstances. Road closure to allow special manoeuvring of the load may need to be done some time in advance to ensure that the road is completely cleared. Bridge assessments are usually carried out for each move because past assessments cannot be relied upon and even recent assessments are not usually acceptable for insurance purposes. Table 1 summarises these costs.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost Estimate</th>
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<tbody>
<tr>
<td>Planning</td>
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<tr>
<td>Operational</td>
<td>£10-40K</td>
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<tr>
<td>Escorting and police</td>
<td>£2-4K</td>
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<tr>
<td>Street furniture removal and replacement</td>
<td>£2.5K</td>
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<tr>
<td>Bridge and structure assessments (where needed)</td>
<td>£20-30K</td>
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</table>
6.9 **ESDAL** - (Electronic Service Delivery for Abnormal Loads) is an internet portal being set up by the Highways Agency which will help hauliers carrying Abnormal Indivisible Loads plan their journeys. It will be launched later in 2005, and will eventually provide near-real time route planning assistance (see Platt 2004). This on-line system will contain information on structures, for example weight and height restrictions, as well as comprehensive network information including names of local authorities who need to be consulted or notified. This project is expected to facilitate the process of choosing road routes, and will be a ‘one-stop-shop’ for notifications.

6.10 **Trailers returning empty** - These are likely to have different characteristics from loaded moves. In particular vehicles will be lighter, and possibly narrower and quicker, then when loaded, and may be less restricted as to their choice of route and travel time. However, they can in principle be treated in the same way as loaded vehicles, with appropriate adjustment to variables if modelled. As an example, a large two-locotive girder-frame set, limited to 12 mph when loaded (>150t) breaks down into two sets each of one locomotive (~40-50t) and one compacted trailer unit (~40-60t), with a maximum width of 4m and maximum speed of 30 mph. Such a convoy, while still large, is much less disruptive than a loaded train, and the drivers will try to take up as little road space as possible, although it may not always be possible to avoid obstructing traffic in lane 2. No data are available on empty mileage, as this depends very much on individual cases. Sometimes a set can return loaded (eg from a port). In other cases, it may have to make a long empty trip from its base to carry a load only a few miles. Since empty transfer is likely to be less disruptive than a loaded move, it should be considered whether the expense of modelling and approval procedure is justifiable.

### 7 Water movement and ‘Test of Reasonableness’

7.1 The idea of a ‘Test of Reasonableness’ is to compare the likely total costs of alternative moves by road and using water, to determine whether a move using water is a reasonable alternative. This is not an exact procedure, because exact costs may not be available, but it can give an indication whether there is a case for considering a water move. For some movements, it may be appropriate to assess whole-journey costs (from load origin) rather than just the final leg to the destination.

7.2 Congestion is not normally an issue of water transportation. For road moves, the estimated congestion cost per mile needs to be based on analysis of the specifics of the actual or planned moves, as there is no general or even average figure for all loads on all roads. Later Sections of this Report will show the extent to which congestion cost can vary depending on the characteristics of the load, its route and timing.

7.3 Moves using water may involve road segments to and from transhipment points, which need to be evaluated in the same way as full road moves. Other water movement costs are less directly dependent on distance than for road transport and involve a large, sometimes dominant, component of intermodal transfer costs, especially craneage. High capacity (eg 1000 tonne) cranes may be required and have to be brought in by road.

7.4 For road portions of moves involving water, operational costs specific to each move will include the costs discussed earlier in Section 6, namely:

- planning costs
- escorting and police
- cost of removal, restoration or protection of street furniture, telephone lines and utilities
- costs of bridge and other structure assessments

7.5 For water moves, operational costs specific to each move include:

- costs, fees and risks involved in extra planning and surveying
- infrastructure costs: upgrading, dredging and civil works to prepare ground or landings
- shipping costs
- cost of road portions of journey where applicable
7.6 Extra survey costs have been reported to be particularly high because access routes to water facilities can be in poor repair and information incomplete. Figures of £20K have been mentioned, compared to £2K for planning a road-only route. Dredging may be undertaken specifically to allow the Abnormal Load to pass, though British Waterways have a statutory duty to dredge inland waterways and some ports, to maintain depth at the 1967 level. Civil works may be needed to prepare landings and bases for cranes. As a consequence of leverage, structures may have to withstand greater forces than the weight of the load would suggest.

7.7 A range of costs associated with a typical ‘water move’ for an Abnormal Load is estimated in Table 2 below. This shows that avoiding craneage can be critical, giving roll-on roll-off (Ro-Ro) vessels an advantage on shorter routes where costs can be reduced. Sea-going vessel costs can vary widely, depending on whether they need to be towed, and where the loads are picked up or deposited in relation to their ‘home’ ports.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost Estimate</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Up to £20K</td>
<td>Depending on special survey needs</td>
</tr>
<tr>
<td>Road Journey to/from water</td>
<td>£10K-40K each time</td>
<td>Depends on distance and weight of load</td>
</tr>
<tr>
<td>Craneage on/off vessel</td>
<td>£5K – 55K</td>
<td>Depends on weight and reach for size of crane required</td>
</tr>
<tr>
<td>Vessel Charges</td>
<td>£5K – 100K</td>
<td>Depends on distance and vessel type – inland or sea-going, scheduled or charter</td>
</tr>
<tr>
<td>Extras: e.g.port fees, surveys, insurance etc</td>
<td>c £10K</td>
<td>Can be greater if extensive dredging is necessary</td>
</tr>
</tbody>
</table>

7.8 Craneage is not only costly but deploying a mobile crane may require the movement by road of a large number of vehicles. For a very large crane (1000 tonne capacity), such as may be required to shift a smaller load where ground conditions call for a long reach, the fleet could consist of:

1 76-125 tonne main crane body, Cat 3 STGO, max speed 20-30 mph but only 3m wide
5 100 tonne gross Cat 3 STGO support vehicles, max speed 40 mph
up to 30 smaller C&U vehicles and escort vehicles.

7.9 For a smaller crane (300 tonne capacity), two 100 tonne support vehicles would be required, and some operators use 80 tonne Cat 2 vehicles. The cost of deploying a 1200 tonne capacity crane has been quoted at £85K (somewhat higher than the maximum given in Table 2), but this is assessed on a ‘per hire’ basis. Such a crane may operate for just one day, but take 3 days to erect and 3 days to dismantle12. One operator says that most travelling is done at night, but another says that fleets tend to travel during the day, using motorways. Vehicles tend to travel individually, not in convoy. Because the number of large cranes in the country is very limited, there is no upper limit to the distance they may have to travel to site.

7.10 When comparing a road move with a water alternative, each case will have an individual set of circumstances, so the costs will need to be evaluated on a case-by-case basis. These should include the costs tabulated above. Because these costs can vary over a wide range, it is not possible to set fixed criteria under which water moves becomes advantageous.

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12 Sources of information: Ainscough Crane Hire and Abnormal Load Engineering Ltd (ALE).
7.11 Although assessing each case individually may expose initial high infrastructure investment costs, if repeat moves are likely over the longer term, then this should be taken into account, as well as whether the move is part of a larger project and whether the load is travelling directly from one port to another port.

7.12 Upgrading canal or wharfage facilities is never likely to be economical unless repeat business can be guaranteed, but this will not be forthcoming unless the availability and quality of the facilities can be guaranteed. Hence the view from the Consultation that government action is needed to initiate a virtuous cycle. Regular business is already present in the form of waste transport, but Abnormal Loads tend to be more sporadic. Therefore, water networks will need to be able to serve a variety of routes and loads.

7.13 However, many Abnormal Loads start or end their journeys at just a few major ports or manufacturing sites, for example: Chepstow, Immingham, Ellesmere Port, Newport, Loughborough and Sheffield. Opportunities may also exist for new dedicated road/water interchanges to take advantage of the modern road network, for example between the Thames and the M25 near Chertsey.

7.14 There are no AIL-specific data on externalities. Water transport is much less polluting than road transport (estimates vary from 3 to 10 times less per tonne-km\(^{13}\)) so externality costs are likely to be less of a factor than for road moves. However, this must be balanced against the possible additional costs and risks associated with water movement and cargo trans-shipment, especially finding that part of a channel has inadequate depth. Externalities are considered in more detail in the next Section.

### 8 Other externality costs besides congestion

8.1 It is clear from the Literature Review that on a tonne-mile basis water transport is both more energy-efficient and less polluting than road transport (and better than rail also). It probable, on the basis of figures estimated for general freight, that externality costs imposed by water moves are less than those for equivalent road moves.

8.2 Other externality costs to be factored in include, in approximate order of importance\(^{14}\):

- Road wear and damage to infrastructure
- pollution caused by load and slow-moving traffic Including impact of diverted traffic
- climate effect
- additional accidents
- damage to the built and natural environment, including removing vegetation to clear path
- impacts of ‘upstream processes’ such as additional fuel production, where relevant
- noise
- inconvenience and disruption of removal, restoration or protection of street furniture.

8.3 The ordering of externalities given above may not apply to AILs. In particular, the presence of queues could increase the importance of those externalities linked to them: pollution, additional accidents and noise. It is worthwhile concentrating on those three, which appear to be quantifiable on a case by case basis, provided that it is judged that other externalities, which cannot be so easily quantified, are likely to be less important for AILs.

8.4 However, there is a lot of variation between different estimates even for general freight (see Modelling Report), and no specific evidence for Abnormal Loads. The following paragraphs contain observations about the externalities listed in the previous Section, bearing in mind there are important differences between Abnormal Loads and general freight, which could affect estimates, namely:

- size and weight (generally much greater than an HGV)
- speed (often much slower than an HGV)
- presence of queuing traffic

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\(^{13}\) Based on sources identified during the Review and Consultation – see Appendix to Modelling Report.

\(^{14}\) The order reflects that estimated for general freight, but may not necessarily apply to AILs.
8.5 Once estimates have been made, a ‘headroom factor’, such as 2, can be applied to uncertain values before comparing total costs to see whether the externality costs can alter any decision based on substantive and congestion costs alone. Expert opinion and detailed studies might furnish a better headroom factor. However, the cost of such research must be balanced against the likely benefit, if externality costs are generally a small fraction of substantive and congestion costs.

8.6 Various sources have estimated overall externality costs of general road traffic (see Modelling Report Appendix I). One authoritative source (Tinch 1995)\(^\text{15}\) breaks these down in to a form which can be used for estimating externality values in parallel with the congestion model.

8.7 *Road wear and damage* - large AILs such as girder-frame sets can have axle loadings up to 16.5 tonnes, but spread over 8 wheels, and hydraulic suspension may distribute the load more evenly than on an HGV. Large sets also tend to move much more slowly than HGVs. Although road wear and damage is known to be highly sensitive to loading (the ‘fourth power law’) there is no *prima facie* reason to suppose than an AIL should do more damage than the equivalent weight of HGVs. Road damage caused by a heavy AIL has been estimated at 50p/mile\(^\text{16}\).

8.8 *Pollution* (airborne and runoff) and climate effect – AILs are usually diesel powered and fuel efficiency is not a priority. Operators are likely to have a good idea of the fuel consumption of different types of vehicle, and to first approximation pollution and CO\(_2\) production (climate effect) can be estimated on this basis, and possibly related to that of an ordinary HGV. This may be outweighed by pollution produced by queuing vehicles, whose nature and quantity will depend on their speed. However, it must be kept in mind that the effect of the AIL in their case is only the *extra* pollution from the change in behaviour of vehicles which would be present in any case. Detailed formulae exist relating production of pollutants to average speed for a wide range of vehicle types, and the average composition of UK traffic is known, so it should be possible to estimate the pollution and climate effect of an AIL move section by section. The *valuation* of pollution depends on the effect it has which may not be linearly related to dose. However, AIL movements are short-term events and a dose-response relationship may not then apply.

8.9 Eleven moves were both monitored and modelled (see Tables 4 and 7 later). These travelled a total of 2201 km (1368 miles) with average load of 197 tonnes and estimated total congestion cost of £256.5K\(^\text{17}\). The average health cost for all driving is estimated as 0.54 p/veh-km while the cost for urban driving is estimated as 2.86 p/veh-km (Tinch 1995). This figures need to be inflated by 1.33 between 1993 and 2004 prices. If the additional pollution in queues caused by AILs is *at most* the difference between these multiplied by the total veh-km spent in queues, the *total* cost of extra pollution by the 11 moves is estimated to be £12.5K (4.9% of congestion cost). The true value could be lower because of the relatively high forward speed of vehicles in the queue. If each AIL is assumed to be equivalent to twenty HGVs (average weight 10 tonnes) in urban driving conditions, its health cost is 289.6 p/km, giving a health cost of £6.4K, making a total of £18.9K (7.4% of congestion cost).

8.10 *Additional accidents* – These fall into two categories: those involving the load directly and those related to the load’s effect on other traffic. Only one recent case of direct collision with a large AIL has been encountered (anecdotally), where a speeding vehicle reportedly struck an AIL on the M4 at night, resulting in a fatality. Verifiable cases which have been reported include cars colliding with a parked trailer in fog, and a car coming in the opposite direction hitting an overhanging load.

8.11 Data on accidents involving STGOs assembled from STATS19 records by TRL\(^\text{18}\) show that these types had a higher accident rate in the study period (1989-1995) than HGVs and other motor vehicles. A total of 194 accidents were recorded, consisting of 10 fatal, 51 serious and 133 slight, for an average annual travel of 29 M veh-km. Adjusted to 2004 prices, this amounts to a cost of 21.2p per vehicle mile, contributing only £290 to the *total* cost of the modelled journeys, which is a negligible proportion of the congestion cost. However, this does not distinguish between different STGO types.

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\(^{15}\) Identified by James Edwards, HA, who also gave advice on assessment methods.

\(^{16}\) Personal communication by Stuart Porter, DfT (2002)

\(^{17}\) These loads are not representative of all AILs, but heavier and more disruptive than average.

\(^{18}\) Internal communication by R Bartlett and I Simmons
8.12 Some Swedish research\textsuperscript{19} suggests that the probability of an HGV being involved in an accident increases with axle loading, although there is no separate analysis of very heavy vehicles. Based on this, the annual accident risk of a heavy vehicle with 16.5t axle loading would be about three times that of a light vehicle with less than 2t axle loading. According to DfT analysis\textsuperscript{20} (see Modelling Report Appendix I) the marginal cost of accidents per HGV-mile is 2.7 pence (2004 prices), but the difference in axle loading between the heaviest AIL and an average HGV would not be as large as indicated above. Also it is not clear that the dependence on axle loading is causative.

8.13 \textit{Additional accidents in queues} – research using M1 and M25 data, principally aimed at measuring the effect of MIDAS or HIOCC queue detection\textsuperscript{21}, arrived at estimates of one injury accident \textit{anywhere in the queue} per 25 hours of queue tail on the M1, and one injury accident \textit{at the queue tail} per 144 hours of queue tail on the M25. The rates of damage-only (DO) accidents were respectively about 1.5 and 2 times the personal injury accident (PIA) rates. These small ratios, incidentally, are at variance with the normally assumed ratio on motorways of 7.6:1 as quoted in the Tables 3 below based on 2002 data, which refer to accidents in all motorway conditions\textsuperscript{22}.

\textbf{Table 3a. Average value of prevention of road accidents in GB by road type (2002 £)}

<table>
<thead>
<tr>
<th>Accident type</th>
<th>BU roads</th>
<th>NBU roads</th>
<th>M-ways</th>
<th>All roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>1,357,240</td>
<td>1,492,360</td>
<td>1,698,930</td>
<td>1,447,490</td>
</tr>
<tr>
<td>Serious</td>
<td>159,880</td>
<td>184,040</td>
<td>190,740</td>
<td>168,260</td>
</tr>
<tr>
<td>Slight</td>
<td>15,850</td>
<td>18,840</td>
<td>21,990</td>
<td>16,750</td>
</tr>
<tr>
<td>Damage only</td>
<td>1,400</td>
<td>2,060</td>
<td>1,990</td>
<td>1,490</td>
</tr>
<tr>
<td>\textit{Average Injury}</td>
<td>44,760</td>
<td>95,700</td>
<td>73,430</td>
<td>57,760</td>
</tr>
</tbody>
</table>

\textbf{Table 3b. Percentage of accidents according to severity (2002)}

<table>
<thead>
<tr>
<th>Accident type</th>
<th>Urban A roads</th>
<th>Rural A roads</th>
<th>Motorways</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>0.98</td>
<td>3.19</td>
<td>1.96</td>
</tr>
<tr>
<td>Serious</td>
<td>12.15</td>
<td>17.31</td>
<td>11.04</td>
</tr>
<tr>
<td>Slight</td>
<td>86.87</td>
<td>79.50</td>
<td>87.00</td>
</tr>
</tbody>
</table>

\textbf{Table 3c. Average number of damage only accidents per injury accident (2002)}

<table>
<thead>
<tr>
<th>Urban roads</th>
<th>Rural roads</th>
<th>Motorways</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.7</td>
<td>7.8</td>
<td>7.6</td>
</tr>
</tbody>
</table>

8.14 Since injury accidents are far more costly than damage only, at around £57.7K compared to around £1.5K, the exact value of the ratio is not critical. Injury accidents on motorways are about 27% more costly than the average for all roads; on other road types of rural character the cost is 66% greater, while on urban roads it is 23% lower. This pattern is also followed approximately by the cost of damage-only accidents, though these represent a higher proportion on urban roads.

8.15 ‘Hours of queue tail’ is synonymous with the total time that a queue is present, which is always available when a queue is modelled. However, while the figures quoted may be generally applicable to motorways, the accident rate must depend also on the amount of traffic exposed per hour of queue tail, which is obviously much more on motorways than other roads. It may therefore be preferable to express accident cost in terms of number of vehicles affected by queues. There is also a distinction between expected (sometimes ‘regular’) and unexpected queue tails. The former might be associated with long-term road works or peak periods, while the latter would apply to incidents.

\textsuperscript{19} Lindberg G (2001). External accident cost of heavy goods vehicles. SNRA.
\textsuperscript{20} Surface Transport Costs and Charges Great Britain 1998 (Sansom \textit{et al} 2001), Tables 7.4 and 7.5
\textsuperscript{22} Personal communication by I Summersgill based on ‘Road accidents GB: the casualty report’ (2002).
8.16 Unexpected queue tails appear to roughly double the cost or risk per unit time or unit number of vehicles exposed compared to expected queues. The M1/M25 figures quoted earlier embrace both types, but an AIL is arguably more likely to produce an unexpected queue tail. Using data from the M25 the costs (DO and PIA) estimated for motorways are between £78K (expected queue) and £182K (unexpected queue) per million vehicles, with (contra-flow) road works intermediate at £109K. Single-carriageway A-road cost is estimated at a lower figure of £13K per million vehicles.

8.17 The additional accident cost resulting from queuing could be overestimated for three reasons:
- the presence of warning or speed limit signs (MIDAS and HIOCC has been found to reduce the proportion of injury accidents by a factor from 1.5 to 3);
- Queues following AILs may expose fewer vehicles to risk, for a given duration of queue tail, than ‘normal’ queues, because of the lower density of traffic in the queue;
- Because of the load’s motion, the tail of the queue is likely to move downstream, decreasing the closing speed for approaching traffic and reducing the likelihood of stop-start waves.

8.18 Taking the motorway road works accident cost as a fair estimate for motorways and a conservative estimate for other roads, and estimating, again for the 11 modelled moves, the number of vehicles exposed to queuing estimated conservatively from the model (a simple calculation), the total cost of accident-risk is estimated to be £5.7K compared to the total congestion cost of £256.5K (a ratio of 2.2%). The highest value for any of the moves is under 10% of congestion cost, this being for a move with very low congestion cost. It must be emphasised that these moves were chosen for the information they could provide on congestion caused by AILs, not to be representative of AIL moves, so they produced much more queuing than on average. The conclusion is that the probable accident cost associated with queuing is not enough to affect decisions in these cases, and this remains true even if the maximum ‘unexpected queue tail’ cost is assumed.

8.19 Other accidents – these could occur in the traffic passing the load or in the dense flow accelerating away from a queue after the load has left the carriageway, or in diverted traffic. It is not obvious how the first two could be estimated since they are potential marginal effects of changed behaviour within traffic that is going to be present anyway. For diverted traffic, we can apply the same ‘equilibrium’ principle used for delay, that the accident rate is calculated for the traffic remaining in the queue behind the load, and factored up for the total traffic affected. Because queues can disrupt the flow of large numbers of vehicles, they probably represent the greatest accident risk, but even if the overall accident-risk cost were assumed to be double that from queuing (say 5% of congestion cost for a fairly disruptive move), it would still not be enough to affect decisions.

8.20 Damage to the environment – which, if not already covered by local authority or utility charges, is difficult to estimate because, by its nature, its impact is likely to be ‘down the line’ and may emerge only slowly. Possibly it could be accommodated by multiplying the LA charge by a factor, which could be arrived at by averaging estimates made by a number of experts. Since AIL loads tend to be engineering products rather than, for example, chemicals, it is unlikely that AIL loads as such pose a proportionately greater risk to the environment than HGV loads. Some types of damage, such as clipping walls, buildings, road signs or trees, may be covered by insurances whose premiums are already included in the operational cost of the move.

8.21 Upstream processes – are unlikely to be proportionately different from those applying to any other transport and so could be covered by an appropriate multiple of figures applying to an HGV.

8.22 Noise – will be strongly case-dependent. Figures exist for average valuation of traffic noise (Tinch 1995), but these may not be relevant since it is additional and unusual noise which is in question. On a motorway the noise of an AIL is not likely to be any more important than that from an equivalent weight of HGVs, but in a town at night or in the early hours it could be considered disruptive. In such cases it is possible that any ‘externality liability’ could be settled through representations to the local authority. Noise could be evaluated in the same way as pollution (health effect) per vehicle-km, but the direct and indirect noise impact of an AIL is harder to visualise in this

23 Personal communication by Ian Summersgill, TRL.
way because the effect of noise is much more local than pollution, and it depends on identifying someone who is disturbed, who would not have been otherwise.

8.23 Alternatively, noise can be valued ‘hedonically’ by comparing property values in areas with different noise levels, or by calculating the cost of suppression, eg by double glazing. The actual valuation varies widely between countries. A typical figure is £500 per person disturbed per annum at 1993 prices (Tinch 1995). If a girder-frame AIL moving at 12 mph disturbs everyone in a street of houses 7m wide each occupied by 2.4 people, for one minute, then the disbenefit it inflicts is (with inflation) about £16 per hour or £1.33 per mile. The practical figure is likely to be much less because most AILs are less noisy and do not spend much time close to habitations. Also, as for pollution, AILs are present only occasionally and for a short time, so their disturbance may be valued less than continual levels of noise. Paradoxically, by slowing traffic on a motorway, an AIL could actually reduce noise disturbance as well as emissions associated with speeding like nitrogen oxides.

8.24 To summarise, for the 11 more than averagely disruptive moves observed and modelled, the following comparative total externality costs have been estimated:

- congestion £256.5K (as modelled)
- road wear and damage £0.7K (based on mileage)
- health <£18.9K (additional, related to queuing)
- accident-risk £5.9K (mainly related to queuing)
- noise <£1.9K (related to mileage)

8.25 Since these figures are calculated for the observed-and-modelled AIL journeys, they are not representative of all AILs but relate only to larger, heavier types. This is double-edged. On the one hand, such AILs might be thought to be relatively major producers of externality costs, particularly associated with queuing. On the other hand, the lower congestion costs of other AILs may mean that their other (non-queue-related) externalities represent a greater proportion of their congestion cost.

8.26 Externalities specific to water moves include particularly the environmental effects of dredging and other works. Dredged sludge may have accumulated potentially harmful industrial or agricultural poisons and anaerobic biological products. The minimum externality cost in addition to the cost of dredging is therefore the cost of safe disposal or treatment of the waste material.

8.27 Emissions and accident costs of inland water transport can estimated as about £6.13 per vessel mile (or a total of about £8.4K for the observed and modelled moves assuming same distance), based on figures for general cargo cost per vessel-km factored by costs per equivalent lorry mile (average load 9.9t) for the same and for inland waterway vessels, plus an accident cost of 81p/km specific to inland vessels. This is somewhat greater than would be estimated on a tonne-mile basis using figures given in the Modelling Report, Appendix I, but would probably apply only to the largest loads.

8.28 For the externalities which have been quantified here, albeit roughly, the indications are that the additional costs are in any case too small to affect decisions about moves or their routing. For externalities which have not been quantified, one possible approach to estimation would be to discuss their value among interested parties, to achieve a consensus or compromise view. Externalities which might be addressed in this way include (as well as noise):

- vibration including bank damage by water craft
- social costs not already considered, such as disruption of public services
- visual intrusion
- barrier effects
- social costs of waterway disruption, eg interference with leisure
- administrative costs borne by society

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24 ‘Valuation of marginal external costs of water transport’ document provided by Highways Agency.
9 Monitoring on the road

9.1 Dunn’s analysis (Dunn 1967) is limited to comparison of the average speeds of traffic with and without the presence of the load, assuming no overtaking. Today, many loads move on multi-lane dual carriageways where there are opportunities for overtaking and the combination of queuing and passing makes analysis of the delay effects more complex. However, Dunn’s report is of historical interest in terms of the types of load surveyed, and the delay costs which ranged from £19 to £179 per mile at present day values of time. For cost and safety reasons it was considered impractical to repeat the approach used by Dunn of stationing observers every 2 miles along routes. The monitoring methods actually used depended on the speed of the load and the type of roads along which it travelled, and also evolved somewhat over the course of the project.

9.2 A monitoring team was mobilised for seventeen AIL moves. These particular moves were chosen for the information they could yield about different types of Abnormal Load under different conditions, not as a representative cross-section. VR1 moves are clearly under-represented, as it is difficult to obtaining reliable information in advance from hauliers about when and where such loads are to travel, because the Highways Agency does not plan their routes. C&U moves up to 4.3m wide, thanks to their higher travelling speeds, are likely to have less of an effect on traffic, and probably not significantly more than that of ordinary HGVs, so it was not considered cost-effective to pursue them. Three moves were cancelled at the last moment, for various operational reasons – eg high winds, unexpected height restriction, wrong type of crane on site. The remaining fourteen moves for which data were obtained are listed in Table 4.

Table 4. Summary of moves observed (excluding cancelled moves)

<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Load Type</th>
<th>Distance (miles)</th>
<th>Width (metres)</th>
<th>Weight (tonnes)(^{25})</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheffield</td>
<td>Immingham</td>
<td>SO</td>
<td>102</td>
<td>3.24</td>
<td>213</td>
<td>Flatbed artic.</td>
<td>Fri night/Sat</td>
</tr>
<tr>
<td>Tilbury</td>
<td>Elstree</td>
<td>SO</td>
<td>56</td>
<td>3.80</td>
<td>270</td>
<td>Girder-frame</td>
<td>Affected by snow</td>
</tr>
<tr>
<td>Sheffield</td>
<td>Hull</td>
<td>SO</td>
<td>68</td>
<td>2.75</td>
<td>194</td>
<td>Flatbed artic.</td>
<td>Non-stop overnight</td>
</tr>
<tr>
<td>St Neots</td>
<td>Cambridge</td>
<td>SO</td>
<td>24</td>
<td>4.50</td>
<td>65</td>
<td>Two artics.</td>
<td>Overnight move</td>
</tr>
<tr>
<td>Stafford</td>
<td>Seaforth</td>
<td>SO</td>
<td>77</td>
<td>5.90</td>
<td>294</td>
<td>Girder-frame</td>
<td>Sat/Sun daytime</td>
</tr>
<tr>
<td>Stafford</td>
<td>Seaforth</td>
<td>SO</td>
<td>77</td>
<td>5.90</td>
<td>294</td>
<td>Girder-frame</td>
<td>Sat/Sun daytime</td>
</tr>
<tr>
<td>Bolton</td>
<td>Liverpool</td>
<td>SO</td>
<td>66</td>
<td>6.13</td>
<td>332</td>
<td>Girder-frame</td>
<td>Indirect route</td>
</tr>
<tr>
<td>Deeside</td>
<td>Stafford</td>
<td>SO</td>
<td>71</td>
<td>4.85</td>
<td>408</td>
<td>Girder-frame</td>
<td>Sat/Sun day</td>
</tr>
<tr>
<td>Ellesmere</td>
<td>Cefn Croes</td>
<td>STGO</td>
<td>97</td>
<td>4.30</td>
<td>93</td>
<td>Artic. convoy</td>
<td>Wind-towers</td>
</tr>
<tr>
<td>Ellesmere</td>
<td>Cefn Croes</td>
<td>STGO</td>
<td>97</td>
<td>4.30</td>
<td>93</td>
<td>Artic. convoy</td>
<td>Wind-towers</td>
</tr>
<tr>
<td>Immingham</td>
<td>Cefn Croes</td>
<td>SO</td>
<td>244</td>
<td>2.70</td>
<td>40</td>
<td>Artic. convoy</td>
<td>Wind-blades (long)</td>
</tr>
<tr>
<td>Acrefair</td>
<td>Ellesmere Port</td>
<td>SO</td>
<td>46</td>
<td>5.10</td>
<td>288</td>
<td>Large artic.</td>
<td>Indirect route</td>
</tr>
<tr>
<td>Southampton</td>
<td>Fleet</td>
<td>SO</td>
<td>39</td>
<td>5.43</td>
<td>301</td>
<td>Girder-frame</td>
<td>Small hours</td>
</tr>
<tr>
<td>Airdrie</td>
<td>Southampton</td>
<td>VR1</td>
<td>452</td>
<td>5.25</td>
<td>110</td>
<td>Short artics.</td>
<td>2 T100 dump trucks</td>
</tr>
</tbody>
</table>

9.3 In addition to the cancellations mentioned above, two of the moves monitored incurred starting delays caused by accident or equipment failure, and two others were held up en route by equipment failure. There appears to be quite a high risk of such delays, but most hauliers, through experience, prudenty allow sufficient time to meet critical deadlines, as well to observe practical constraints on moving during busy periods. For example, the moves from St Neots to Cambridge were

\(^{25}\) Weight per vehicle where several in convoy.
the final stage of journeys starting at Sunderland on Fridays, having to coordinate with a critical railway possession in Cambridge on Sunday night. One of these was stopped for a whole day on the A1(M) by an unrelated fatal accident which, because of road surface damage and repair work, effectively closed the road to the large vehicles. Nevertheless, the convoy still managed to meet its deadline.

9.4 The method of monitoring depended on the nature of the move, its speed and the type of roads it would use, and did not necessarily cover the entire journey but concentrated on the points where the most useful data were expected. In the earlier moves, an observer travelled with the convoy, as a passenger in an escort vehicle or a police vehicle. This gave an insight into escorting practice, and enabled section speeds, traffic flows and delays to be assessed under light traffic conditions. However, it was not so useful in heavy traffic because no direct information could be obtained about the build-up of large queues, and in one case the responsibilities of the police driver meant that the viewpoint was less than ideal during critical stages of the move.

9.5 Later SO moves, in particular from Stafford to Seaforth via M6 and M62, were observed by ‘flying car’, driving to various vantage points where flows before and after the passage of the load could be measured, at least approximately given the short time often available. Because of the length of queues involved, opportunity to measure the queues was limited to two occasions. By driving down the opposite carriageway of the M6 it was possible to record where the queue ended, and the number of vehicles could be measured directly when observing a load traversing the Thelwall viaduct just south of the M62 junction with the M6. Even though the load travelled no quicker than 12 mph on the motorway, it could be difficult to ‘outflank’ it using the surrounding general purpose road network.

9.6 These exercises yielded useful information allowing the Model estimates and MIDAS results to be compared with observation (see following Sections).

9.7 The convoys carrying wind-farm components to Cefn Croes in mid-Wales were of particular interest because they represented quick-moving loads (averaging around 30 mph) using rural single-carriageways in remote hilly areas where passing and diversion were virtually impossible. The optimum survey technique in this case was to station observers at five key points to measure timings and queue lengths, and to estimate speeds and flows. This was backed up by video recording. It was also possible to get a good idea of progress, speeds and the effect (if any) on opposite-direction traffic by following the convoy in a car, but not easy to measure queues in this way. On the more bendy sections, the convoys intermittently blocked traffic in the opposite direction. Travelling with a convoy, incidentally, allows counts to be made of opposite-direction flow, which, if speeds can be estimated and there is no tidality, give an indication of ambient traffic levels at the time of the move.

9.8 The slow Acrefair-Ellesmere move (average speed 4.4 mph) had to use predominantly single carriageways because of height restrictions on a more direct route, but there appeared to be greater opportunity for diversion because of the greater density of minor roads in rural Shropshire, and also possibly because more of the traffic was generated locally and had local knowledge. In this case it was possible to use the ‘flying car’ method, and observations were made at nine sites over the two days of the move.

9.9 In the case of the Airdrie to Southampton move, where transporters carrying dump trucks made steady progress averaging about 30 mph, a ‘flying car’ was used to gather data in the area of the A34 and M3 in southern England, where some delays were expected, but the high speed of the convoy made ‘out-flanking’ impracticable. Earlier, the passage of the loads down the M6, M5, M42 and M40 motorways was observed on CCTV by staff of the National Traffic Control Centre at Quinton. However, any resulting delay was not noted because traffic appeared to remain free-flowing. TheModelling Report (Taylor 2006) describes how delay behind fast-moving Abnormal Loads can occur in the form of regions of slower and higher-density traffic than normal. These are hardly ‘queues’ in the everyday sense, and so may not be identified according to conventional criteria such as slow or congested traffic, but could nevertheless produce measurable delay over long distances.

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26 This is a feature of queuing behind moving vehicles which necessitates modelling to estimate delays.
10 Modelling method

10.1 The Excel Spreadsheet Model developed consists of four main worksheets, as follows:

- The Inputs worksheet is used to list the road sections along the load’s route and their characteristics such as section length and load speed, and source of volume data. The inputs are divided into ‘compulsory’, which contain essential data about the road sections and ‘voluntary’, which contain information about stops, diversion and linkage between sections.

- The Defaults worksheet holds some common data including cost/vehicle-hour and characteristics of various road standards such as capacity per lane, based on advice by ITEA.

- The Summary worksheet holds certain important common data and displays certain overall results, including total cost, cost-per-mile and other statistics. The common data include the start day and time, maximum load speed, number of lanes occupied, and the length of the Zone of Influence. The latter can in practice vary along the route, tending to be longest when the convoy is under way at speed, but this usually has only a small effect on results.

- The Model worksheet itself is generated from the Inputs worksheet, and also contains the working and results for each section of the route. Some data are user-modifiable, but care is needed as overwriting these cells may disconnect them from the corresponding Inputs entries.

10.2 Accurate time-dependent traffic volumes on each road section are essential for correct estimation of delays to traffic. Applying volume profiles is assisted by a macro facility.

10.3 An example of the first three main worksheets is shown in Figure 11. The Model and Summary worksheets, as displayed, apply only to the start day and time specified in the Summary worksheet and the timings shown in the Model worksheet. A macro invoked from an Excel menu runs the model for all day types and every hour of the day to generate a profile of costs/mile (see Figure 12). If individual start day and time values are entered in the Summary worksheet, results for that timing only are displayed in it and the Model worksheet, the profile graph and table being unaffected.

10.4 The modelling approach is to estimate queuing, delays and cost deterministically on each of the road sections into which a load’s route is divided. This subdivision, which can affect the results, is not automatic but is at the discretion of the user. Since Abnormal Loads tend to move slower than the ambient traffic and make predetermined stops, the speed of a load on each section, and hence its timings along the route, can usually be estimated in advance. A full description is given in the separate Modelling Report (Taylor 2006). Calculation is more complex than for an incident, because the ‘bottleneck’ is moving, and while there are similarities to the moving block model developed for Convoy Control (Taylor 2004), it is also necessary to allow for some traffic being able to overtake.

10.5 The core of the model on each road section consists of five elements, the first two of which have been covered above, supplemented by a number of secondary effects which are discussed later.

- Section description, including number of lanes, capacity and speed/flow characteristics of road, traffic volume and proportion of heavy vehicles, and load arrival time, speed and lane take, plus information about any breaks taken on the section
- Queuing behind the load and resultant delay
- Economic cost of delay
- Ambient traffic volumes
- Capacity for passing, and speed drop when passing, assuming this is possible
- Diversion
- Queuing in opposite direction because of road closure or special manoeuvre
- Effect of queue following the load from one section onto the next, and effect of breaks.

27 The deterministic approach does not consider random or other probabilistic variations in variables such as load speed, traffic demand and capacity.
Figure 11. Example of Model Spreadsheet showing main Inputs, Model and Summary worksheets.
The DfT’s on-line portal WebTAG (2004) provides information on the average cost of delay time. Although there are different values for different vehicle classes and journey purposes, and there are also arguments about the relative value of time spent driving and time spent queuing, it is considered sufficient in the present study to adopt an average figure of £11.28 per vehicle-hour (the range across different vehicles classes and journey purposes being about £10-12.50).

Data on normal traffic volumes

To define the normal traffic flow on each section at the time the load is present, the model requires a TRADS28 ‘Hourly Variation’ table (as Excel file), or if this is not available an ADT29 value. The most detailed data on section traffic volumes are found on the Highways Agency’s TRADS web site where it is possible to get 24h hourly veh/h flow profiles for different days of the week aggregated over a specified period (eg one month). TRADS data are available for most motorways and many trunk and major A roads. The data month selected should be that most similar to the month of travel – eg the same month in the previous year if available. Otherwise, an ADT (Average Daily Traffic) figure may be obtained from DfT or some other source. The coverage provided by TRADS and ADTs is indicated in Table 5. All sections have available Site Coordinates (OS Easting and Northing) which can be used as an aid to locating the relevant road section or site.

Table 5. Road coverage by TRADS and ADTs (2001-2005)

<table>
<thead>
<tr>
<th>Road class</th>
<th>TRADS sections</th>
<th>ADT sections</th>
<th>ADT miles</th>
<th>Total miles in GB</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>919</td>
<td>1086</td>
<td>2006</td>
<td>2161</td>
</tr>
<tr>
<td>A</td>
<td>1258</td>
<td>16736</td>
<td>29137</td>
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<td>-</td>
<td>18762</td>
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<tr>
<td>C</td>
<td>0</td>
<td>1126</td>
<td>-</td>
<td>52813</td>
</tr>
<tr>
<td>U</td>
<td>0</td>
<td>2326</td>
<td>-</td>
<td>141111</td>
</tr>
</tbody>
</table>

28 TRaffic and Accident Data Statistics database maintained by the Highways Agency.
29 ADT=Average Daily Traffic collected by local authorities and the DfT.
30 Only sections for which an AADT is available, representing about 39% of total sections defined.
31 Estimated from ADT tables by adding up section lengths in kilometres, so there may be accumulated errors.
10.8 A Profile Calculator worksheet has been developed in this project to estimate 24-hour hourly veh/h flows from the ADT using interpolated QUADRO profiles (DMRB). Profile Calculator worksheets are incorporated in the model automatically using one-way ADT values specified in the Inputs table, while TRADS tables are incorporated semi-manually using a macro facility. Both types of worksheet interpolate the volume profile, to avoid sudden jumps in demand in response to small changes in the load’s timing on the section.

**Passing distance and capacity**

10.9 Not all Abnormal Loads leave space to pass, but when they do passing traffic tends to move more slowly than normal over a distance known as the Zone of Influence. This includes not only the load vehicle(s) but any escort vehicles and space reserved by them. It is usually in the range 0.05 – 0.5 miles, depending on the type of load or convoy involved, but can vary with location and speed.

10.10 A critical factor determining the amount of queuing is the traffic capacity of any free lanes past the load. Roberts et al (1994) found the capacity for traffic passing an incident to be on average 75.8% of the free-flow capacity. Assuming a free-flow lane capacity of 2000 PCU/h, and 12% Heavies, this is equivalent to around 1600 veh/h. The reduction affecting traffic passing an Abnormal Load appears to be greater (see Figures 14 and 16). In the absence of data, initially the factor 0.78 assumed by ITEA was adopted, but a value of 0.65 is now recommended (see later in Section 14). Apart from such driver behaviour as lane-changing and hesitation, the mere fact of slowing down below the minimum free-flow speed of 40-50 mph can reduce effective capacity.

**Diversion**

10.11 Diversion is situation-specific. The network-based approach used by the QUADRO software for modelling the effect of road works (DMRB Vol 14) is too complex to be used in the present model, and the situation is different because of the forward motion and relatively short presence of an Abnormal Load. The model allows a proportion of traffic to be diverted from the normal demand on each section before calculating delay. It then applies to each diverting vehicle a proportion of the delay suffered by each vehicle remaining with the load. A proportion of unity represents the equilibrium principle that if drivers do divert, their extra journey time should equal the delay in the queue. If the proportion is less than 1 it supposes that diverters are exploiting local knowledge, while if greater than 1 it implies they have misjudged either the benefit to them or their effect on surrounding roads. Since the end product of the model is cost, this factor could be used to allow for the impact of diverted traffic on the surrounding network being greater or less than it would have been on its original route. The amount of diversion to allow depends the nature of the local network. It is likely to be small from motorways, because it is seldom possible to achieve a higher average speed on smaller and less direct roads, or in sparse or geographically constrained networks where there is little route choice. On the other hand, in areas with rich local road networks, some drivers with local knowledge may well succeed in avoiding delay compared to those who remain with the load.

**Road closures and special manoeuvres**

10.12 Where a road section has to be closed in both directions, the Model applies a simplified queue calculation to opposite direction traffic that is stopped for the duration of the load’s travel along the section. This can also be used to model short periods closure of wider road sections to allow the load to manoeuvre, eg across a motorway to exit by the opposite ‘on’ slip road. The time of closure may be that actually required by the load to execute the manoeuvre, or can be extended by specifying a very slow speed on the section.

**Effect of queue following load onto next section, and effect of breaks**

10.13 Road sections in the model are normally defined according to where junctions occur. If a queue follows the load from one section onto another identical section, with no traffic leaving or joining at the junction, then the final queue is double that on the first section and the total delay is four times what it would be on the first section alone. This is provided for by a user-settable linking factor,
in the range 0 to 1, associated with the upstream section, which modifies the outflow from that section in such a way that the queue on the downstream section is increased appropriately. For a sequence of identical sections, when fully linked this causes total delay to increase as the square of the number of sections rather than linearly. Provision is made for defaulting the linking factors according to road type, but empirical values should be used in preference if available.

10.14 The number and length in minutes of breaks on a section can be entered in the Inputs worksheet. This assumes that the load no longer causes an obstruction, so allowing some or all of the queue to pass. If the number of breaks given is zero, but a duration is specified, then one stop is assumed to occur at the end of the road section. This reduces delay only if the queues on this and the next section are linked. A facility is also provided to recommend the number and placing of breaks.

**Other effects**

10.15 ‘Knock-on’ queuing may be caused by dense traffic flow leaving the main queue hitting a capacity restriction downstream, where queuing would not normally have occurred. The Model worksheet allows a dispersion factor and downstream capacity to be specified. However, this depends on knowing the location and capacity of the bottleneck in advance.

**11 Monitoring by MIDAS**

11.1 MIDAS provides 1-minute-average flows, speeds and other variables, by lane, at a number of detector sites on certain motorways, spaced at intervals down to 500m. Currently MIDAS is installed on the following road sections which are 3-lane motorway unless otherwise stated:

- M1 Junctions 11 and above (Luton and northward)
- M5 Junctions 1-4a (Birmingham ‘box’)
- M6 Junctions 4-20
- M25 Junctions 6-16 (including Controlled Motorway where 4 lane)
- M42 Junctions 1-7 (Birmingham ‘box’)
- M62 Junctions 4-30
- M60 Manchester ‘box’ (not all 3 lane)

11.2 Analysis of MIDAS data is aided by a TRL-developed software package called MTV37. This enables traffic speeds on a stretch of motorway over time to be visualised (see for example Figure 13 later), and also allows total vehicle-hours of delay to be calculated from speeds relative to a ‘reference speed’ of 65 mph. Available coverage of MIDAS is variable, being poor on parts of the M6 because of temporary network bandwidth constraints. Table 6 gives an indication of the quality of MIDAS data for the sections measured. Load speed estimates measured ‘by eye’ from MTV plots were considered good on 55% of load-miles, and fair otherwise.

<table>
<thead>
<tr>
<th>Percentage of load-miles</th>
<th>Very poor</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>18</td>
<td>25</td>
<td>54</td>
</tr>
</tbody>
</table>

11.3 MIDAS traces of some 60 loads selected from a total of 575 moves have been analysed. This is fewer than was planned but was limited by the availability of suitable data, and the need to select current or recent moves (March-October 2004 in practice) so that hauliers would be likely to be able to provide details of route, timing and any significant events. The process consists of 9 steps:

- Receive information on SO and VR1 moves from Highways Agency
- Identify origins and destinations and match to nodes in a model network using OS coordinates
- Estimate optimum routes including use of CONTRAM38 or AA Route Finder

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37 Motorway Traffic Viewer – developed originally by B Williams and P Still, who have since left TRL.
38 Dynamic network traffic assignment software - see [www.contram.com](http://www.contram.com)
• Estimate a ‘footprint’ based on an elliptical envelope around the direct (airline) route
• Using a database of MIDAS-equipped sections, identify incidence of move on MIDAS sections in terms of both mileage and specific junction-junction sections
• Select those moves with probable MIDAS exposure and rank for analysis
• Establish actual routes and timings of moves, and actual MIDAS exposure, from hauliers, and SO permits if applicable
• Identify and check visually (by MTV) MIDAS data sets containing the presence of the load
• Estimate and tabulate load and passing speeds, passing flows and delays to traffic.

11.4 The ‘footprint’ method was devised in case optimum routes showed a tendency to use unsuitable roads. In practice most optimum routes tended to use motorways and major roads, and most AIL moves also tend to use these, except where there are special restrictions such as weight limits on certain motorway overbridges or viaducts. Together or separately, these routes provided an estimate of the MIDAS exposure of the move, enabling moves to be ranked for investigation.

11.5 Several observations and limitations apply in the analysis:

1) Information received from hauliers about the route and particularly timing of their loads was not always accurate. This was more of a problem with VR1 moves. Generally, hauliers tried to be helpful, but did not always have information to hand when approached, and a more formal arrangement for receiving information would have been beneficial (one company added TRL to its emailing list, which was very helpful).

2) MIDAS data could be time-consuming to obtain. Most had to be specifically requested because the server stores only 3-4 months’. Each load could pass through several Control Offices, meaning a separate data file from each, and the amount of data which had to be analysed could be very large, especially if a haulier could provide only approximate information about the moves.

3) Not all MIDAS detectors provided data at the time of observation.

4) The number of lanes occupied by a load could not be determined from the data, because of the inherently limited resolution of MIDAS data (normally 500m between loops).

5) Again because of the limited resolution of MIDAS data, passing capacity, measured as the average flow in a region downstream of a load, could be measured meaningfully only where there was congestion, which occurred on only 23 out of 144 sections, or just under 20% of total mileage. Although the number of lanes available for passing cannot be ascertained, the presence of congestion caused by the load is suggestive of two lanes being blocked, so the passing capacity can be taken as at least an upper limit to capacity on a single passing lane.

6) Speed in the Zone of Influence was generally measured on each major section as the low end of the range of speeds in the offside lane. This could not be measured reliably in the presence of congestion.

7) It was not found practical to investigate rubbernecking on the opposite carriageway.

11.6 A series of Saturday daytime moves of large slow girder-frame loads up the M6, expected to produce heavy queuing in the high traffic volumes, was identified as ideal for comparing observation, modelling and MIDAS results. Unfortunately, it was not appreciated until afterwards that MIDAS coverage of the main queuing region would be very limited. Even so, the MTV plots still yield useful information from the visible geometry of the queuing regions, as shown by Figure 13. Dark bands (dark grey in monochrome) represent high-speed traffic. Low-speed traffic is indicated by the lighter grey to white bands. Undetected regions appear as medium blue (black in monochrome). Red areas indicate where loops were detecting no traffic because of lane closures, or because traffic had been stopped temporarily by the police, as at the Thelwall Viaduct (near Junction 21 of the M6).

11.7 Between Junctions 14 and 16 of the M6 (lower half of Figure 13), data were available from only around 20% of loops, and the proportion of queuing visible on the MTV plots is slightly less, but the triangular shape of the queue can be discerned. Coverage was much better between Junctions 16
and 21a, on the Sunday (upper half of Figure). Queuing occurred only at the Thelwall Viaduct, where the load was required to move at crawl speed in the centre of the carriageway. Even if the load itself is not visible, its path and speed can be inferred from the trace of slow traffic behind it. Total delay, that is the sum of the delays to all individual vehicles affected by the event, and hence cost and cost/mile, can be estimated by factoring up the MTV estimate of delay from the detected regions.

11.8 Results are subject to uncertainty for other reasons than reduced MIDAS coverage. Resolution is limited by the 500m spacing of loop detectors, data from the ends of a section will be affected by manoeuvring of the load on or off the carriageway, and the tail of the queue may become ragged with stop-start waves, complicating delay estimation.

Figure 13. MTV plots of traffic speeds (light = low, dark = high) on Lane 1 of the M6 showing effect of girder-frame Sat/Sun 22-23 May. Traffic flow upward. Axes: horizontal = time, vertical = distance.
11.9 The analysis of the MIDAS traces of the 60 loads which could be positively identified as such, based on known routes or confirmation from hauliers, was necessarily limited to a subset of motorway sections in England. Figure 14 plots the total travel distance identified against estimated cost-per-mile bands. The distribution has an extended shape, with over 40% of load-miles causing virtually no delay (the right-hand end of the horizontal scale has been compressed non-linearly). The median delay was only £2.50/mile, consistent with most delay being caused by a small number of loads. The highest figure measured was about £1600/mile on one motorway section, but only around 8% of motorway load miles were associated with delay costs over £100/mile.

11.10 These results apply only to loads whose routes were known, travelling on some motorway sections which have MIDAS detectors, so they are not necessarily representative of all motorways, and not representative of other road types, but may indicate likely magnitudes.

![Figure 14. Total mileage in cost-per-mile bands of moves on motorways monitored by MIDAS](image)

11.11 The variability of cost not only reflects the familiar way in which delays to individual vehicles vary with place and time, eg between peak periods near cities and night-time on rural roads, but is also magnified by the fact that the heavier the traffic the more vehicles are affected by the Abnormal Load and any queuing it causes. It is emphasised that the Model does not depend on such statistics since it calculates delays from traffic and queuing theory. The only use made by the Model of MIDAS results is in calibrating certain values such as passing capacity and speed (see below). On the other hand, the MIDAS results cover a broader range of moves than those directly observed and modelled.

11.12 As mentioned earlier in Section 6, observers judged that on the M6 and M62, despite the possibility of passing safely at 40-45 mph, the presence of police brought occasional passing speeds down to 30 mph or even as low as 20 mph. This was despite traffic flows being so low on the M62 that there was no congestion. MIDAS had set 40 mph advisory speed limit signs on the M6, but traffic speeds within the queue were well below 30 mph, so the main effect of the signs may have been to protect the back of the queue. Some Variable Message Signs were also set on the M6.

11.13 The average speed of passing traffic could be measured from MIDAS/MTV only on sections where there was no congestion, as pointed out earlier in this Section. Its distribution in terms of total mileage is shown in Figure 15. Since passing speed could not be ascertained for the loads with the highest cost per mile, representing 20% of total mileage, this distribution could be biased somewhat towards higher speeds.
11.14 Plotting traffic passing speed against load speed, as shown in Figure 16, yields a possible relationship which could usefully serve as a default in the model. Although there is quite a lot of scatter there appears to be a trend, at least for higher load speeds, as indicated by the plotted line, with the formula: $v_{\text{pass}} = 35.1 + 0.575 \, v_{\text{load}}$ (mph). Passing speed appears to be further reduced for the slowest loads (under 20 mph), possibly for the reasons suggested earlier.

11.15 Being able to estimate capacity for passing traffic is clearly important for modelling. Passing flow is that measured by a stationary observer some way ahead of the load, and its maximum value is the practical capacity of the ‘channel’ left by the load. By allowing for the speed of the load, passing flow can in principle be calculated from measurements by an observer travelling with a convoy, but this is prone to inaccuracy. Measurements indicate that passing capacity is less than the normal lane capacity and highly variable, because of factors not yet fully understood.
11.16  Passing flow was measured only for loads which *did* cause congestion. Its distribution in terms of total mileage is shown in Figure 17, the distance-weighted average being 1065 veh/h. While lane-take could not be measured directly thanks to the limited resolution of the data, only one passing flow measurement (2400 veh/h) exceeded the normal capacity of one lane, and was so much greater that it has been assumed to represent flow in two lanes.

![Figure 17. MIDAS load-miles against passing flow on 3-lane motorway sections with queuing](image)

11.17  In Figure 18, passing flow is plotted against load speed for the cases where there was congestion. There appears to be a slight tendency for flow to *decrease* with increasing load speed, which may be the result of the flow being more likely to be below capacity at higher load speeds. The average flow in Figures 17 and 18 is likely to understate actual capacity, and the results are consistent with a ceiling around 1300 veh/h, similar to that measured from counts on the M6 when the traffic was known to be saturated (see also later in Section 12).

![Figure 18. Scatter plot of traffic passing flow against load speed](image)
11.18 Passing capacity is hard to predict because it depends much on driver behaviour\(^{39}\), but the results indicate that it is substantially less than maximum free flow, which is around 2000 veh/h/lane (assuming 12% Heavies), and less than that found for incidents by Roberts et al (1994). There are several reasons why this could be the case:

- Greater caution or hesitancy by drivers faced with the ‘unpredictable’ moving load, and possibly influenced by the presence of police vehicles, leading to greater headways developing in the passing traffic than normal at the prevailing speed;
- Passing speed being reduced below that which corresponds to normal maximum flow;
- Capacity per lane reducing with the number of lanes available (eg compared to 3-lane motorway), as exhibited by DfT recommended capacities for various road types.

11.19 As pointed out earlier, passing behaviour appears to be influenced by the presence of police escort vehicles, usually recognised by their flashing blue lights, possessing lane 2 some distance astern of a convoy. While observing loads on motorways, it was noted that the loads themselves often attempted to keep left on straight sections, occupying only 1½ lanes, but it is not clear how much difference this made, since there was no opportunity to observe the ‘natural’ behaviour of traffic in those cases.

### 12 Comparison of Model results with observation

12.1 In the course of the project spreadsheet models were constructed for several moves observed. The estimated costs-per-mile varied considerably, as shown in Table 7 (in three cases, marked by *, the estimates were derived directly from observational data by a different method, as described in Appendix I to the Modelling Report). These results were obtained using model versions available at the time, and may differ from results obtained from subsequent versions.

<table>
<thead>
<tr>
<th>Move</th>
<th>Description</th>
<th>Total Mileage</th>
<th>Modelled cost/mile</th>
<th>Modelled ave. delay/veh (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheffield-Immingham</td>
<td>Flatbed night/weekend move</td>
<td>102</td>
<td>4.7</td>
<td>1.1</td>
</tr>
<tr>
<td>Tilbury-Elstree(^{40})</td>
<td>Girder-frame Sunday morning, snow</td>
<td>56</td>
<td>4.0</td>
<td>-</td>
</tr>
<tr>
<td>St Neots-Cambridge*</td>
<td>Rigid trailers moving at night</td>
<td>24</td>
<td>0.4</td>
<td>-</td>
</tr>
<tr>
<td>Sheffield-Hull*</td>
<td>Flatbed overnight move</td>
<td>68</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Stafford-Seaforth</td>
<td>Girder-frame, weekend daytime move</td>
<td>77</td>
<td>886</td>
<td>25.0</td>
</tr>
<tr>
<td>Stafford-Seaforth</td>
<td>Girder-frame, weekend daytime move</td>
<td>77</td>
<td>604</td>
<td>20.2</td>
</tr>
<tr>
<td>Bolton-Liverpool</td>
<td>Girder-frame, weekend daytime move</td>
<td>66</td>
<td>954</td>
<td>24.9</td>
</tr>
<tr>
<td>Deeside-Stafford</td>
<td>Girder-frame, Sunday daytime move</td>
<td>71</td>
<td>278</td>
<td>12.3</td>
</tr>
<tr>
<td>Ellesmere-Cefn Croes</td>
<td>Rigid trailers in daytime convoy, travelling part of route on mid-Welsh single-carriageway roads</td>
<td>97</td>
<td>34</td>
<td>10.5</td>
</tr>
<tr>
<td>Ellesmere-Cefn Croes</td>
<td>Rigid trailers in daytime convoy, travelling part of route on mid-Welsh single-carriageway roads</td>
<td>97</td>
<td>59</td>
<td>14.4</td>
</tr>
<tr>
<td>Immingham-Cefn Croes</td>
<td></td>
<td>244</td>
<td>2.1</td>
<td>1.4</td>
</tr>
<tr>
<td>Acrefair-Ellesmere</td>
<td>Slow wide load by day on small roads</td>
<td>46</td>
<td>528(^{41})</td>
<td>9.6</td>
</tr>
<tr>
<td>Southampton-Fleet</td>
<td>Girder-frame, weekday small hours</td>
<td>39</td>
<td>33</td>
<td>3.6</td>
</tr>
<tr>
<td>Airdrie-Southampton</td>
<td>Dump trucks by day and night (VR1)</td>
<td>452</td>
<td>52</td>
<td>5.4</td>
</tr>
</tbody>
</table>

\(^{39}\) One night on the M3, the number of vehicles moving past the load fell almost to zero when some traffic, including a double-decker bus, for a time declined to move quicker than the 40 mph being achieved by the load.

\(^{40}\) The delay cost of the Tilbury-Elstree may be underestimated because it was not possible to observe fully a queue which built up on the single-carriageway A41 after the load left the M25.

\(^{41}\) The delay cost of the Acrefair-Ellesmere move may be overestimated because diverted traffic may have been delayed less than traffic which remained queuing behind the load.
12.2 The average cost of the moves observed was £177/mile, but this is certainly not representative of all moves, since monitoring was deliberately aimed at those likely to cause congestion and so yield useful data. The cost distribution in Figure 14 earlier applies only to motorway sections. For moves observed and modelled using the spreadsheet, the total distances travelled and average cost-per-mile on different road types are given by Table 8. However, as before, these results are not representative of all moves, nor are the road sections used necessarily representative of all roads of their type, and it is not possible to determine, with any real accuracy, an average figure for different types of road.

Table 8. Distance and modelled cost of observed moves only on different types of road

<table>
<thead>
<tr>
<th>Standard of road</th>
<th>Dual 3-lane</th>
<th>Dual 2-lane</th>
<th>Single C’way</th>
<th>All/average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total miles observed</td>
<td>675</td>
<td>325</td>
<td>343</td>
<td>1343</td>
</tr>
<tr>
<td>Modelled cost/mile (£)</td>
<td>173</td>
<td>55</td>
<td>301</td>
<td>177</td>
</tr>
</tbody>
</table>

12.3 The average delay per vehicle is a combination of average queuing delay per vehicle affected by the load, including those which suffered no queuing delay\footnote{\textsuperscript{42}}, and average delay experienced by vehicles while passing the load. Figure 19 shows that an approximate relationship exists between average delay per vehicle and overall cost. It appears from these results that the most disruptive loads delayed vehicles on average by in the range of 15-25 minutes. This relationship is non-linear because the number of vehicles affected also tends to increase with congestion cost. The average delay experienced by a vehicle on any one section could be much greater, and the model results indicate it tends to be about double the average delay/vehicle on the whole route. The maximum delay experienced by any vehicle, either by section or overall, is about double the average, but the minimum is that incurred in passing the load, which in none of the moves observed exceeded 4 minutes.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure19.png}
\caption{Relationship between average delay per vehicle and overall cost/mile for moves modelled}
\end{figure}

12.4 Large girder-frame moves from \textbf{Stafford to Seaforth} using the M6 on Sat/Sun 15/16 and 22/23 May 2004 provided the first test of the queuing model. Large queues occurred on the Saturdays between Junctions 14 and 16 (see Figure 13 earlier), as a result of the slow vehicle taking 2 lanes in

\footnote{\textsuperscript{42} It would be unfair to measure only delay to vehicles affect by queuing, since this might occur only on a small part of the load’s route, so the chance of a randomly chosen vehicle being so affected could be small.}
the presence of quite heavy traffic volumes. There was also some queuing on the Sundays at the Thelwall Viaduct, near Junction 21, where the load was required to move at crawl speed in the centre of the carriageway (see Figure 1 photograph). Table 9 compares the various measurements, estimates and model results. Unexpectedly low MIDAS coverage (see Section 10 earlier) meant that effects on traffic had to be estimated by factoring up data from a limited number of detectors. Despite the resulting uncertainty, which particularly affects MIDAS/MTV delay and capacity estimates, the model results show good agreement with observation and can be considered to validate the model.

Table 9. Estimates and modelled results for large girder-frame moves on M6 compared

<table>
<thead>
<tr>
<th>Saturday 8 May 2004</th>
<th>Observed</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume on M6 J14-16 (veh/h) (a)</td>
<td>3200-3500</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Saturday 15 May 2004</th>
<th>Observed</th>
<th>TRADS</th>
<th>MIDAS/MTV</th>
<th>Model input/result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume on M6 J14-16 (veh/h) (a)</td>
<td>3135</td>
<td>1080</td>
<td>1600 PCU/h = 1391 veh/h</td>
<td></td>
</tr>
<tr>
<td>Passing capacity (veh/h) (b)</td>
<td>1396</td>
<td>10.7</td>
<td>10.7</td>
<td></td>
</tr>
<tr>
<td>Speed of load (mph) (c)</td>
<td>~ 14</td>
<td>13.5</td>
<td>13.9</td>
<td></td>
</tr>
<tr>
<td>Maximum queue length (miles) (d)</td>
<td>3739</td>
<td>4017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay on M6 J14-16 (veh-h) (e)</td>
<td>~ 750 veh</td>
<td>611 veh / 1.3 miles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed of queue tail (mph)</td>
<td></td>
<td>3.2</td>
<td>3.3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Saturday 22 May 2004</th>
<th>Observed</th>
<th>TRADS</th>
<th>MIDAS/MTV</th>
<th>Model input/result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume on M6 J14-16 (veh/h) (a)</td>
<td>3425</td>
<td>1260</td>
<td>1600 PCU/h = 1391 veh/h</td>
<td></td>
</tr>
<tr>
<td>Passing capacity (veh/h) (b)</td>
<td>12.7</td>
<td>12.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed of load (mph) (c)</td>
<td>12.6</td>
<td>12.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum queue length (miles)</td>
<td>1975</td>
<td>2669</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delay on M6 J14-16 (veh-h) (e)</td>
<td>611 veh / 1.3 miles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed of queue tail (mph)</td>
<td></td>
<td>4.8</td>
<td>4.8</td>
<td></td>
</tr>
</tbody>
</table>

Notes:

(a) Normal M6 volumes based on counts made on 8 May, when no load travelled. ‘TRADS’ volumes are roughly interpolated TRADS data for all Saturdays in May 2004, so typical of values which might be entered in the model, but are not actual figures for the days in question. Modelled volume is mean of observed range.

(b) Observed passing capacity is based on limited counts made a short time ahead of the load on 15/5.

(c) Load speed is estimated by eye from plots, so is the same for both MIDAS/MTV and Model.

(d) Queue length was estimated on 15/5 by driving along the opposite carriageway after the load departed.

(e) Queuing and passing delay combined. MTV factored veh-h estimates from MTV measurements, with adjustment for limited coverage by estimated factors within queuing region: (15/5) 731/.1955, (22/5) 346/.1752

12.5 The volumes used in the model are as observed except on the M6, J14-16, where they lie in the range 3200-3500 veh/h indicated at the time by TRADS and supported by opposite-direction counts from a moving car on 8 May when a move was cancelled. It was not possible to measure actual M6 volume on the move days because of the effect of the loads and the rapid rise in volume during the period when the load was on the road. In any case it is preferable to use independent and rounded data for model validation.
12.6 Passing capacity was estimated from counts made a short time ahead of the load on the M6 – there is some difference from the MTV estimates. On the basis of the modelled queues, the differences between the moves appear to be related mainly to the speed of the load (see also later in Section 13). No queues were observed or predicted on the M62 on the Sundays.

12.7 The movement of wind-farm parts to Cefn Croes in mid-Wales was important for several reasons. First, a series of similar convoys ran both on weekdays and on Sundays, making it possible to plan a survey well in advance. Second, they used single carriageway A-road sections where there appeared to be few if any opportunities for diversion around each major section. Third, they were relatively fast moving, so their effects should be quite localised. A drawback was that, because of the impossibility of overtaking, measuring flows and queues at several points required a team of several observers. Section volumes were estimated using DfT’s four-period (A-D) subdivision of ADTs, since at the time of the surveys the method of attaching TRADS or Profile Calculated volumes to the model spreadsheet had not been developed. Table 10 shows that while measured volumes varied considerably between the survey days, measured queues were reasonably consistent with corresponding flows, and there is fair agreement between measured and modelled queues.

12.8 For the last convoy observed (Thursday), it is possible that the lower volumes were a seasonal effect. The queue measured just north of Newtown may include vehicles held by the load in the town centre, which the model estimates separately. The overall cost per mile of this move is much lower than the others partly because the narrower wind-blade convoys could move more freely and partly because of the greater distance travelled along dual carriageways on the overall journey.

Table 10. Results for Cefn Croes wind-turbine moves. Estimated volumes are in *italics* and some volumes are extrapolated to the next section where no data available or no major junction between.

<table>
<thead>
<tr>
<th>Section</th>
<th>Distance (miles)</th>
<th>Volumes on Sun in August (veh/h)</th>
<th>Volumes on Tue in August (veh/h)</th>
<th>Volumes on Thu in October (veh/h)</th>
<th>Queues measured on Thu (veh)</th>
<th>Queues estimated by model Thu (veh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of load</td>
<td></td>
<td>Towers</td>
<td>Towers</td>
<td>Blades</td>
<td>Blades</td>
<td>Blades</td>
</tr>
<tr>
<td>A483/A5 past Oswestry</td>
<td>13.0</td>
<td>1047</td>
<td>1047</td>
<td>1087</td>
<td>-</td>
<td>50</td>
</tr>
<tr>
<td>A483 towards Welshpool</td>
<td>14.6</td>
<td>288</td>
<td>490</td>
<td>221</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>A483 passing Welshpool</td>
<td>3.0</td>
<td>515</td>
<td>876</td>
<td>221</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>A483 to Newtown centre</td>
<td>12.7</td>
<td>600</td>
<td>1020</td>
<td>361</td>
<td>50</td>
<td>46&lt;sup&gt;43&lt;/sup&gt;</td>
</tr>
<tr>
<td>A489 towards Caersws</td>
<td>3.2</td>
<td>400</td>
<td>680</td>
<td>300</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>A470 towards Llanidloes</td>
<td>7.8</td>
<td>143</td>
<td>243</td>
<td>206</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>A470 towards Llangurig</td>
<td>4.7</td>
<td>143</td>
<td>243</td>
<td>206</td>
<td>-</td>
<td>7</td>
</tr>
<tr>
<td>A44 to Cefn Croes site</td>
<td>8.8</td>
<td>219</td>
<td>372</td>
<td>180</td>
<td>36</td>
<td>27</td>
</tr>
</tbody>
</table>

12.9 The move from Acrefair to Ellesmere Port consisted of a very large Special Order vehicle travelling very slowly (average 4.4 mph) and occupying two lanes. Passing in either direction was impossible on most of the predominantly single carriageway route. The police used a rolling block to stop traffic entering sections against the direction of the load, and also closed a section of the dual carriageway A483 near Ruabon for two hours (simulated in the model in each direction by a stationary load with one passing lane, representing the signed B-road diversion). This load was monitored quite comprehensively by an observer with the convoy, and a ‘flying car’ which collected data at nine sites over its two day journey. There were some long queues, but to reconcile the queues measured with contemporaneous counts of unaffected volumes it was necessary to assume some traffic was diverted or suppressed. Queues and estimated levels of diversion are given in Table 11.

<sup>43</sup>This figure results from merging modelled queues in the centre and approach to Newtown.
12.10 While too much should not be read into these results, the impression they give is that where practical alternative routes were available they were used. Unlike central Wales, the border area has a dense network of minor roads with scattered habitations. The lowest apparent diversion rates are on a short B-road ‘rat run’ to Bangor-is-y-coed and on the Whitchurch by-pass, where the alternatives would have been to ‘go the long way round’ or through the town centre respectively. Elsewhere major road diversions around longer sections (eg using the A528/539 and the A534/A49) were feasible.

12.11 Given the load’s low average speed of 4.4 mph excluding breaks, the alternative routes should be a lot quicker than staying with the load. However, it would be a major exercise to estimate the alternative journey times. On the basis of the diversion principle described earlier in Section 11, the cost/mile for this move estimated in Table 7 is an upper limit, and may well be an overestimate.

12.12 The Southampton-Fleet transformer move along the M3 took place mostly in the small hours of a Tuesday morning after being postponed from Sunday thanks to equipment failure. The model, which used only TRADS volume profiles without any calibration, but a realistic maximum average speed to give correct section timings, predicted no queuing until the J6-5 section of the M3, where volumes were just beginning to rise. The 5.425m wide load occupied two lanes, except on the 2-lane section J9-8 where it used the hard shoulder, which had been specially swept.

12.13 The queues estimated and observed from M3 J5 to the site on the A287 are given in Table 12. This move demonstrated the importance of knowing detailed timing. For example, it was not apparent at first that the load would need two hours to reach the M27 from Southampton Docks, a distance of only about four miles, whereas in practice a tortuous route had to be used.

Table 12. Queues caused by Southampton-Fleet transformer move, early weekday morning

<table>
<thead>
<tr>
<th>Location</th>
<th>Time</th>
<th>Observed queue (vehs)</th>
<th>Modelled queue (vehs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A35, Southampton</td>
<td>0200</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>M271</td>
<td>0220</td>
<td>-</td>
<td>19</td>
</tr>
<tr>
<td>M3 Junction 5</td>
<td>0550</td>
<td>212</td>
<td>281</td>
</tr>
<tr>
<td>A287, junction</td>
<td>0615</td>
<td>~10 (with some passing)</td>
<td>35 (assuming no passing)</td>
</tr>
<tr>
<td>A287, after moving</td>
<td>0630</td>
<td>45</td>
<td>55</td>
</tr>
</tbody>
</table>

12.14 The timing of the load’s arrival at Junction 5 of the M3 was quite critical, and the decision to allow the move to take place on a weekday was dependent on confidence that the load would reach its destination before the morning peak. According to the model, an hour’s delay would have increased cost per mile from £41 to £339, thanks to hitting morning peak traffic (see later in Section 13).
12.15 The Airdrie-Southampton dump truck move gave an opportunity to monitor VR1 loads, though incomplete information about the starting time and a detail of the route led to some excitement. Although expected to take up two lanes, most of the journey would be on three-lane roads so serious delays were not expected, except possibly on the dual-2-lane A34 sections between the M40 and the M4, and between the M4 and the A303, and possibly on the M3 with high traffic flows.

12.16 When the convoy travelled down the M6, M5, M42 and M40 during daylight hours on Saturday, it was monitored on CCTV by the National Traffic Control Centre which was able to note accurate timings. Unfortunately queues were not recorded, only the fact that there was slow traffic, although the model predicted some queuing on the M6 based on TRADS volumes. However, the speed of vehicles in these queues, as predicted by the model, would have been between 35 and 42 mph, which might not be recognised as ‘queuing’ in the usual sense (see remarks earlier in Section 9).

12.17 On the A34, the queue was measured to be 1.3 miles long at a point 5 miles north of the M4. A similar queue, of at least 156 vehicles, was counted after the loads had reached the A303. These are consistent with the model only if some passing capacity, between about 450 and 1000 veh/h, is assumed. On the M3 dual-2-lane section, Junctions 8-9, the loads were kept to the left so one passing lane was available, and on dual-3-lane sections farther south, again one passing lane was available. However passing capacity could not be measured because of the slow relative speed of passing traffic.

12.18 The large girder-frame move from Bolton to Liverpool was possibly exceptional in its use of a large number of short single-carriageway sections, including some B-roads and even unclassified lanes, to avoid weight restrictions on larger roads. This required some awkward manoeuvres, at one point effectively blocking all traffic movements at a junction for 30 minutes while the load attempted to negotiate it. Although it travelled on a Sunday, the load spent all day on the road, running through the peak which generally occurs in the late afternoon. Most of the manoeuvring and other delays occurred around midday while the load was still in the Bolton area, while the heaviest traffic was encountered nearer Liverpool where the roads were better. For modelling, there appeared to be no TRADS data available along the route, so the cost/mile was estimated using profiled ADTs, which rely on the assumption that QUADRO profiles are appropriate to the roads in question.
13 Modelling issues and sensitivities

13.1 The availability of the delay model allows the sensitivity of traffic disruption to move characteristics to be investigated, both at the generic (typical) road section level and for route-specific movements. This Section discusses the sensitivity of the traffic delays to the assumptions made in the planning of Abnormal Load movements. The tests described are for the most part designed to indicate the effect of parameters on the results under ‘typical conditions’; the numbers are unlikely to be reproduced exactly on specific links. Except where stated otherwise, all tests are based on a 3-lane motorway section, not an actual load movement. The 3-lane motorway section is assumed to have a normal capacity of 6900 PCU/h, and the proportion of Heavies is assumed to be 12%.

13.2 The variables that have the greatest effect on traffic delays on individual sections are traffic volume, lane take, load speed (which can affect the queue and passing capacity), and length of haul before queues can be cleared (which will be affected by any breaks taken on the section). Day and time of movement can have a major effect on local and total delays through the variation in traffic volumes. Although the delays can also be affected by the speed limit of the road, the speed of traffic passing the load and the proportion of Heavies, these do not have a major effect directly. Indirectly, the proportion of Heavies could tip the balance between capacity being sufficient or insufficient to avoid queuing. Their presence might affect the effective passing capacity even more by modifying traffic behaviour in the vicinity of the load, but how often this occurs is unknown. Variations in haulier, police and escorting practice may also have an effect on load speed and lane take, and on passing capacity though their effect on the behaviour of passing traffic (see Sections 6 and 11 earlier).

13.3 An accurate estimate of opportunities for stopping to let queues pass requires detailed knowledge of the route, in view of practical and regulatory limitations on where loads can stop. The value of breaks in reducing delay is related to its sensitivity to section length as well as the weight of traffic (see later). The model allows breaks to be inserted within and/or at the end of each road section, where the load is assumed not to obstruct the carriageway.

**Demand and passing capacity**

13.4 Figure 20 gives an example of the effect of demand and passing (channel) capacity on delay cost based on a 10-mile section. The alternative capacities represent one and two lanes free for passing. As long as effective demand is below capacity of the passing lanes, the only delay is incurred by vehicles slowing to pass, negligible on this scale. Once queuing begins, cost rises rapidly. The demand levels at which this occurs are not exactly proportional to the capacities because the speeds of normal and queuing traffic depend on the demand flow, and this affects how the queue develops.

![Figure 20. Effect of demand and capacity on delay cost on a 1 mile section of 3-lane motorway](image-url)
Load speed

13.5 The effect of load speed on delay cost is particularly marked where demand is high in relation to capacity, as shown in Figure 21. Dependence can rise faster than the inverse square of load speed.

![Figure 21. Effect of load speed on delay cost on 1 mile section of 3-lane motorway](image)

Proportion of Heavy vehicles

13.6 At typical levels of 0-10% the effect of Heavies is modest. If they are more numerous the pressure they put on capacity could cause delay costs almost to double, as shown in Figure 22. However, the highest proportions are usually recorded at night when overall traffic flows are low.

![Figure 22. Effect of percentage Heavies on delay cost on various lengths of 3-lane motorway](image)
Passing capacity and escorting practice

13.7 Passing capacity is defined as the maximum rate at which vehicles flow past a fixed point some way ahead of the load. It is not clear exactly what determines its value, and it can be sensitive to driver tactics such as positioning the vehicle well to the left or temporary use of a hard shoulder. Passing speed by default is calculated from load speed, as described earlier in Section 11. Passing speed appears to affect only overtaking time, while passing capacity affects only queuing. No empirical link between them has been established, as they could not be measured simultaneously through MIDAS.

13.8 In the model, passing capacity is either specified explicitly or estimated by reducing the standard capacity of spare lanes by a specified factor. If it were governed by a speed/flow relationship like Figure 4 in the Modelling Report, reducing passing speed from the maximum capacity point (70 km/h in the figure) to 30 km/h should reduce flow to about 70% of maximum ‘congested’ capacity, or as little as 60% of maximum free-flow capacity, but such a mechanism is only speculative.

13.9 The ‘congested’ part of speed/flow applies within the bodies of queues. Where traffic is not constrained by an actual bottleneck downstream, as when it is in the process of passing the convoy, the relationship between flow and speed disappears, speed probably depending somehow on acceptable distance headways to traffic ahead. Passing capacity could be determined by acceptable time or distance headways different from those applying in normal conditions. For the Stafford-Seaforth moves on the M6, where there was heavy queuing, passing speed was higher (~30 mph) than on the M62 (~20 mph), where there was no queuing. The CMPG escort may have had less slowing effect on traffic than the Cheshire force, or the lighter M62 traffic may have behaved more cautiously because little delay was involved. The passing capacity estimated from observation on the M6 was relatively high compared to both the average and the specific values estimated from MIDAS observations, so it offers no evidence on the effect of police tactics under heavy traffic conditions, while on the M62 it is not possible to say what the passing capacity was, since the flow remained well below it. Hence it is possible only to say that reducing passing speed could reduce passing capacity, and that reducing speed below that which is considered necessary for safety is undesirable.

13.10 Normally, whole lanes are occupied by Abnormal Loads, but the capacity of the channel past the load can vary considerably as shown by the observations undertaken for this study. Figure 23 accordingly shows the effect on cost of variations of the practical value of passing capacity.

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Figure 23. Effect of passing capacity on delay cost for 1 mile section of 3-lane motorway

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44 At low demand levels, with no queuing, the model may predict a slight increase in delay cost since vehicles have a higher normal speed and therefore lose more speed when passing than they would at higher volumes.
Practice regarding load speed and lane take

13.11 In practical moves, once a load’s width is somewhat over 4m, a decision will be required on whether one or two lanes should be possessed. Keeping a second passing lane free reduces delay cost and queue length considerably, as shown in Figure 24, which assumes a fairly high demand flow. The graphs show that the absolute cost is very sensitive to the speed of the load, as is queue size to a lesser degree. There may therefore be a case for reviewing the maximum speed of wide loads, as well as escorting practice as discussed earlier, provided it can be shown that safety is not compromised.

![Figure 24. Effect of load speed and lane take on 1 mile of 3-lane motorway with 4000 veh/h](image)

Section length and breaks

13.12 Section length in this context means the distance between points where any queue is able to pass the load or depart from the load’s route. Figure 25 shows how section length affects delay costs for various demand levels, again using a 3-lane motorway model.

![Figure 25. Effect of section length on delay cost on 3-lane motorway with load blocking 2 lanes](image)
13.13 While queue size is approximately proportional to section length, the delay cost rises approximately as the square of the section length, as more vehicles are delayed for longer. As soon as queues form the delay costs are almost totally the result of queuing, not passing delay. This clearly shows that if it is unavoidable to move a load at busy times the haulier and escorts should be instructed to allow queues to dissipate at regular intervals as otherwise delay costs can escalate.

13.14 The Model allows breaks to be specified so their benefit can be included in the estimated cost. It also has a facility to recommend the number and location of breaks of a given length (normally 15 minutes) which may provide substantial benefit. Tests using three modelled moves suggest that the level of benefit in percentage terms may be fairly consistent, as Table 13 shows.

Table 13. Effect of ‘recommended’ breaks in various moves

<table>
<thead>
<tr>
<th>Type of move</th>
<th>Speed (mph)</th>
<th>Lane take</th>
<th>Cost % start day/hours when breaks would be beneficial</th>
<th>Recommended breaks giving practical delay saving (see text)</th>
<th>Average % cost saving where breaks taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girder-frame via Mway</td>
<td>12</td>
<td>High</td>
<td>64 Weekday 48 Weekend</td>
<td>7</td>
<td>38</td>
</tr>
<tr>
<td>Move via mix D2-D4</td>
<td>35-40</td>
<td>Med.</td>
<td>52 Weekday 35 Weekend</td>
<td>2</td>
<td>43</td>
</tr>
<tr>
<td>Move mostly via Mway</td>
<td>35-40</td>
<td>Med.</td>
<td>63 Weekday 52 Weekend</td>
<td>3</td>
<td>51</td>
</tr>
</tbody>
</table>

13.15 The number of breaks recommended for the girder-frame move (lasting about 4½ hours) is probably impractical, but the Breaks Analysis identifies nearly 80% of delay saving on just one section, where 3 breaks are recommended (this pattern may be typical). On any one section, saving increases (not quite proportionally) with number of breaks, but depends on many factors, so there is no simple rule as to when breaks should be taken. Hence the value of running the Analysis, and inspecting the most costly likely schedule to find the pattern of breaks recommended and where the maximum benefit is likely. Once this has been determined, taking account of operational constraints and the actual feasibility of pulling out of the traffic, the chosen break pattern can be entered into the Inputs worksheet and the Model re-run to estimate the actual cost savings with this break scheme.

Day and time of movement

13.16 The effect of day and start time is so specific to each movement that it is not possible to generalise. Figure 12 (earlier) reflects traffic peaks to a degree. However, the example shown in Figure 26 is from a move predominantly along 3-lane motorway where, after a few hours, a weekday move runs into a sharp tidal morning peak and cost builds up rapidly. In this case, overall costs can be highly sensitive to timing, and hence to any starting delay, taking into account travel time. The model enables any likely sensitivity of this kind to be assessed in advance in the light of possible delays.

Figure 26. Effect of hypothetical variation of travel day and start time on motorway move
14 Summary of monitoring, analysis and modelling

14.1 Abnormal Loads have unique characteristics which call for particular approaches to monitoring and modelling, and raise particular issues.

14.2 Several issues concerning the limits of modelling have arisen from the monitoring work:

- Accurate volume estimates are needed. Construction of the spreadsheet model is aided by macros, but an appropriate time-dependent volume profile or ADT value needs to be obtained ‘manually’ for each road section;
- Results are sensitive to the behaviour of passing traffic, and the effect of ‘tactical’ manoeuvres by hauliers and police to allow traffic to pass. The results of this study from MIDAS data have shown what the range of passing speeds and capacities is likely to be;
- When the convoy and traffic are relatively quick moving, any delay caused may not be not obvious to an observer, although this does not present a problem for modelling;
- Estimating the extent and impact of diversion requires additional information about where opportunities for diversion exist along the route.

14.3 Neither modelling nor MIDAS analysis is an exact science. The model depends on many variables which can only be estimated, derived from historical data or samples, or in extreme cases guessed on the basis of professional experience. MIDAS analysis depends on detectors being available and on the correct choice of parameters such as the reference speed of ‘normal’ traffic. In practice MIDAS data quality was variable, with just over half of detected load-miles being rated as good. During the project data on Abnormal Load movements on parts of the M6, either from MIDAS or CCTV coverage, were restricted because of lack of data network bandwidth.

14.4 As explained earlier in Section 8, a ‘test of reasonableness’ must take into account the highly case-specific nature of operational and planning costs associated with Abnormal Load moves by road or water, as well as the estimated congestion cost of road moves. On the other hand, it is possible to rank moves according to the magnitude of their likely congestion costs, which are highly variable.

14.5 Table 14 gives values recommended on advice by ITEA\(^5\) for various road section and traffic parameters. These are installed as defaults in the Model but can if necessary be changed. Ideally, the proportion of Heavies ought to vary with time of day as their volume varies differently from light traffic, and their proportion increases at night. However, the practical impact is thought to be small.

Table 14. Recommended default characteristics of standard road types

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Single (‘urban’)</th>
<th>Single (‘rural’)</th>
<th>Wide Single</th>
<th>Dual (‘urban’)</th>
<th>Dual (‘rural’)</th>
<th>Motorway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed limit</td>
<td>mph</td>
<td>30/40</td>
<td>50/60</td>
<td>All</td>
<td>30/40</td>
<td>50/60</td>
<td>All</td>
</tr>
<tr>
<td>Lanes (each way)</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1-3</td>
<td>1-3</td>
<td>1-4</td>
<td></td>
</tr>
<tr>
<td>Carriageway free speed</td>
<td>mph</td>
<td>30</td>
<td>50</td>
<td>58</td>
<td>40</td>
<td>60</td>
<td>68</td>
</tr>
<tr>
<td>C’way speed at capacity</td>
<td>mph</td>
<td>15</td>
<td>35</td>
<td>35</td>
<td>15</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>C’way capacity per lane</td>
<td>PCU/h</td>
<td>1000</td>
<td>1200</td>
<td>1500</td>
<td>1700</td>
<td>2100</td>
<td>2300</td>
</tr>
<tr>
<td>Percent Heavies</td>
<td>%</td>
<td>6</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>PCU/Heavy</td>
<td>PCU</td>
<td>2</td>
<td>2.5</td>
<td>2.5</td>
<td>2</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Average PCU factor</td>
<td></td>
<td>1.06</td>
<td>1.12</td>
<td>1.12</td>
<td>1.06</td>
<td>1.12</td>
<td>1.21</td>
</tr>
</tbody>
</table>

14.6 As shown previously in Section 13, cost is sensitive to factors such as load speed, behaviour of passing traffic, and day and time of travel. Measurements of passing capacity are quite variable and

\(^5\) Integrated Transport Economics and Appraisal division of the Department for Transport
somewhat uncertain, but on motorways values in the range 1000-1600 veh/h per lane, that is between 50% and 80% of normal lane capacity, are probably appropriate, with 1300 veh/h or 65% of normal lane capacity being recommended. For estimating passing speed a simple relationship to load speed may be used, viz. $v_{pass} = 35.1 + 0.575 v_{load}$ (mph), though actual speeds are quite variable and do not match the formula so well at the slowest load speeds. Sensitivity tests show that prevailing traffic demand, load speed, and length of section unrelieved by opportunities to let queues disperse, are also important variables, while proportion of Heavies has a relatively small effect.

14.7 There are no data specifically relating to the safety and environmental impacts of Abnormal Load movements. Sources on these costs for ordinary HGVs and effects associated with queuing suggest they are relatively small in relation to congestion costs and would not affect routing decisions.

14.8 The congestion costs produced by Abnormal Loads are highly variable, measured values for moves monitored on motorway sections ranging from virtually zero to £1600/mile in one case, though only about 8% of motorway load miles exceeded £100/mile. While it is not meaningful to suggest an average value, the median congestion cost on motorways of £2.50/mile (ie that exceeded on half of load-miles measured) is unlikely to affect decisions about whether, when and how to permit a load to move. For the moves observed, which are not representative of all moves but were chosen to give the maximum information, the most disruptive moves delayed other traffic by 15 to 25 minutes.

14.9 Abnormal Load hauliers may require lay-over sites, of adequate capacity, for temporary or overnight use for several reasons: long journeys requiring two or more days, avoidance of peak traffic periods, and limitations on drivers’ daily working hours. Currently, they rely on experience to find and secure these sites, planning and timing their moves accordingly. Use of motorway service areas is limited and they need to be on the agreed route.

14.10 In order to maximise the amount of information gathered, the results of this study have been obtained by analysing SO (loads over 150,000kgs, or 30m long, or 6.1m wide) and VR1 (wide loads exceeding 5.0 up to 6.1m) moves, but the modelling principles and general findings apply equally well to other types of load such as STGO and C&U (smaller and lighter loads).

15 General conclusions
15.1 A Literature Review has provided background information and brought into focus issues of external and environmental impacts and water transport policy. While it has yielded little quantitative data about the congestion effects of Abnormal Loads, and no data on other impacts specific to AILs were found, it has provided the basis for a general quantitative estimate of the cost of external and environmental impacts of road freight transport.

15.2 The project has allowed the Expert Panel the opportunity to influence the course of the project, and in particular the monitoring of Abnormal Loads. Consultation of members of the Expert Panel and other Stakeholders has aired issues of escorting practice and fair comparison between road and water modes. Stakeholders have raised various specific concerns such as divided responsibilities for managing waterways and uncertainty about dredged depths, imposition of tolls, ‘hidden subsidy’ for roads, and the benefits of targeted investment, eg new motorway-waterway interchanges.

15.3 Several Abnormal Load moves have been observed directly, and a larger number analysed using data from MIDAS on motorway sections. While neither data set can be said to be fully representative of all AILs, the five observations have been targeted to use limited resources most effectively, and it is believed that a good understanding has been obtained of the possible magnitude of effects of different types of Abnormal Load moving under different conditions.

15.4 A mathematical spreadsheet Model has been developed which takes into account the specific characteristics of each Abnormal Load movement including the load’s size, speed and route, and variations in ambient traffic by day of week and time of day, so its results can contribute to the decision-making process. It calculates queues and delays from traffic and queuing theory, and does not rely on statistical results from monitoring, except to calibrate certain values such as passing speeds and capacities. Given realistic data it can produce a description of an AIL’s effect on traffic...
which corresponds with observation. Provided with the appropriate vehicle and route descriptions, it can model both loaded (outward) and unloaded (return) journeys of AIL vehicles, though these would normally be separate exercises.

15.5 Specific conclusions concerning modelling are:

- The model depends on the data put into it being realistic, which includes correctly identifying the independent sections of the route, inputting accurate time-dependent traffic volumes, and making correct assumptions about diversion. Experience suggests that use of ADTs where TRADS data are unavailable, even if correct for the day of travel, may reduce accuracy, but is unlikely to affect conclusions about the general magnitude of congestion impact;

- Congestion caused is most sensitive to load speed, load width or lane-take and the effective capacity of passing lanes, and ambient traffic volume where this is comparable to capacity;

- Congestion costs are highly variable. Estimates from moves monitored by MIDAS on some motorway sections ranged from virtually zero to £1600/mile on one section. However, it is estimated that £100/mile is exceeded on only 8% of motorway load-miles. These results are not necessarily representative of other motorways or other types of road. Overall costs of moves observed directly are estimated to be intermediate in the MIDAS range.

- Based on modelling results, the average delay incurred by individual vehicles caused by the most disruptive loads is estimated to be in the range 15-25 minutes.

- Traffic can incur measurable delay even when appearing to flow freely at 30-50 mph, when the presence of a ‘queue’ may not be obvious to an observer;

- Diversion may be important only on certain routes, depending on local conditions;

- Empty transfer can be modelled in a similar way to loaded moves, with the appropriate route and vehicle characteristic data, but empty mileage is strongly case-dependent;

- There are no data on externality costs specific to AILs. However, some costs (other than congestion) can be estimated, and are unlikely to be large enough to affect decisions;

- The Literature Review has concluded that there is no other current or relevant research.

15.6 When estimating costs of transport by water, it must be kept in mind that water transport can also involve substantial road segments, but that water costs are less directly dependent on distance than road transport and involve a large, sometimes dominant, component of intermodal transfer costs, especially craneage, although roll-on-roll-off operation can reduce this. Water costs can also be affected by infrastructure operations such as dredging or civil works, and the impact of these costs will depend on whether they are ‘one off’ or can be shared among several moves.

15.7 In summary, this project has revisited Abnormal Loads after a gap of 37 years, during which time the quality and capacity of roads, and the performance of transporters, have increased considerably, while the road network has become more congested. Although this is a complex subject with a strong component of practical experience on the part of haulage and manufacturing industries and the police, it is believed that an airing and understanding has been achieved of the operational issues of road and water transport. The impact of Abnormal Loads on traffic has been addressed quantitatively, with a new capability of predicting traffic delays and costs, potentially allowing a ‘test of reasonableness’ between road and water modes.
16 Recommendations

It is recommended that:

- Abnormal Loads occupy the minimum number of lanes possible without jeopardising safety, and that the shortest possible closures of roads and side-entries be made;
- Better information be gathered from practitioners on the actual operational costs of both road and water moves so that the uncertainties in comparing road and water modes can be reduced;
- A study be set up to determine the specific externality impacts and costs of Abnormal Loads, much of which may be related to the congestion and delay caused by them;
- An inventory of lay-over sites and their capacity be compiled, with clarification of the responsible authorities;
- Where necessary, bandwidth for MIDAS data be increased to facilitate more wide-ranging monitoring.

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