The management and impact of abnormal loads

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Executive summary

Congestion on Britain’s roads is an increasing problem, and in recent years traffic volumes have increased to the extent that parts of the network are often operating close to capacity. The Department for Transport and the English Highways Agency are committed to reducing traffic congestion by better management of the road network.

The movement of large and heavy abnormal indivisible loads (AILs), and potentially also more numerous smaller loads, through the road network can cause additional delays to other traffic. Delays caused by AILs could be reduced by a better understanding of how they are related to the types of load and the conditions under which the loads 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. Alternative modes for large and heavy loads, such as rail and water (and even air), have their own issues of capacity, accessibility, investment and operating and external costs.

A series of projects covered by this Insight Report has been aimed at gaining a better understanding of the congestion and other impacts caused by the movement of AILs and the issues surrounding such loads, including their impact on the average vehicle delay (AVD) measure related to journey time reliability. All types of AIL or larger-than-normal vehicle have been considered, ranging from construction and use (eg mobile cranes) through moderate-sized special types general order loads to wide VR1 and the longest or heaviest and slowest special order types. The different studies have involved literature reviews, consultations with hauliers and other stakeholders, collection of data through observation and surveys and modelling the effect of AILs on the road network. This has enabled a thorough understanding of the prevalence of abnormal loads and the potential for reducing impacts.

AILs represent 0.049% of total vehicle mileage in England, and their impact on AVD is very small overall, no more than about 1.3% of the figure of 3.95 minutes per ten vehicle miles reported for March 2008. Furthermore, most of the impact comes from the small number of large, slow AILs. Congestion cost and delay caused by an AIL increase rapidly as its speed is reduced and as it occupies more lanes. The implication is that measures to reduce congestion impact will be most effective if selectively targeted. On the other hand, improvements to safety, best practice, information and support systems can be applied more widely, and after suitable scrutiny and consultation there may also be scope for reviewing regulations.
Abstract

Congestion on Britain’s roads is an increasing problem. The movement of large and heavy abnormal indivisible loads (AILs) through the road network can cause additional delays to other traffic. Delays caused by AILs could potentially be reduced by management measures based on a better understanding of how they are related to the types of load and the conditions under which the loads are moved. This Insight Report covers several projects that have investigated the prevalence and congestion impact of AILs and the effect of mitigation measures such as movement by water or by night. It concludes, however, that the overall impact of AILs on network delay is small and mitigation measures will be most effective if selectively targeted.
1 Introduction

Congestion on Britain's roads is an increasing problem, and in recent years traffic volumes have increased to the extent that parts of the network are often operating close to capacity. The Department for Transport (DfT) and the English Highways Agency (HA) are committed to reducing traffic congestion by better management of the road network.

The movement of large and heavy abnormal indivisible loads (AILs) through the road network can cause additional delays to other traffic. Delays caused by AILs could be reduced by a better understanding of how they are related to the types of load and the conditions under which the loads 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. The several projects covered by this Insight Report have been aimed at gaining a better understanding of the congestion and other impacts caused by the movement of AILs and the issues surrounding such loads.

2 Categorisation of AILs

Loads fall into several categories, as indicated by tables 2.1 and 2.2. Those exceeding a width of 6.1 m (20'), length of 30 m (rigid) or weight of 150 000 kg require a special order (SO) permit from the HA (also known as a BE6, after the form used), of which 300–400 are issued each year. Other loads exceeding 5.0 m (16'4") up to 6.1 m (20') have to be authorised under Vehicle Regulations (VR1), and about 700–800 authorisations are made each year (see Highways Agency (2009), Department for Transport (2009a), VCA (2009) or Dudley (2004) for summary). Each SO or VR1 authorisation can cover a number of identical moves, but not all authorised moves actually take place. Lesser loads are classified under other special types general order (STGO) and construction and use (C&U) regulations, but do not require specific authorisation.

A variety of vehicles are used to transport heavier or larger abnormal loads. These range from articulated vehicles, which are used for VR1 wide loads or lighter loads like wind-turbine parts (figures 2.1–2.3), to dual-locomotive "girder-frame" sets; the latter use a low-slung trailer to reduce overall height with adjustable width and a large number of axles to spread the load more evenly. Girder-frame transporters are particularly able to operate on motorways and their associated bridges, which have relatively restrictive height and weight limits and are currently limited to 2 mph (9 km/h), so making them of particular interest from the point of view of congestion. The Faun Goliath is the classic system of this type (Figure 2.4). Articulated flat-bed vehicles with comparable load-carrying ability exist and are potentially capable of higher speeds (Figure 2.5). Very long loads may be mounted unenclosed on separate trailer sections (Figure 2.6). These may have to move as slowly as 4 mph (6 km/h) and may be unable to use motorways because of height or weight restrictions. Another factor affecting congestion is that some types of move may take place with several vehicles in convoy.

<table>
<thead>
<tr>
<th>Gross vehicle weight</th>
<th>Individual axle weight</th>
<th>Width &lt; 2.9 m and length &lt; 25.9 m</th>
<th>Width 2.9–5.0 m or length &gt; 25.9 m</th>
<th>Width 5.0–6.1 m</th>
<th>Width &gt; 6.1 m or length &gt; 27.4 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 18 t (two-axle)</td>
<td>&lt; 11.5 t</td>
<td>No special requirements</td>
<td>Police notification*</td>
<td>HA AIL team and police notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>&lt; 26 t (three-axle)</td>
<td>&lt; 11.5 t</td>
<td>No special requirements</td>
<td>Police notification*</td>
<td>HA AIL team and police notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>&lt; 32 t (four-axle rigid)</td>
<td>&lt; 11.5 t</td>
<td>No special requirements</td>
<td>Police notification*</td>
<td>HA AIL team and police notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>&lt; 36 t (2+2 axle articulated)</td>
<td>&lt; 11.5 t</td>
<td>No special requirements</td>
<td>Police notification*</td>
<td>HA AIL team and police notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>&lt; 40 t (five-axle)</td>
<td>&lt; 11.5 t</td>
<td>No special requirements</td>
<td>Police notification*</td>
<td>HA AIL team and police notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>&lt; 44 t (others)</td>
<td>&lt; 11.5 t</td>
<td>No special requirements</td>
<td>Police notification*</td>
<td>HA AIL team and police notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>≥ 46 t (STGO category 1)</td>
<td>11.5–12.5 t</td>
<td>HA notification</td>
<td>Police and HA notification</td>
<td>HA AIL team, police andHA notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>&gt; 46 t and ≤ 80 t (STGO category 2)</td>
<td>11.5–12.5 t</td>
<td>HA notification</td>
<td>Police and HA notification</td>
<td>HA AIL team, police andHA notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>&gt; 80 t and ≤ 150 000 kg (STGO category 3)</td>
<td>12.5–16.5 t</td>
<td>Police and HA notification</td>
<td>HA AIL team, police andHA notification</td>
<td>HA AIL team, police andHA notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
<tr>
<td>&gt; 150 t (SO within category 3)</td>
<td>&gt; 16.5 t</td>
<td>HA AIL team, police and HA notification</td>
<td>HA AIL team, police andHA notification</td>
<td>HA AIL team, police andHA notification</td>
<td>HA AIL team, police andHA notification</td>
</tr>
</tbody>
</table>

* Note that there are other factors that also affect the notification requirements, eg rigid length and overhangs. † Loads wider than 4.3 m are subject to STGO regulations.
Table 2.2 Speed limits (mph) applying to different STGO categories

<table>
<thead>
<tr>
<th>STGO category</th>
<th>Motorway</th>
<th>Dual carriageway</th>
<th>Other roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>50</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>SO &gt; 150 000 kg</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

Figure 2.1 Convoy of wind-turbine tower parts on rural A-road (STGO)

Figure 2.2 Convoy of wind-turbine blades (SO because of length)

Figure 2.3 Short articulated transporter carrying dump truck (VR1)

Figure 2.4 Two-locomotive girder-frame transporter carrying transformer (SO)

Figure 2.5 Articulated flatbed transporter with casting, negotiating roundabout (SO)

Figure 2.6 Unenclosed cold box articulated with two trailers (SO)
3 Statistics of AILs

Based on analysis of data from weigh-in-motion (WIM) equipment and notifications of movements (Hardman et al., 2008), it is estimated that AILs of all types make 3.1 million journeys and travel 67.8 million vehicle kilometres (veh-km) annually in the UK. However, this represents only about 0.049% of all road travel. As described in Section 2, approval is required only for the larger or heavier AILs, although HA interest extends to all vehicles using trunk roads in England in its jurisdiction. In practice, many AIL moves begin and end in Scotland and Wales, and AILs may use non-trunk roads, especially at the start and end of their journeys.

Each approval may involve several physical moves. For assessing the impact on other traffic, the number of convoys is more important than the number of moves since the effect of a compact convoy will be closer to that of a single vehicle than the same number of separate moves, especially if overtaking is impracticable. Data on moves in the three years from October 2004 to October 2007, which were used as the basis for estimates of impact on average vehicle delay (AVD)*, have been analysed to produce statistics of gross weight and estimated journey distance (Table 3.1). The actual number of moves taking place is not recorded, so an estimate of the number of convoys has been made.

<table>
<thead>
<tr>
<th></th>
<th>Great Britain</th>
<th>HA roads</th>
<th>Great Britain</th>
<th>HA roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO</td>
<td>1231</td>
<td>993</td>
<td>164</td>
<td>155</td>
</tr>
<tr>
<td>VR1</td>
<td>1053</td>
<td>889</td>
<td>178</td>
<td>158</td>
</tr>
</tbody>
</table>

*AVD (formerly the PSA1 measure) is defined as the average delay on the 10% most delayed journeys on a specified set of primary routes in England, calculated relative to journey times based on reference speeds.

Frequency distributions of journey length and gross weight on HA roads are shown in figures 3.1 and 3.2. Overall distributions are broadly similar.

It is important to remember that SOs include long loads, which can be relatively light. Some common wide loads, like boat hulls, are also relatively light, but a significant proportion of VR1 moves are of large dump trucks, as used in open-cast mining, which weigh around 100 t. Figure 3.3 shows a scatter plot of approvals for moves estimated to travel at up to 25 mph, so being the most likely to cause congestion. Points marked “HA” represent moves that travelled at least five miles on HA roads. The cross-hairs isolate those limited to 12 mph and those likely to occupy two or more lanes.

![Figure 3.1 Frequency distributions of SO and VR1 move lengths on HA roads](image-url)
Figure 3.2 Frequency distributions of SO and VR1 move weights on HA roads

Figure 3.3 Scatter plot of slow moves (up to 25 mph)
4 Practicalities of AIL movement

4.1 Haulage companies

Most SO and VR1 haulage is done by specialist firms, some of which have been in the business for more than a century. They are highly knowledgeable, skilled and experienced, and where they use the same routes repeatedly, intimately knowledgeable about the problems and opportunities. Significant issues that they have to address include:

- Height, width and weight restrictions – planning is being made easier by the rollout of the HA’s electronic service delivery for abnormal loads (ESDAL) website and database.
- Timing of pick-up and delivery of goods – which may be determined by "just-in-time" policies†, arrival or departure of shipping at docks, and times of engineering possessions‡, or optimal timing of works to avoid disruption to other services (eg installing new electricity transformers in summer when demand is lowest, although their movement could conflict with holiday traffic).
- Traffic conditions – most hauliers prefer to avoid peak periods, not least because of the stress these put on the haulage drivers, and some moves may be chosen or obliged to take place by day for safety reasons, or by night to avoid traffic.
- Drivers’ maximum hours – which are limited by law to nine hours per 24, with 45 minutes of breaks being taken for every 4.5 driving hours.
- Escorting – according to the circumstances, this may be done by the hauliers themselves, by specialist companies or by the police (see Section 4.2).
- Removal of street furniture – usually done by the local authorities, this can mean temporarily lowering telephone or power lines or dismantling traffic islands.
- Finding suitable lay-bys for breaks or overnight stops. These are limited in number throughout the country, and need to be planned, and even reserved, in advance. Certain places are used repeatedly, and the time needed to reach them can affect the timing of moves. Motorway service areas are not always available, as their operators may refuse access to AILs or at least decline to reserve space.

In all cases, hauliers are likely to have a detailed plan for their route, taking account of hazards on the way. SO permits specify routes and cautions in detail, down to maximum speeds, path to be taken (eg move to centre-line of bridge) and specific instructions such as whether suspension may need to be lowered when passing under a bridge. Some typical costs associated with the road movement of AILs are given in Table 4.1.

4.2 Escorting

Large, slow loads used to require a police escort for all or part of their journey, and where the police continue to do this they are increasingly charging for the service. Police are still required to close roads and to perform full direction of traffic, but since 2005 accredited self-escorts, who are appropriately trained and equipped, have been able to take over most escorting functions, in accordance with a Code of Practice for self-escorters of abnormal loads and abnormal vehicles (Highways Agency, 2009).

While they have no powers to stop or direct other road users and are there only to warn them of the presence of the load, in practice abnormal load escorts effectively provide a traffic management function, eg they may occupy additional traffic lanes in order to ward traffic approaching from behind.

4.3 Alternative water mode

Apart from the obvious alternative of rail, which is limited, particularly in the UK, by its loading gauge, the main alternative is water transport. In 2004, the DfT committed £8 million to finance a special combination consisting of an unpowered semi-submersible sea-going barge, the Terra Marique (Latin for “by land and sea”), which can contain a powered inland barge, the Inland Navigator, able to negotiate larger and suitably maintained canals and navigations. The maximum load is 1200 t evenly distributed, with a maximum indivisible load of 400 t. The system was officially launched in a ceremony at the House of Commons in April 2004 (Figure 4.1).

While the Terra Marique avoids external vessel charges and some of the complications of trans-shipment at docks, it cannot be a complete substitute for road haulage, even between points accessible to water. Nevertheless, it demonstrates the commitment of the DfT and the operator to sustainability.

Costing transport by water is more complex than by road. Table 4.2 gives indicative costs estimated in 2006 for various stages, including the possibility of road journeys at either end (compare with Table 4.1). The government’s “water preference” policy takes these into account by a “test of reasonableness”, which consists of a set of forms in which the costs of road-only and water-included movements can be compared, on the basis of which the authority may ask for the water option or approve a road option. A major factor not included is remedial work or dredging to guarantee access or landing, which will clearly be more economical the more repeat movements are planned.

According to the document Sustainable distribution: a strategy (Department for Transport, 2009b), research has indicated that there may be scope to divert up to 3.5% of the UK’s road traffic to water, split roughly equally between ships re-routing to ports nearer the origin and destination of their loads, and the potential for bulk and unit loads to shift to “coastal highways”. In general, water movement of abnormal loads is used extensively where suitable sea-going or inland routes exist, a notable example being the transport of Airbus A380 parts to final assembly at Toulouse, including wings made at Broughton in Wales.

† Where an activity or process is scheduled to begin just after the necessary components or supplies are delivered.
‡ “Possession” is the technical term for when engineers have exclusive access to a site, such as a bridge or section of railway line.
4.4 Air modes
Some types of heavy load can be transported by airplane, in particular by the Antonov AN-124 Ruslan operated by Antonov and Volga-Dnepr, with a capacity up to 150 t, or its unique Antonov AN-225 Mriya variant, with a capacity up to 250 t. However, in general transport by plane is necessarily a specialised and expensive option.

An interesting idea is the transport of large loads by airship, proposed by SkyCat based in Cardington, Bedfordshire, the largest version having a maximum load of 1000 t (Figure 4.2), and also by the German company CargoLifter, based near Berlin, which proposed a semi-rigid craft capable of carrying up to 160 t (Figure 4.3). Sadly, work was halted on the CargoLifter in 2002 and on the SkyCat in 2005.

**Table 4.1 Estimated cost ranges related to major road movement**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>£2000</td>
</tr>
<tr>
<td>Operational</td>
<td>£10 000–40 000</td>
</tr>
<tr>
<td>Escorting and/or police</td>
<td>£2000–4000</td>
</tr>
<tr>
<td>Street furniture removal and replacement</td>
<td>£2000–5000</td>
</tr>
<tr>
<td>Bridge and structure assessments (where needed)</td>
<td>£20 000–30 000</td>
</tr>
</tbody>
</table>

**Table 4.2 Estimated cost ranges related to water movement**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Cost estimate</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra planning</td>
<td>Up to £20 000</td>
<td>Depending on special survey needs</td>
</tr>
<tr>
<td>Road journey to/from water</td>
<td>£10 000–40 000</td>
<td>Depends on distance and weight of load</td>
</tr>
<tr>
<td>Craneage on/off vessel</td>
<td>£5000–55 000</td>
<td>Depends on weight and reach for size of crane required</td>
</tr>
<tr>
<td>Vessel charges</td>
<td>£5000–100 000</td>
<td>Depends on distance and vessel type – inland or sea-going, scheduled or charter</td>
</tr>
<tr>
<td>Extras (eg port fees, surveys, insurance)</td>
<td>~ £10 000</td>
<td>Can be greater if extensive dredging is necessary</td>
</tr>
</tbody>
</table>
Figure 4.2 Proposed SkyCat-1000 airship (307 m long) (reduced from original image)

Figure 4.3 Proposed CargoLifter 160 semi-rigid airship (260 m long)
5 Project stages

The main purpose of the original project, commissioned with TRL by the HA’s Abnormal Loads Unit based in Birmingham, was to investigate the congestion caused by AILs, focusing on the larger, heavier types of vehicle (Taylor et al., 2006). The drivers for this were the need to make more effective use of the existing road system in the light of the continuing trend against further road building, and the need to establish rational criteria for the use of alternative modes, in particular water, with its potential environmental benefits.

Consequently the project, which ran from the beginning of 2004 to the end of 2005, embraced a number of activities, including:

- Literature review
- Consultation with stakeholders including water interests
- Live monitoring of moves
- Estimation of actual congestion costs
- Estimation of environmental impacts
- Development of mathematical congestion model
- Implementation of model in a software tool
- Recommendations

Several follow-on projects were commissioned up to 2008, including:

- Estimation of impact of AILs on the AVD performance measure
- Study of impact and issues of moving more AILs by night
- Review of the management of STGO and C&U movements
- Study of AIL lighting, marking, signage and safety equipment
- Study of the potential impact of modified speed regulations

5.1 Literature review and environmental impacts

Literature relating to abnormal loads is not extensive, but 50 references were found that were considered relevant, ranging from press articles to formal reports, originating from the UK, the rest of Europe and the USA. These covered the following topics:

- Costs of transporting abnormal loads by road (14)
- Environmental and socioeconomic effects (12)
- Intermodal transport (4)
- Potential of waterways (16)
- Regulation and guidance (4)

It was concluded that information about costs was sketchy and estimates highly variable, and safety and environmental impacts could only be inferred from other data such as accident rates in queues and environmental effects of heavy goods vehicles (HGVs). In short, there are simply not enough data on the effects of AIL movements, if only because these are relatively rare and heterogeneous. Nevertheless, by combining evidence from several sources, it was possible to arrive at an estimate of the relative impacts of larger, more disruptive road movements in monetary terms (Table 5.1).

Smaller types of AIL will cause relatively less congestion impact, and the smallest C&U types would be expected to have a similar impact to HGVs. In addition to differences in relative impact, both absolute impact and the number of movements are highly dependent on vehicle type. Estimating the impact of all types would be complex, and so far only congestion has been tackled, as it is the largest component according to current methods of calculation.

Based on the very small and unrepresentative sample available, the total average monetary cost amounted to about £150 per km, the non-congestion component therefore being about £14.40 per km. By comparison, non-congestion costs of water movement of similar loads were estimated at about £3.81 per km excluding bank damage, and there are no congestion costs. Against this, as pointed out earlier, are the greater operational costs of water movement, and the fact that the comparison is between the saving in road distance and the total distance travelled by water, which could be greater than the equivalent road distance. Another significant factor in water movement can be craneage, ie the provision of cranes to transfer the load at the quayside. The largest cranes are transported in sections, so this may involve a convoy of C&U vehicles.

5.2 Accidents involving AILs

Information about accidents involving abnormal loads is very limited because of the way accident data are recorded. Therefore, investigations have been focused on accidents where there is evidence that an AIL may have been involved, and also on the accident risk associated with travel at night (Bourne et al., 2008). The DfT’s STATS9 accident database does not specifically record abnormal loads, so accidents involving AILs were identified as those where “slow-moving vehicles” had been recorded as a contributory factor and where certain journey types (eg commuting) were excluded. In the two-year period studied, there were 73 such accidents involving 74 vehicles, 20 of which were HGVs. From this number and the estimated number of ve-km travelled by abnormal loads, the accident rate was estimated as six per 100 million AIL ve-km. This is about the same as the rate of fatal or serious accidents for all traffic in Great Britain in 2001 (Department for Transport, 2009c).

Accidents involving vehicles of all types were more severe at night than during the day. The proportion of accidents resulting in fatal or serious injuries involving HGVs or vehicles classified as “other motor vehicles” was 27% at night, compared with 13% during the day. This could be an effect of different behaviour as well as ambient conditions, eg less congestion being associated with higher driving speeds. Comparison of the accident rates by time of day showed that the accident rate at night is about 30% greater than during the day on motorways, and about 50% greater than during

<table>
<thead>
<tr>
<th>Impact</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestion</td>
<td>90.35%</td>
</tr>
<tr>
<td>Pollution</td>
<td>6.66%</td>
</tr>
<tr>
<td>Safety</td>
<td>2.08%</td>
</tr>
<tr>
<td>Noise</td>
<td>0.67%</td>
</tr>
<tr>
<td>Road damage and wear</td>
<td>0.25%</td>
</tr>
</tbody>
</table>
the day on A-roads. Furthermore, for both motorways and A-roads, the early hours of the morning carry the greatest risk, with about twice the risk between 0:00 and 04:00 compared with during the day.

5.3 Consultation with stakeholders
Consultation was carried out by setting up an expert panel to oversee the project and advise the HA directly. The panel consisted of stakeholders drawn from several interest groups, including:
- Water authorities and associations
- Representatives of road hauliers
- Utility providers and their representative organisations
- The Association of Chief Police Officers
- Local authorities
- National government (the DfT and the Environment Agency)

In addition, several stakeholders were contacted individually for their views and a number of visits were arranged to carry out more in-depth interviews. It emerged that there was a difference of view between road and water interests. It was pointed out that road movement suffers to a degree from complicated regulations and divided responsibilities, incomplete information about the condition of the road network (now being addressed by ESDLAL) and restrictions on the timing of moves. On the other hand, it was mentioned that road travel benefits from a high level of public investment and largely free access, while water movement suffers from lack of coordination between the bodies responsible for waterways, the imposition of tolls (considered by some respondents to be archaic) and a chronic lack of infrastructure and investment, as well as the operational costs of wharfage and craneage.

5.4 Live monitoring of AIL moves
At an early stage of the project, information about forthcoming moves was provided and several were selected to be observed “live”, either by travelling with the escort vehicle or by following or intercepting the AIL. This allowed detailed profiles of several moves and their impacts (as far as could be determined) to be recorded, which served later as benchmarks for modelling. This was made possible by the helpfulness and cooperation of hauliers, escorts and the police. The AIL moves observed are summarised in Table 5.2.

Several things became clear though this exercise:
- AIL hauliers are highly organised and experienced, and generally aware of their effect on other traffic. They try as far as they can to minimise disruption, eg by tucking into the nearside to leave a passing lane clear, by stopping when safe to do so to let queues pass, by avoiding peak traffic and by informing the authorities so that warning messages can be posted well in advance.
- Delays and breakdowns are unavoidable, as a result, for example, of burst tyres on transporters with up to 28 wheels, as well as other problems such as tight clearances under bridges, stopping places found to be already occupied and escorts arriving late because of delays elsewhere. Tactical management is par for the course.
- Congestion impact is highly variable, not only between moves but during moves. This was noted for addressing by the modelling, which would need to be dynamic rather than average.
- Definitive data by which modelling could be validated were hard to come by. Queues in particular were difficult to measure. Where they could not be counted accurately from a vehicle in the convoy, they were measured variously by stationary observers posted in advance along the route.

**Table 5.2 Summary of AIL moves observed**

<table>
<thead>
<tr>
<th>Start</th>
<th>Finish</th>
<th>Load type</th>
<th>Distance (miles)</th>
<th>Width (metres)</th>
<th>Weight (tonnes)*</th>
<th>Description</th>
<th>Remarks</th>
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<td>Immingham</td>
<td>SO</td>
<td>102</td>
<td>3.24</td>
<td>213</td>
<td>Flatbed artic.</td>
<td>Friday night–Saturday morning</td>
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<tr>
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<td>SO</td>
<td>56</td>
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<td>Affected by snow</td>
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<td>SO</td>
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<td>Saturday daytime–Sunday daytime</td>
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<tr>
<td>Bolton</td>
<td>Liverpool</td>
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<td>6.13</td>
<td>332</td>
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<td>Indirect route</td>
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<td>SO</td>
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<td>4.85</td>
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<td>Saturday daytime–Sunday daytime</td>
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<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>
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<td>Cefn Croes</td>
<td>STGO</td>
<td>97</td>
<td>4.30</td>
<td>93</td>
<td>Artic. convoy</td>
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<td>SO</td>
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<td>SO</td>
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<td>Small hours</td>
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<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>

* Weight per vehicle where several in convoy.
Artic. = articulated vehicle.
or by *ad hoc* measurements made from motorway bridges or lay-bys by “flying observers”, and in one case while driving back along the route on the opposite carriageway of a motorway. Queues were also normally in motion, complicating the estimation of delays (see sections 6 and 7). Finally, it was suspected that on some routes a proportion of traffic had diverted to avoid the convoy, but this could not be proved. Impacts on opposite-direction traffic on single-carriageway roads were particularly difficult to ascertain.

• While in principle an “army” of observers could be deployed to monitor every aspect of a move, in practice the cost would be prohibitive given the variety of move types and the unpredictability of the impact of individual moves, and the consequent large number that would need to be monitored.

5.5 Remote monitoring of AIL moves

Some 60 other moves, whose approximate routes and timings were known in advance, were monitored through MIDAS records from several motorways including the M1, M4, M5, M6, M25, M42, M56 and M62.

Gathering the data raised some problems and issues, including:

• Unreliable route and timing information, particularly for VR1 moves, as hauliers, though generally helpful, did not always have details to hand when approached.
• At the time, MIDAS data could be time-consuming to obtain as most had to be specifically requested. Each AIL could pass through several control offices, requiring a separate data file from each, and the amount of data that had to be analysed could be very large, especially if a haulier could provide only approximate information.
• Some MIDAS detectors did not provide data either because of faults or because of bandwidth limitation of the data network.
• Because of the limited resolution of MIDAS data (normally 500 m between loops), passing capacity could be measured meaningfully only where there was some congestion, which occurred on under 20% of total road length.
• The number of lanes occupied by an AIL, and hence the number available for passing, could not be determined from the data. However, the presence of congestion caused by the AIL on the predominantly three-lane motorway sections was suggestive of two lanes being blocked, so the passing capacity could be taken as at least an upper limit to capacity on a single passing lane.
• Speed in the zone of influence of the AIL 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.
• Rubbernecking on the opposite carriageway was not monitored.

5.6 Recommendations

Some of the concerns identified in the first project, such as water preference, environmental impacts and availability of data, have been largely addressed or have faded with the passage of time. One of the most significant recommendations was that an inventory of stopping places should be compiled, and this has been done in one of the later projects. Bourne *et al.* (2008) contains information on 379 lay-bys (not all suitable for the largest AILs) and 33 motorway service areas with contact details.

Other issues raised at various points that have been addressed in this series of projects include movement by night, conspicuity and equipment of both AILs and their escorts, and the possibility of relaxing speed restrictions because of the sensitivity of delays to low speeds. Safety is a particular concern because, although AILs are seldom involved in accidents, their unusual configuration and behaviour can lead to misjudgments on the part of approaching drivers, especially on an otherwise empty road at night. This work is anticipated to go to consultation that could lead to a Code of Practice for lighting, marking, signage and safety equipment, and an extension to vehicle types identified in STATS19 accident report forms may be considered.
6 Monitoring and its influence on the modelling approach

6.1 Evidence from live monitoring

Most of the moves in Table 5.1 took place along roads not equipped with MIDAS. However, the transport of two girderframes from Stafford to Seaforth (Merseyside), which each took two days along the M6 in fairly busy weekend traffic, gave the opportunity to both observe the impacts live and to compare the observations with MIDAS evidence. These results are useful in providing a relatively uncomplicated, verified and repeated benchmark for queue modelling, so they are discussed here in some detail.

Figures 6.1 and 6.2 show Motorway Traffic Viewer (MTV) plots of the whole impact of the AIL moves northbound on the M6 on Saturday 15 May 2004 and Saturday 22 May 2004, respectively. A move planned on Saturday 8 May 2004 was cancelled, but the opportunity was taken to study the route and measure some unaffected flows. The moves themselves took place from junctions 14 to 16 (J14–16), where the AIL parked in a special area inside the roundabout.

For the first move, after initial insertion onto the motorway at crawl speed, progress along the sections J14–15–16 was steady at speed in the 10–12 mph range, occupying two lanes. At J16, traffic was stopped for a few minutes while the AIL manœuvred off the motorway. On both dates, MIDAS monitoring of J14–16 was reduced by bandwidth limitations, the blue bands in the figures indicating where data were not available. Nevertheless, the triangular shape of the queue can be discerned quite clearly, and has been marked out by white lines. Beyond J16, the increased flow produced by the "compression" effect of the AIL appears to cause flow breakdown at a fixed bottleneck downstream. Such "knock-on" effects, and flow breakdown generally and the formation of jam waves (often referred to improperly as "shockwaves") in queues, are difficult to model except on a case-by-case basis. Our main attention is therefore focused on the direct queuing effect of the AIL.

The effect of the second AIL move (Figure 6.2) was somewhat less than that of the first, probably thanks to its slightly higher speed, but the overall pattern is similar.

On the Sundays following, the AILs continued through lighter traffic towards J20a where, after negotiating the Thelwall Viaduct at crawl speed (Figure 2.4), they moved onto the M62 westbound. Figure 6.3 shows the MTV trace of the second AIL move on the M6, where its impact was slight, and queuing at the Thelwall Viaduct.

Various observations were used to compile a table of estimated values from the three moves (Table 6.1). Volumes were estimated from the HA's Traffic flow Data Systems (TRADS) database, roughly interpolated from all Saturdays in May 2004, because the actual flows were affected by the AILs. The difference in the estimates for the two days reflects the different times of movement. Passing capacities were estimated by short-term manual counts made downstream of the AILs. Queuing and passing delays combined were estimated from the MTV plots, with adjustment for the limited MIDAS coverage. All flow and delay estimates are very approximate. Speeds could be estimated directly from MTV plots, but their reliability suffers somewhat from the obscuration of data on the J14–16 section. Queue length could also be estimated directly from MTV, but was confirmed on 15 May 2004 by driving down the opposite carriageway.

6.2 Evidence from remote monitoring

Most of the 60 moves monitored through MIDAS alone produced little impact on traffic, as could be seen directly on MTV plots. However, on some plots of the remotely monitored moves, a phenomenon was noticed whereby the passage of an AIL through a point of relative constriction, such as a merge, could trigger flow breakdown and queuing persisting for a short time after the load had passed (Figure 6.4). Again, flow breakdown is not sufficiently well understood to model in this context.

Nevertheless, monitoring was able to produce or support two statistical relationships useful for modelling: the capacity and speed of passing traffic. Previous research (Roberts et al., 1994) had found that average lane capacity for traffic passing an incident is 75.8% of free-flow capacity, but capacity passing an AIL was found to be lower, around 70%. Assuming free-flow lane capacity of 2300 passenger car units per hour (PCU/h), and 14% HGVs with a PCU value of 2.5, this is equivalent to around 1900 veh/h. The reduction factor affecting traffic passing an abnormal load appears to be greater (figures 6.5 and 6.6), and is estimated to be 65–70%. An effective capacity of around 1350 veh/h was based on the data plotted in Figure 4.5 and measurements of the two major moves discussed above. 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. These results are therefore broadly compatible with the observations in Table 6.1.

Regressing traffic passing speed against load speed (Figure 6.6) yielded the approximate relationship

$$v_{pass} = \frac{35.1}{1.075} v_{AIL} \text{ (mph)},$$

which could serve as a default in modelling. Passing speed appears to be further reduced for the slowest loads (under 20 mph), which was surmised to be caused by the highly visible presence of police.
Figure 6.1 Annotated MTV plot of queue produced by SO move on M6, Saturday 15 May 2004
Figure 6.2 Annotated MTV plot of queue produced by SO move on M6, Saturday 22 May 2004

M6 northbound (A) from 07:00 Saturday 22 May 2004 to 15:00
Background: Offside – 2 lane speed
Table 6.1 Estimates for girder-frame SO moves on M6 compared

<table>
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<th></th>
<th></th>
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<tr>
<td>Volume on M6 J14–16 (veh/h)</td>
<td>3200–3500</td>
<td>-</td>
<td>3135</td>
<td>3425</td>
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<td>Passing capacity (veh/h)</td>
<td>-</td>
<td>1396</td>
<td>1080</td>
<td>1260</td>
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<td>Speed of All (mph)</td>
<td>-</td>
<td>-</td>
<td>10.7</td>
<td>12.7</td>
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<td>Maximum queue length (miles)</td>
<td>-</td>
<td>~ 14</td>
<td>13.5</td>
<td>12.6</td>
</tr>
<tr>
<td>Speed of queue tail (mph)</td>
<td>-</td>
<td>-</td>
<td>3.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Delay on M6 J14–16 (veh-h)</td>
<td>-</td>
<td>-</td>
<td>3739</td>
<td>1975</td>
</tr>
<tr>
<td>Queue Thelwall Viaduct (veh)</td>
<td>-</td>
<td>~ 750</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Figure 6.3 Annotated MTV plot of queue produced by SO move on M6, Sunday 23 May 2004
Figure 6.4 MTV plot showing effect on average traffic speed of SO move on M42 (thinner trace on right), Monday 23 February 2004

Figure 6.5 Scatter plot of traffic passing flow against All speed
6.3 Development of the congestion model
The basic principles of modelling queuing and delay are simple: assuming demand has exceeded capacity, queue size is the difference between what has joined the queue and what has left it. Delay per vehicle affected by queuing is the time taken to pass through the queue minus the normal time to cover the same distance. The simplest type of queuing model is what is known as “vertical deterministic”. Vertical means that the queue is assessed as if it were concentrated at the bottleneck, and deterministic means that only the average arrival and departure rates are considered, not their random variations. Random effects alone tend to produce queues whose size depends on the ratio of demand to capacity, but not on the absolute flows. They therefore tend to be small in relation to motorway flows and can be ignored.

However, queues on motorways are often greatly extended and in motion, and this is even more the case where the bottleneck is moving, so a “horizontal deterministic moving bottleneck” model is needed, and also allowance for the possibility of traffic overtaking. The results will depend on the number of lanes occupied and available for passing, the speed of the AIL and the approach and passing speed of traffic. Queues will also depend on the location, the day of the week and the time of day. Fortunately, relatively comprehensive data on hourly traffic flows are available in the HA’s TRADS and HATRIS (Highways Agency Traffic Information System) databases.

The model also has to take account of the unique circumstances of each abnormal load movement. As the AIL moves along its route, it meets varying levels of traffic, some of which may join or leave the route at each junction. The model therefore has to be able to carry forward queues from one route section to the next, and also to estimate not only total delay, but also the average delay to the average ambient traveller, who will not normally be following the AIL all the way, or may be able to overtake it at some point.

A theoretical problem arises with queues extending over several route sections, in that the presence of the AIL on one section, say \( i \), can cause delay on as many sections upstream of the AIL as the queue extends through, say \( \{i - j \ldots i\} \), and even on sections upstream that are not on the route. This means that an exact model of a route of \( n \) sections requires up to at least \( n^2 \) calculations. To avoid this “explosion”, a simpler model has been developed involving just one calculation for each route section, with some interaction between adjacent sections. This model can be accurate provided that queuing extends across similar road sections. For various reasons, it is unlikely that a major queue would extend across sections of very different type, such as a motorway section and a non-motorway section feeding into it, bearing in mind that even slow AILs do not produce the kind of dense queues typical of a major fixed blockage.

Such a model can be realised in a spreadsheet in which each column represents one section of the route, with some interaction between adjacent sections. This in turn can be generated automatically from a route list, which in turn can draw from a database of road characteristics and traffic flows. With such a model, it is possible to vary the AIL type and the day and time of travel to explore the effect of different options. This is very important for large, slow AILs especially, since it will not be intuitively obvious when and where they are likely to meet heavy traffic and cause congestion. The ability to vary journey timing is also valuable for determining whether a delay in starting the move could cause disproportionate disruption.

![Figure 6.6 Scatter plot of traffic passing speed against AIL speed (with “trend”)](image)
6.4 Indirect effects of AILs

An unavoidable observation from figures 6.1 and 6.2 is that the AILs caused "knock-on" effects by concentrating traffic into a high-density queue. Even after travelling more than 20 km, the departing traffic, though gradually dispersing, was sufficiently dense to trigger flow breakdown at a geometric bottleneck. The indirect effects of the AIL also are visibly more diffuse than the direct queuing effect. A lesser case of locally triggered flow breakdown by a quicker moving AIL in Figure 6.4 has already been remarked upon. Closer scrutiny of the MIDAS data confirms that a speed drop and a flow drop occurred just after the AIL had passed (Taylor, 2008a). It is perhaps significant that without the MTV plots of MIDAS data, the true origin of these secondary queuing events would not have been known.

While the main attention is focused on the direct queuing effect of the AIL, a simplified model has been developed to assess the magnitude of knock-on effects, which, calibrated with the available information on traffic speed, dispersion rate and bottleneck capacity, suggests that the “knock-on” delays on the M6 were about one-third of the direct delays in these cases. Smaller proportional knock-on effects would be expected in less extreme cases.

Dynamic traffic behaviours, like dispersion from the head of a queue, flow breakdown and the formation of jam waves, are currently not sufficiently well understood to be incorporated in a general model. While unlikely to affect assessments or decisions about AILs, these effects may be worthy of study in themselves. Flow breakdown events are also probabilistic, but it is becoming apparent that they are often triggered by deterministic causes, whether unusually heavy traffic or capacity deficits associated with local road geometry and junctions. Although this offers a handle for prediction, it would require a more detailed description of the road network than that available for the AIL congestion modelling work.

7 Outline of the congestion model

This section aims to give an understanding of the mathematical principles of the model without going into exhaustive detail. Full details can be found in Taylor (2006).

7.1 Moving bottleneck horizontal queuing model

Traffic in a steady state can be described by three variables: flow $q$ (veh/h), speed $v$ (km/h) and density $k$ (veh/km), which are related by the "fundamental relationship":

$$ q = v k $$

(Equation 7.1)

If there are two bodies or states of traffic, 1 and 2, separated by a sharp boundary moving at speed $v_{12}$ (where positive by convention means downstream), then from the viewpoint of an observer moving with the boundary, the flow $q_{12}$ entering the boundary must equal the flow leaving, since vehicles are conserved. For a stationary observer, the measured speeds both increase by $v_{12}$ and the densities remain the same; so:

$$(v_1 - v_{12})k_1 = q_{12} = (v_2 - v_{12})k_2$$

(Equation 7.2)

Rearranging Equation 7.2 using Equation 7.1, the boundary propagates at speed given by Equation 7.3:

$$ v_{12} = \frac{q_1 - q_2}{k_1 - k_2} $$

(Equation 7.3)

This also works in reverse, relating the states of traffic on either side of an imposed boundary or bottleneck. A moving AIL creates an effective “moving bottleneck” at the upstream end of the “zone of influence” around the AIL, which includes its escort vehicles and space required for weaving movements. Figure 7.1 sketches the traffic states around this moving bottleneck, where the subscripts $a$, $b$, $c$ and $L$ represent “arrivals”, “bottleneck”, “(passing) channel” and “load”, respectively.

![Figure 7.1 Sketch of traffic regions with moving bottleneck queue boundaries](image-url)
The overall effect of the AIL can be modelled as two components:

- a boundary between the different states of traffic flow upstream and downstream of it, described by Equation 7.3;
- a delay to passing traffic caused by slowing down in the zone of influence, the length and capacity of which can vary with the speed and size of the AIL and driver behaviour.

In Figure 7.1, the speed of the boundary \( v_L \) is known, as is the traffic state \( c \) downstream assuming that the passing channel is saturated. Equation 7.2 takes the particular form:

\[
q_b = q_c + (k_b - k_c)v_L
\]  
(Equation 7.4)

Note that \( k_b \) applies to traffic in a steady state well downstream of the AIL, not to traffic in the process of overtaking or accelerating away. Since \( k_b \) is related to \( v_b \) through Equation 7.1, this defines a relationship between speed and flow in the queue \( b \) (provided, of course, that the demand is high enough to produce queuing), which is rewritten as Equation 7.5:

\[
q_b = q_c + \frac{k_b - k_c}{(1 - \frac{v_L}{v_b})}v_L
\]  
(Equation 7.5)

In order to get the actual state of the queuing traffic, we need another relationship, which is the intrinsic speed–flow relationship in the queue. Intrinsic speed–flow relationships are still the subject of much research, as they depend on the details of driver behaviour. A discussion of some popular macroscopic relationships is given by Taylor (2008b). For present purposes, we use a simple type of relationship identified at TRL by Neil C Duncan, and also proposed by others, which essentially spaces vehicles at the minimum safe distance at each speed:

\[
q_b = \frac{v_b}{n} \left[ \frac{1}{\lambda} + \frac{\tau}{v_L} \right]
\]  
(Equation 7.6)

where \( n \) is the number of lanes, \( \lambda \) is the space occupied by a vehicle under jam conditions and \( \tau \) is the minimum time headway between vehicles. (In this model, \( 1/\lambda \) is the maximum flow per lane, \( 1/\lambda \) is the jam density of crawling traffic and \( -\lambda/\tau \) is the speed at which jam waves propagate in queuing traffic – about 20 km/h upstream.) Solving equations 7.5 and 7.6 simultaneously gives an explicit state for queuing traffic, as shown in Figure 7.2, where a separate intrinsic uncongested relationship is also shown. Having got the traffic state in the queue, Equation 7.3 is applied to calculate the speed of the queue’s “tail wave” \( v_{ab} \), where it is joined by free-flowing approaching traffic – the extreme left of Figure 7.1. For the queue to exist, the tail wave speed must be more negative than the speed of the AIL. This means that the tail of the queue can move downstream, whereas at a fixed bottleneck it can of course move only upstream.

When the AIL reaches a junction or leaves the road, it may be possible for traffic at the head of the queue to escape. As can be observed in practice, departing traffic does not move as a block but vehicles take it in turn to move away. This creates an upstream-moving head or discharge wave. The speed of this is again governed by Equation 7.2, and Equation 7.6 has the property that it is always equal to the jam wave speed. In reality, the maximum exit flow from a slow-moving or stationary queue is less than the maximum flow under high-speed conditions, and this will affect the speed at which head waves propagate. However, this is not well enough understood to be included in the model.

![Figure 7.2 Solution of the traffic state within the queue using typical parameter values](image-url)
We can now construct a simple model of the queue produced by an AIL moving along a homogeneous road section (Figure 7.3). This may be compared with the real queues identified earlier in figures 6.1 and 6.2.

Results of modelling those two moves (as previously published in Taylor et al., 2006) are given in Table 7.1. Here the flows and capacities assumed are generic, and the differences in results arise entirely from the difference in the AIL speeds.

In the simple case of Figure 7.3, the maximum queue size (in vehicles) can be calculated explicitly by Equation 7.7, where the function $V_f$ represents the free-flow speed well downstream of the AIL and $t$ is the time of queue growth as in Figure 7.3.

\[
L = \left( q_a - \frac{V_a}{V_s} \right) - \mu \left( 1 - \frac{V_a}{V_s (\mu)} \right) t
\]

(Equation 7.7)

In this formula, it can be seen that the speed of the AIL effectively diminishes both the demand and the capacity, so reducing the queue size, but the influence of horizontal queuing (the denominator, which is less than 1) is to increase queue size, reflecting the way the growing queue “sweeps up” approaching traffic.

### Table 7.1 Model results for girder-frame SO moves on M6 (compare Table 6.1)

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<tr>
<td>Volume on M6 J14–16 (veh/h)</td>
<td>3350</td>
<td>-</td>
<td>3350</td>
<td>-</td>
</tr>
<tr>
<td>Passing capacity (veh/h)</td>
<td>1391</td>
<td>-</td>
<td>1391</td>
<td>-</td>
</tr>
<tr>
<td>Speed of AIL (mph)</td>
<td>10.7</td>
<td>-</td>
<td>12.7</td>
<td>-</td>
</tr>
<tr>
<td>Maximum queue extent (miles)</td>
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<td>13.9</td>
<td></td>
<td>12.4</td>
</tr>
<tr>
<td>Speed of queue tail wave (mph)</td>
<td></td>
<td>3.3</td>
<td></td>
<td>4.8</td>
</tr>
<tr>
<td>Delay on M6 J14–16 (veh-h)</td>
<td></td>
<td>4017</td>
<td></td>
<td>2669</td>
</tr>
<tr>
<td>Queue at Thelwall Viaduct (veh)</td>
<td></td>
<td>611</td>
<td></td>
<td>611</td>
</tr>
</tbody>
</table>
7.2 Calculation of delay

It is more convenient to calculate delay from the geometry of the queue. Writing the maximum physical extent of the queue measured from its head gives Equation 7.8:

\[ X = (v_c - v_{ab})t \]  
\[ \text{(Equation 7.8)} \]

The time taken for the queue to disperse, with \( v_{bd} \) the discharge head wave speed, is shown in Equation 7.9:

\[ t_d = \frac{X}{v_{ab} - v_{bd}} \]  
\[ \text{(Equation 7.9)} \]

Total delay, taking into account the motion of the queue, is then shown by Equation 7.10:

\[ D_b = \frac{1}{2} X k_b \left( t + t_d \right) \left( 1 - \frac{v_c}{v_{ab}} \right) \]  
\[ \text{(Equation 7.10)} \]

The delay per vehicle depends on the traffic deemed to be affected by the AIL, as shown in equations 7.11 and 7.12:

\[ Q_b = q_a \left( t + t_d \right) \left( 1 - \frac{v_c}{v_{ab}} \right) \]  
\[ \text{(Equation 7.11)} \]

\[ d_c = \frac{D_c}{Q_b} = \frac{X k_b \left( 1 - \frac{v_c}{v_{ab}} \right)}{2 q_a \left( 1 - \frac{v_{ab}}{v_{bd}} \right)} \left( 1 - \frac{v_{ab}}{v_{bd}} \right) \]  
\[ \text{(Equation 7.12)} \]

In most cases of interest, from the viewpoint of congestion the queuing delay greatly outweighs the passing delay.

7.3 Complications

Calculating congestion caused by AILs would be simple if every move resembled figures 6.1, 6.2 and 7.3. However, several factors cause complications:

- Routes usually consist of several segments where road standard and traffic conditions can vary.
- Ambient traffic flows vary with time – the exact flows are unpredictable, but historical hourly flows are available for major roads.
- Traffic may join or leave at junctions – turning proportions are generally not known and have to be estimated.
- Traffic may divert, and the amount of diversion is difficult to estimate, although it is probably small on motorways because of the lack of known suitable alternative routes.
- Queues may extend upstream for variable distances and periods, and may even affect roads not on the AIL’s route.

These issues are addressed in the implemented model (Taylor, 2006), where, as pointed out earlier, certain approximations are accepted for reason of practicality – in particular, the assumption that delay can be calculated on a section-by-section basis. To enable this, queue segments with quadrilateral rather than triangular geometry are analysed, then fitted together (Figure 7.4).

7.4 Practical implementation in the Congestion Calculator spreadsheet

A spreadsheet implementation was chosen for several reasons: rapidity of development; transparency of calculations and data; ease of presenting results including comparing multiple options; and relative unimportance of computational efficiency. The front end (Figure 7.5) is linked to a database of strategic road network sections, enabling routes to be constructed using drop-down lists. The starting day and time and characteristics of the AIL are also set up here. The
model calculations are programmed into a column of another worksheet and duplicated for as many road sections as required. This model is linked to a database of HATRIS traffic volumes accessed according to the day and time when the AIL arrives on each section. Other sources can be used if HATRIS volumes are not available, including hourly profiles generated from average daily traffic.

Once the model has been generated, the day, time and AIL type can be changed and the results appear immediately. There are also several macros whose function is to generate...
and/or run models for a range of starting times or AIL types, outputting the collected results to text files for further analysis. These multi-run facilities have been needed mostly for the follow-on projects, but the ability to display congestion profiles for a range of starting days and times is useful for identifying better or worse plans. For planning purposes, the main result needed is the congestion cost, total per mile, using a default value of travel time based on DfT advice.

The main disadvantage of a spreadsheet as opposed to a compiled scripted program is that data are not separated from the program, which makes it more difficult to do repeat runs, and that each move model occupies a lot of disc space because of all the code it carries with it. However, implementation of the main calculations by formulae has the definite advantage of greater transparency and easier debugging than macro code.

7.5 Model sensitivity

The results of applying the model to the simple case of a three-lane motorway section of length one mile with normal traffic flow of 4000 veh/h are shown in Figure 7.6. The important observations are:

- Queue size and delay rise rapidly as the AIL’s speed reduces and as the number of lanes taken up by the AIL increases.
- Cost, which is proportional to delay, increases more rapidly than (in fact as the square of) queue size, and is even more sensitive to lane take.

7.6 Model predictions for observed moves

When applied to the observed moves, the model gave the results shown in Table 7.2, most but not all of which were obtained using an early version of the spreadsheet program. Average costs or delays per mile disguise enormous variation along each route, and depend very much on the ambient traffic. When looking at Table 7.2, it is important to remember that the costs are absolute while the delays per vehicle are perceived only by those vehicles affected. Nevertheless, both results can still give a guide to the impact of a move and do seem to be related rationally to the type of load.

However, it must be reiterated that these particular moves are not a representative sample and the results cannot be taken as typical. They are also subject to a degree of uncertainty, as indicated in footnotes. As regards uncertainty in general, the modelling program includes the facility to enter the uncertainty in all data as a percentage. The model then estimates, using an ad hoc method (Taylor, 2006), how this uncertainty translates to the outputs, although typically this turns out to be similar to the input level. Absolute uncertainties have not been addressed as they would be of the order of percentages while the effects of parameters like AIL speed are more of the order of magnitude.

Figure 7.6 Effect of AIL speed and lane take on a three-lane motorway section
Table 7.2 Estimated congestion costs and delays for moves observed

<table>
<thead>
<tr>
<th>Move</th>
<th>Description</th>
<th>Total miles</th>
<th>Modelled cost/mile (£)</th>
<th>Modelled average 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 *†</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>0.0</td>
<td>-</td>
</tr>
<tr>
<td>Stafford–Seaford 1</td>
<td>Girder-frame, weekend daytime move</td>
<td>77</td>
<td>886.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Stafford–Seaford 2</td>
<td>Girder-frame, weekend daytime move</td>
<td>77</td>
<td>604.0</td>
<td>20.2</td>
</tr>
<tr>
<td>Bolton–Liverpool</td>
<td>Girder-frame, weekend daytime move</td>
<td>66</td>
<td>954.0</td>
<td>24.9</td>
</tr>
<tr>
<td>Deeside–Stafford</td>
<td>Girder-frame, Sunday daytime move</td>
<td>71</td>
<td>278.0</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>34.0</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>59.0</td>
<td>14.4</td>
</tr>
<tr>
<td>Immingham–Cefn Croes</td>
<td>Rigid trailers in daytime convoy, travelling part of route on mid-Welsh single-carriageway roads</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>528.0</td>
<td>9.6</td>
</tr>
<tr>
<td>Southampton–Fleet</td>
<td>Girder-frame, weekday small hours</td>
<td>39</td>
<td>33.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Airdrie–Southampton</td>
<td>Dump trucks by day and night (VR1)</td>
<td>452</td>
<td>52.0</td>
<td>5.4</td>
</tr>
</tbody>
</table>

* The effect of the Tilbury–Elstree move may be underestimated because it was not possible to observe fully a queue that built up on the single-carriageway A41 after the load left the M25.
† These estimates were calculated directly from observational data.
‡ Veh·mi in the calculation are those travelled by all traffic.
§ The effect of the Acrefair–Ellesmere move may be overestimated because diverted traffic, relying on local knowledge, may have been delayed less than traffic that remained queuing behind the load.
8 Calculating the impact on AVD

8.1 Definition of AVD

The AVD measure is defined as the average delay in minutes per ten veh-mi on the 10% most delayed journeys on the strategic road network where flow is distance-weighted:

\[
\text{AVD}_{\text{measure}} = \frac{10 \sum \text{Delay}_{\text{veh-mi,slowest,10\%}}}{\sum \text{Flow}_{\text{veh-mi,slowest,10\%}}}
\]

(Equation 8.1)

In practice, this is evaluated on 91 routes, each separated into two directions, specified by the DfT ("DfT routes") covering the network. The routes have an average length of 63 km and are made up of about 43% motorway, 36% dual carriageway and 21% single carriageway. Traffic data, known as Merged All Data for Journeys (MADJ), are merged from various sources apart from MIDAS, including National Traffic Control Centre detectors and Trafficmaster.

The AVD database amounts to about 145 000 "charts", each of which relates to one 5-minute period within the daytime range 06:00–20:00 on one normal day type of the week on one DfT route. Each chart contains up to 53 weekly journey time measurements made over a rolling year, updated each calendar month. The whole network AVD delay value as at March 2008 was 3.95 minutes per ten veh-mi or about 14.6 seconds per veh-km. AVD is considered to be a measure of journey time reliability, and was until March 2008 a target of the Public Services Agreement (PSA). Although the original target value set in 2005 was not achieved, AVD has been falling since mid-2007 (or even earlier since it is an annual rolling average), as Figure 8.1 shows.

To measure actual journey times along a route is not practical. Instead, sample journeys are synthesised by "chaining" travel times along the component road links, starting each journey in the middle of a 15-minute time period. An illustration of this process is given in Figure 8.2. This hypothetical example also shows how the effect of an AIL can be estimated. Each number in a cell represents the travel time in minutes along the corresponding link (column) in one 15-minute time period (row). Yellow cells contain normal travel times, while pink cells contain times affected by the passage of an AIL along the first two links. By following the arrows, it can be seen how the AIL not only delays the "probe" vehicle, but displaces it in the grid so that its travel time may be affected on a subsequent link, eg because it meets heavier normal traffic. The overall effect appears on Link 7 in the time period starting 17:15, amounting to seven minutes’ delay to its whole journey.

The baseline charts are calculated on the same principle, except that measured link travel times are compared with times based on reference speeds. A typical reference speed is 67 mph for a motorway link, representing free-flowing traffic within the speed limit. Actual link travel times tend to be distributed asymmetrically (Figure 8.3).

Figure 8.1 Graph of the AVD measure as published by the DfT (from DfT annual report, April 2008, Figure D1)
Figure 8.2 Chaining link travel times to estimate journey time with and without an AIL

Figure 8.3 Typical travel time distribution on a motorway link
8.2 Estimating the AVD impact of all AIL moves

The baseline charts described earlier of course include the effect of all AILs that have travelled during the past year, so it is the effect of an additional AIL that is being calculated. Provided that the effect of AILs is a small proportion of total delay, this is a good estimate of the actual effect that the AIL would have produced. However, it is impractical to model all the AILs that actually moved because, apart from the sheer number of moves or their exact journeys. Consequently, TRL used available data sources to estimate:

- The annual number of moves of AILs in each of several speed/width categories
- A set of representative routes covering the strategic road network
- Adjustment factors to the routes to reflect actual journey distance distributions

Initially, the routes modelled were the DfT routes themselves, and the results used to calculate generic impacts per unit distance travelled on different road types for moves taking place on all days and starting between 06:00 and 19:45. These took the form of the slope coefficients in a simple regression equation (Equation 8.2):

\[
AVD_{\text{impact}} = \text{Slope(Road type, AIL_width, AIL_speed)} \times \text{Distance}
\]

(Equation 8.2)

While the simplicity of the slope coefficients given in Table 8.1 is attractive, the coefficients do not specifically take into account traffic conditions and the routes modelled are arguably unrealistic, but the sensitivity to AIL speed and lane take is again evident.

Subsequently, routes were derived from actual move records. As described in Bourne et al. (2008), 100 sample routes were derived by estimating the routes within the strategic road network of a randomly selected sample of database origins and destinations of AIL moves in the October 2004–October 2007 BE6/VR1 database. While therefore typical of database AIL routes, the set was not truly representative because the frequency distribution of the route lengths did not reflect that of the database AIL routes, shorter routes in particular being under-represented. Consequently, a scaling function was derived to weight the impacts of the sample routes.

While the main aim of the work was to evaluate the impact of moving more loads by night, in order to do this the impact of all daylight moves had to be estimated. The 100 routes were modelled for:

- Four speed categories – 4 mph, 12 mph, 25 mph and 40 mph
- Three width categories – occupying one, two or three lanes (three-lane moves at 12 mph only)
- Five day types – Monday, midweek, Friday, Saturday and Sunday
- Three start times – 08:00, 11:00 and 14:00

Current overnight moves were assumed to be 15% of the total for 4 mph and 12 mph moves, and 5% of the total for 25 mph and 40 mph moves, and were assumed to start late enough not to meet significant traffic and so to cause no congestion. Seventy percent of daylight moves at 4 mph and 12 mph were assumed to start at 08:00, but 25 mph and 40 mph moves were assumed to be equally likely to start at any of the three times.

Moves that could not be completed by 20:00 were assumed to stop overnight and restart at 08:00. This was considered to be realistic, as few moves start in the afternoon or early evening and large, slow moves tend to start early, while smaller, quicker moves are more flexible (indeed often consist of a succession of vehicles starting at intervals, though not actually in convoy).

The 100 sample routes were stored so that all model variations could be run automatically. To determine the effect on the DfT routes, these also were programmed in, and the delay on each AIL route section that coincided with a DfT route link was projected back to the start of the DfT route, taking account of any delay on upstream links also affected by the AIL or its queues. The effects of temporary official closure of single-carriageway DfT sections in the opposite direction were also accounted for, but the model is not able to deal with more subtle effects on single-carriageway roads such as overtaking, or temporary obstruction or slowing of opposite-direction traffic (see, for example, Figure 2.1). For each scenario, the model outputs not only the details of the AIL’s route, but also the delay on each DfT route affected by it. The 13 500 scenarios yielded 67 884 DfT route delay effects.

| Table 8.1 Average AVD impact per mile travelled by AIL by speed and road |
|-----------------|-----------------|-------------|-----------------|-----------------|-----------------|
| AIL speed (mph) | Motorway         |             | Dual carriageway |             | Single carriageway |
|                 | Three lanes taken| Two lanes taken | One lane taken | Three lanes taken | Two lanes taken | One lane taken |
| 4               | 0.066623         | 0.031993   | 0.003136 | 0.190012 | 0.188134 | 0.134042 | 0.028711 |
| 12              | 0.001055         | 0.000133   | 1.64E-05 | 0.011732 | 0.011508 | 0.008479 | 7.39E-05 |
| 25              | 6.41E-07         | 3.67E-07   |             | 0.000157 | 0.000108 | 8.27E-06 |
| 30              | 3.68E-07         | 2.16E-07   |             | 6.29E-05 | 4.01E-05 | 6.86E-06 |
| 35              | 2.07E-07         | -          |             | 2.36E-05 | -       | 1.36E-07 |
| 40              | 2.13E-07         | 3.16E-07   |             | 7.56E-06 | 1.89E-06 | 2.38E-07 |
| 60              | Infeasible       | 5.93E-08   |             | Infeasible | 2.77E-06 | 5.04E-12 |
To convert delay effect on a DfT route into AVD impact, it is necessary to determine whether and to what extent the extra delay caused by the AIL modifies the charts of journey times for that route. The effect can be complex: a range of chart start times may be affected, and the effect could even extend into more than one day. Since the AIL move is hypothetical, it could in principle take place on any day in the rolling year. On some days there will already be a delay, but if this exceeds the delay that the AIL would cause on a normal day, then it can be assumed that rather than adding to the delay the AIL would be delayed but it would not add significant delay to the traffic, so its effect is negated. This is taken account of by the method shown in Figure 8.4. This inserts a proportion of the AIL’s delay according to where it falls in the chart. Because the chart is re-normalised to its original total veh-mi, any effect of the AIL will be manifested as an adjustment of the delay-days in the chart and a shift of the 90th percentile line, from which the new average delay for the chart can be calculated. The result of this process is a merged effect record containing the additional AVD contribution of the AIL in each scenario.

The total impact of each move type is then assessed by aggregating the total delays and veh-mi of the modified charts, calculating the AVD measure according to Equation 8.1 and subtracting the baseline value. Once again, this assumes that the effects of AIL moves are independent and relatively small. Each type effect is then factored according to the estimated total annual distance travelled by that type and the proportions starting on each day type and at each of the three starting times.

The results are summarised in Table 8.2, which includes the further results for numerous STGO moves at higher speeds (50 mph or 60 mph) estimated by the follow-on study of STGO and C&U moves (Hardman et al., 2008). The impact is very sensitive to AIL width and speed. The total must be treated with caution because of exaggeration of the effect of large, very slow (4 mph) moves, few of which actually take place on the strategic road network. Therefore, the true AVD impact could be as low as 0.033 minutes per ten veh-mi††.

8.3 Impact in terms of congestion cost
Average congestion costs and delays per affected vehicle in the various AIL categories are shown in Figure 8.5, from which it is clear that lane take and speed are critical. These results are broadly compatible with Table 7.2, but the impact of very slow (4 mph) loads is exaggerated because these would not normally travel on the strategic road network and so would affect much smaller traffic volumes than modelled. Taking Table 7.2 and Figure 8.5 together, one may judge that the practical limits of AIL congestion effect are around £3000/mile or 25 minutes per vehicle affected.

8.4 Effect of policies
To estimate the effect of diverting a percentage of AIL moves to overnight, it is not sufficient to simply factor the impact by that percentage, because the impact is highly variable, as illustrated by Figure 8.6 for 12 mph AILs occupying two lanes such as that shown in Figure 2.4.

Using the individual frequency distributions for the various AIL types, the impact of diverting a given percentage of any type can be estimated. It is estimated that only 7% of AILs in the 12–40 mph speed range would need to be diverted to night to virtually eliminate AVD impact, though this would need to be done selectively (Figure 8.7). In Figure 8.7, the straight line shows the effect of choosing a certain percentage of AILs at random, the curved line shows the effect of choosing the most disruptive AILs up to the same percentage of each type and the red cross represents a strategy that varies the most disruptive percentage for each type diverted. This presupposes that all the most disruptive moves could be diverted to night, which is unlikely for the reasons given in Section 4.1. Moves at 4 mph are excluded as they probably cannot be moved at night for operational and safety reasons, and moves with speeds exceeding 40 mph are also excluded.

Practically, AIL impact represents between 0.8% and 1.5% of the current network value of 3.95 minutes per ten veh-mi. To put this further in perspective, it is equivalent to at most a quarter of the average year-to-year variation of the AVD value over the three years of the PSA delay target, or a third of the change (reduction) up to March 2008. On the other hand, the 3.1 million journeys and 67.8 million veh-km travelled annually by AILs represent only about 0.049% of all travel (based on a WIM survey; see Hardman et al., 2008) and their impact in proportion to distance travelled is relatively high, 16–30 times greater than that of the average vehicle.

Fuller discussions of the issues and results in this section may be found in Taylor (2008a) and Taylor et al. (2009).
## Table 8.2 Estimated statistics of annual impacts of various AIL types

<table>
<thead>
<tr>
<th>AIL type</th>
<th>Lanes taken</th>
<th>Speed (mph)</th>
<th>Annual veh-km</th>
<th>Veh-h delay (1000s)</th>
<th>Average cost/mile (£)</th>
<th>AVD impact/10 veh-mi (min)</th>
<th>Cumulative AVD impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO</td>
<td>2</td>
<td>4</td>
<td>848</td>
<td>584</td>
<td>12 493</td>
<td>0.023218</td>
<td>0.023218</td>
</tr>
<tr>
<td>SO/VR1</td>
<td>2</td>
<td>25</td>
<td>78 188</td>
<td>817</td>
<td>190</td>
<td>0.010883</td>
<td>0.034101</td>
</tr>
<tr>
<td>STGO</td>
<td>2</td>
<td>40</td>
<td>1 542 666</td>
<td>1511</td>
<td>17.77</td>
<td>0.005656</td>
<td>0.039757</td>
</tr>
<tr>
<td>SO/VR1</td>
<td>2</td>
<td>12</td>
<td>1987</td>
<td>169</td>
<td>1548</td>
<td>0.005133</td>
<td>0.044890</td>
</tr>
<tr>
<td>SO</td>
<td>1</td>
<td>25</td>
<td>100 910</td>
<td>296</td>
<td>53.15</td>
<td>0.002978</td>
<td>0.051490</td>
</tr>
<tr>
<td>STGO</td>
<td>1</td>
<td>40</td>
<td>18 986 651</td>
<td>2791</td>
<td>2.67</td>
<td>0.003344</td>
<td>0.054834</td>
</tr>
<tr>
<td>SO</td>
<td>1</td>
<td>4</td>
<td>69</td>
<td>16</td>
<td>4107</td>
<td>0.000515</td>
<td>0.055349</td>
</tr>
<tr>
<td>SO</td>
<td>1</td>
<td>12</td>
<td>899</td>
<td>25</td>
<td>498</td>
<td>0.000452</td>
<td>0.055801</td>
</tr>
<tr>
<td>STGO</td>
<td>1</td>
<td>50</td>
<td>32 929 973</td>
<td>100</td>
<td>0.05</td>
<td>0.000364</td>
<td>0.056165</td>
</tr>
<tr>
<td>STGO</td>
<td>2</td>
<td>50</td>
<td>2 669 997</td>
<td>568</td>
<td>3.86</td>
<td>0.000156</td>
<td>0.056321</td>
</tr>
<tr>
<td>SO/VR1</td>
<td>2</td>
<td>40</td>
<td>57 934</td>
<td>72</td>
<td>22.61</td>
<td>0.000134</td>
<td>0.056455</td>
</tr>
<tr>
<td>SO</td>
<td>1</td>
<td>40</td>
<td>50 822</td>
<td>9</td>
<td>3.09</td>
<td>0.000007</td>
<td>0.056462</td>
</tr>
<tr>
<td>STGO</td>
<td>1</td>
<td>60</td>
<td>2 966 665</td>
<td>3</td>
<td>0.02</td>
<td>0.000004</td>
<td>0.056466</td>
</tr>
<tr>
<td>STGO</td>
<td>2</td>
<td>60</td>
<td>237 334</td>
<td>38</td>
<td>2.93</td>
<td>0.000001</td>
<td>0.056467</td>
</tr>
<tr>
<td><strong>Total or average</strong></td>
<td><strong>59 625 620</strong></td>
<td><strong>7101</strong></td>
<td><strong>2.16</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>0.056467</strong></td>
</tr>
</tbody>
</table>

### Figure 8.5
Average cost and delay caused by various AIL types as modelled
Figure 8.6 Modelled frequency distribution of impacts for 12 mph AILs using two lanes

Figure 8.7 Potential AVD reduction as a function of the percentage of AILs rescheduled
9 Conclusions on the movement of AILs by night

The aim of this work was to establish the advantages and disadvantages of moving AILs at night and to provide advice and recommendations to help facilitate the practice. The impact of abnormal loads on congestion and the AVD delay measure has been estimated using the Congestion Calculator. The main conclusion is that rescheduling just a few of the loads can lead to a disproportionate reduction in the AVD impact of AILs, provided that moves are rescheduled selectively rather than randomly; the impact of rescheduling is considerably improved by selecting the moves most likely to produce the worst delays. Bourne et al. (2008) conclude that these would need to be selected on a case-by-case basis, because in addition to the motivation to select those most likely to cause disruption to traffic, there are several other considerations:

- Possible increase in accident risk and severity at night
- Current visibility requirements not adequate for safe travel at night
- Travel generally not permitted on local roads at night
- Road works information inadequate for planning purposes
- Limited choice of lay-bys suitable for AILs
- Logistical issues such as increased working time and costs for hauliers

In addressing these factors, it is recommended that:

- Exceptions to the current police “night policy” preventing travel by night on non-network roads should be collected and published. This could include “night corridors” to allow loads to reach a lay-by, initial origin or final destination slightly off the network.
- The escorting Code of Practice should include specific night-time guidance.
- Lighting regulations and equipment available in Europe and their application in the UK should be reviewed and their updating considered (see Section 11).
- A database of potential lay-bys and motorway service areas should be included in an integrated planning system, which could include a reservation system for motorway service areas. Lay-bys suitable for AILs could also be built into road upgrade schemes or new developments.
- Ways to improve communication and integration between the various parties in the current road works notification system should be considered.

10 Review of the management of STGO and C&U moves

The objectives of the work reported by Hardman et al. (2008) were somewhat different from the work by Bourne et al. (2008), mainly to improve the understanding of C&U and STGO (excluding SO) movements, including quantifying their numbers and their impact on the AVD measure (as noted earlier) and studying a range of options for management.

To estimate the total number of AIL movements and distance travelled, data were obtained from a number of sources, including weigh-in-motion (WIM) equipment, CCTV images and notifications (both police and county council).

WIM equipment is located at several locations on the UK road network and produces data on a regular basis, from which nine sites in England were selected where all running lanes are covered. The data provided by the equipment contain many fields, including:

- Date and time
- Gross vehicle weight
- Individual axle weights, type (eg single or dual) and spacings
- Total length of vehicle
- Speed of vehicle
- The lane the vehicle was travelling in
- An indication if the vehicle was straddling two lanes
- The headway (in seconds and metres) with the vehicle in front
- A chassis code and class (based on the axle configuration)
- A validity code

No information is available on vehicle width. Although there is a field indicating whether a vehicle was straddling two lanes, this could also arise because the vehicle was changing lanes. However, the number of very wide loads is known from data provided by the HA. The 91.4 million valid WIM records from the nine sites were categorised into four bands:

1) All vehicles not identified as STGO or SO
2) STGO categories 1 and 2
3) STGO category 3
4) SO

The overall results for the proportions of vehicles of various types in the total traffic are given in Table 10.1. The proportion of SOs travelling at night is consistent with the value of 15% assumed earlier for AVD estimation (Section 8.2), but the assumption of 5% for smaller AILs is shown to have been incorrect, as about 20% were recorded as travelling between late evening and early morning, the effect of this being to reduce the estimated AVD impact of 0.056 in Table 8.2 by just over 9% to 0.051.

A sample of CCTV footage from sites on the M5, M6 and M25, amounting to nearly 62 hours of observation, was used to check the identification of 40 AILs, but only moderate-sized vehicles travelling at an average speed of 82 km/h were seen, highlighting the difficulty of observing the effect of AILs as they occur, and it could be difficult to determine their widths accurately.

Further data from Vehicle and Operator Services Agency (VOSA) sites, which combine WIM data with photography and speed measurement using automatic number plate...
Table 10.1 WIM counts of AILs by road type and time period

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage on motorways</th>
<th>Percentage on A-roads</th>
<th>Overall percentage</th>
<th>20:00–06:00</th>
<th>Percentage by night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light vehicles</td>
<td>81.654%</td>
<td>91.833%</td>
<td>85.126%</td>
<td>76.031%</td>
<td>12.09%</td>
</tr>
<tr>
<td>HGVs or C&amp;U</td>
<td>16.868%</td>
<td>7.724%</td>
<td>13.749%</td>
<td>22.342%</td>
<td>21.99%</td>
</tr>
<tr>
<td>STGO category 1 or 2</td>
<td>1.115%</td>
<td>0.378%</td>
<td>0.863%</td>
<td>1.228%</td>
<td>19.26%</td>
</tr>
<tr>
<td>STGO category 3</td>
<td>0.340%</td>
<td>0.056%</td>
<td>0.244%</td>
<td>0.379%</td>
<td>21.02%</td>
</tr>
<tr>
<td>SO</td>
<td>0.022%</td>
<td>0.009%</td>
<td>0.017%</td>
<td>0.018%</td>
<td>14.33%</td>
</tr>
<tr>
<td>Total STGO, SO</td>
<td>1.477%</td>
<td>0.443%</td>
<td>1.124%</td>
<td>1.6254%</td>
<td>19.57%</td>
</tr>
</tbody>
</table>

Sample size: 60,233,937 31,176,518 91,410,455 12,372,734

While it is concluded that C&U and STGO AILs do not make a significant impact on the AVD measure, several improvements to their management are suggested.
- The main improvement that could be made is in the recording of notifications and actual journeys. This not only has the potential to provide better quality data on numbers of movements, but also to help highway authorities in approving plans and highway operators in providing information to road users.
- Better facilities for weighing vehicles, both at public weighbridges and at enforcement sites, would lead to higher compliance with regulations and would possibly lead to less road and structural damage on the network. WIM has the potential to help in this process, and to quantify the extent of the problem, but WIM sites must be correctly calibrated at frequent intervals for the data to be of value.
- Improved recording of accidents involving AILs would enable black spots or other traffic patterns involving these vehicles to be identified. Extending the vehicle categories recorded in STATS9 reports would contribute to this.

Table 10.2 AILs identified through VOSA

<table>
<thead>
<tr>
<th>Numbers according to length</th>
<th>Average speed (mph)</th>
<th>Standard deviation of speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Under 25.9 m</td>
<td>Over 25.9 m</td>
</tr>
<tr>
<td>C&amp;U AIL</td>
<td>37</td>
<td>0</td>
</tr>
<tr>
<td>STGO category 1</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>STGO category 2</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>STGO category 3 including one SO</td>
<td>35</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 10.3 Proportion in each STGO/C&U category assumed for modelling

<table>
<thead>
<tr>
<th>Speed</th>
<th>One lane</th>
<th>Two lanes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 mph</td>
<td>32.0%</td>
<td>2.6%</td>
<td>34.5%</td>
</tr>
<tr>
<td>50 mph</td>
<td>55.5%</td>
<td>4.5%</td>
<td>60.0%</td>
</tr>
<tr>
<td>60 mph</td>
<td>5.0%</td>
<td>0.4%</td>
<td>5.5%</td>
</tr>
<tr>
<td>Total</td>
<td>92.5%</td>
<td>7.5%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>
Figure 10.1 Average congestion cost per mile caused by each category of STG/C&U
11 Review of the lighting, marking and signage of AILs and escorts

As mentioned in Section 9, previous work by Bourne et al. (2008) concluded that lack of conspicuity (how easily drivers can detect and recognise potential hazards) was a safety concern for transporting AILs at night and that the current lighting and signage regulations are inadequate. This conclusion is driven by the rolling out of self-escorting and the potential for moving more loads by night to reduce congestion effects. Concerns include increased accident risk and the need to define and conform to European standards because foreign vehicles may be affected. The research therefore looked at several aspects including:

- Visibility and conspicuity of AILs and their escorts under various conditions
- Driver hazard perception, including peripheral and subliminal aspects
- Driver response, eg reaction to different shapes or coloured flashing lights
- Approach speeds and avoidance dynamics
- UK and UNECE regulations
- Best practice of marking and signage in several European countries

The analysis extended the concept of “zone of influence” used in congestion modelling to approach, decision, manoeuvring and passing zones each involving different driver perception and behaviour, and thus requiring different types and levels of conspicuity. The outcome of this work was to generate a specification for improved lighting, marking, signage and safety equipment of AILs and escort vehicles, which increases their conspicuity. These specifications form the basis of draft best practice documents that will be targeted at industry (both hauliers and escorters), providing information on how to improve AIL and escort vehicle conspicuity. These recommendations are currently being prepared for consultation.

12 Effect of AIL speeds

Some exploratory work has been carried out using the Congestion Calculator to estimate how AIL impacts would be affected by hypothetical relaxation of speed limits on some heavier SO types. This required a different categorisation of AILs because their practical speeds depend on the vehicle configuration and weight. The BE16 records used for the earlier studies were sorted and 131 relevant records found (Table 12.1).

For the purposes of modelling, the lighter articulated semi-trailer (AS) and light drawbar (LD) types are assumed to be physically capable of any speed up to 60 mph. Other types are typically girder-frames, which are practically not capable of speeds above 20 mph. The lighter AS and LD types are assumed to be able to run on a 12-hour cycle consisting of eight-hour shifts followed by four-hour rest periods and a change of driver. Heavier vehicles – heavy drawbar (HD) and other types (OT) – are assumed to require specialised drivers and to run only by day with overnight stops.

Some modelling results are shown in Figure 2. These are not conclusions of the study, which is still in progress, but they show how increasing speeds can reduce both congestion cost and AVD impact. Note that realistic speed caps have been imposed on HD and OT types. For the AS and LD types, the maximum speeds will depend on regulation, currently defined as in Table 2.2 earlier.

| Code | Description            | Weight range | BE16 records | Annual moves | Annual veh-mi | Average miles | Need two lanes |
|------|------------------------|--------------|--------------|--------------|---------------|---------------|----------------|----------------|
| AS   | Articulated semi-trailer | 150–250 t    | 36           | 31           | 2322.6        | 74.1          | 30%            |
| LD   | Light drawbar          | 150–250 t    | 33           | 43           | 1640.8        | 38.2          | 48%            |
| HD   | Heavy drawbar          | > 250 t      | 15           | 9            | 561.7         | 64.8          | 77%            |
| OT   | Other types            | > 150 t      | 47           | 18           | 809.0         | 44.9          | 100%           |
Figure 12.1 Effect of hypothetical speeds for each SO type
13 Conclusion

A series of projects has been conducted to study the congestion caused by AILs and their impact on the AVD measure related to journey time reliability. In the process, through literature review, consultation, observation, modelling and data gathering, understanding of abnormal loads, their prevalence in the network, the concerns of hauliers and other stakeholders and the potential for reducing impacts has been extended. AILs represent 0.049% of total mileage in England, and their overall impact on AVD is very small, no more than about 1.3% of the figure of 3.95 minutes per ten veh-mi reported for March 2008. Furthermore, most of the impact comes from the small number of large, slow AILs. Congestion cost and delay caused by an AIL increase rapidly as its speed is reduced and as it occupies more lanes. The implication is that measures to reduce congestion impact will be most effective if selectively targeted. On the other hand, improvements to safety, best practice, information and support systems can be applied more widely, and after suitable scrutiny and consultation there may also be scope for reviewing regulations.

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Department for Transport (2009a). Notification requirements for large or heavy loads. Accessed 28 September 2009. Available at www.dft.gov.uk (Policy, guidance and research > Road safety > Driver and rider safety > Driving for work > Notification requirements for large or heavy loads > Background and definitions).


The management and impact of abnormal loads

Congestion on Britain’s roads is an increasing problem. The movement of large and heavy abnormal indivisible loads (AILs) through the road network can cause additional delays to other traffic. Delays caused by AILs could potentially be reduced by management measures based on a better understanding of how they are related to the types of load and the conditions under which the loads are moved. This Insight Report covers several projects that have investigated the prevalence and congestion impact of AILs and the effect of mitigation measures such as movement by water or by night. It concludes, however, that the overall impact of AILs on network delay is small and mitigation measures will be most effective if selectively targeted.

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