Estimating the Impact of Abnormal Loads on the PSA Value

N B Taylor
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PPR 347
PSF M3B

PUBLISHED PROJECT REPORT
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by N B Taylor (TRL)

Prepared for: Project Record: PSF M3B
Impact of Abnormal Loads on the PSA Value
Client: Highways Agency, Abnormal Loads Unit
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<td>Issue 3</td>
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Executive summary

Abnormal Loads (AIL) can cause delay to other traffic, and by doing so may affect journeys which contribute to the Public Services Agreement (PSA1) ‘average of 10% slowest journey times’ measure for some of the routes specified by the Department for Transport for evaluation of performance indicators. The Congestion Calculator, a spreadsheet and VBA macro program created by TRL to calculate the delay and cost caused by a specific Abnormal Load movement for a specific route and starting time on a specific type of day, and the PSA Value Calculator, also based on a spreadsheet and VBA macros, are applied here to estimate the impact of various types of AIL move on the PSA delay value, as specified under Highways Agency PSF Task Order M3B.

The report begins by describing how delay to individual PSA probe values passing through the queues caused by an AIL is evaluated. For specific AIL movements, this can be done by tracing the path of the probe vehicles in detail, which also enables the effect on more than one PSA route to be calculated as a function of the PSA time period, including those links adjacent to but not on the AIL’s route. Where all possible day types and timings of a move have to be evaluated, a more efficient alternative method is described and shown to give results approximate to those of the detailed method.

Once the delay caused by an AIL movement has been calculated, the impact on any PSA chart is calculated by merging the movement into the chart as a ‘modified day’ (originally it was proposed that an ‘extra day’ should be inserted in the chart, but in reality the number of days is fixed). Hence a procedure is used to normalise the chart so that the effect of one or more AIL moves is distributed fairly over the available days. This is quite important because many AIL moves occur in a series over several weeks, often starting around the same time on the same day of the week.

The method of using the Congestion Calculator and PSA Value Calculator software to calculate and display graphically the impact estimates is described and illustrated. A further Task is to estimate the impact of a range of AIL types generically on different road standards. This is done by running the Congestion Calculator in ‘batch’ mode for 292 usable1 PSA route segments of either Motorway, Dual carriageway or Single carriageway standard, for 22 combinations of AIL width2 and speed in the ranges 2.5-9m and 4-60 mph, seven day types (normal days of the week), and start times at half-hour intervals in the daytime range 06:00-19:30. The impact is evaluated nominally for the PSA periods between 06:00 and 20:00 which contribute to the Network PSA Value.

Whole-day generic impacts are analysed. These found to be predictable on average, though with considerable scatter, approximately by linear regression formulae, though for AILs whose speed is above 35 mph the slopes appear to be unreliable, so mean PSA impacts for each continuous segment travelled may be preferred:

$$\text{PSA\_increase} \approx \text{Slope(Road\_type, AIL\_width, AIL\_speed)} \times \text{Distance\_travelled}$$

This approach enables the relative impact of different moves to be appreciated to a degree, although aggregating impacts for the large number of smaller (eg C&U and STGO) moves could be problematic if their effect turns out to be large, because it is already present in the PSA value and probably spread evenly over routes and days. The generic formulae are not time dependent, but dependence on day type and start time can be seen for specific AIL combinations and routes by plotting their data sets within the PSA Value Calculator. Studies of PSA impact using more realistic route sets and data on annual AIL movements of various types are expected to be reported elsewhere.

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1 Consisting of at least 3 consecutive links of the same standard.
2 Note that the Congestion Model is sensitive only to the number of lanes occupied by an AIL, so several of the width categories have identical effects.
Abstract
Abnormal Loads (AIL) can cause delay to other traffic, and by doing so may affect journeys which contribute to the Public Services Agreement (PSA1) ‘average of 10% slowest journey times’ measure for some of the routes specified by DfT for evaluation of performance indicators. The Congestion Calculator, a spreadsheet and VBA macro program created by TRL to calculate the delay and cost caused by a specific Abnormal Load movement for a specific route and starting time on a specific type of day, and the PSA Value Calculator, also based on a spreadsheet and VBA macros, are applied here to estimate the impact on the PSA delay value of various types of AIL move on different types and lengths of road in generic terms.
1 Purpose and structure of the PSA impact calculation

Abnormal Loads can cause delay to other traffic, and by doing so may affect journeys which contribute to the (Public Services Agreement) PSA1 ‘average of 10% slowest journey times’ measure for some of the routes specified by DfT for evaluation of performance indicators. The HATRIS network (Figure 1) for this purpose consists of around 2470 motorway, trunk and major road links, and currently 91 bi-directional routes in use, totalling 11,856 km (each route averaging about 11 links and 65 km3).

The Congestion Cost Calculator is a spreadsheet and VBA macro program created by TRL to calculate the delay and cost caused by a specific Abnormal Load movement for a specific route and starting time on a specific type of day. This has been extended to determine the HATRIS links and PSA routes affected and calculate the effect on specimen journeys along these routes according to the PSA methodology. It is deemed to provide effect data for a ‘modified day’ to be introduced into the ‘chart’ of up to 53 days for a particular day of the week and journey starting time. The PSA Value Calculator, another spreadsheet and macro program, then calculates the average delay on the 10% slowest journeys using the methodology defined by Cottell (2006) and historical charts. Comparing this with the result without the Abnormal Load movement gives a value for the impact\(^4\) of the Abnormal Load on the PSA value. Figure 2 is a flowchart showing the principal data types and processes.

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\(^3\) These figures are from the network data used for this work, which may not be the very latest data.

\(^4\) We use ‘effect’ to mean delay caused by an AIL on a PSA route, and ‘impact’ to mean the resulting change in the PSA value, which depends only on the 10% most delayed journeys.
Figure 2. Flowchart of PSA Impact Calculation for an Abnormal Load movement
2 Delay along the route of an Abnormal Load

Queues caused by Abnormal Loads can have a complex shape and extend over several road sections, and are also generally in motion. In Figure 3, a queue on two sections is visualised (solid black and blue lines), with tracks (dotted) of individual vehicles shown passing through it.

![Figure 3. Traces of vehicles through queue caused by an Abnormal Load, with PSA grid, showing datum points (P_n) defining the queue segment associated with road section 2 and line segments relating to the trajectory of the vehicle (TV_x) – see following text.](image)

Where the tracks are blue, the vehicles move at their normal speed, but where the tracks are red they are delayed. As modelled in the Congestion Cost Calculator, the queue associated with one road section in general has a quadrilateral shape (of which a triangular shape is a special case), and can extend over sections upstream as well as its originating section. This modelling approach is dictated by computational considerations, in which a single computation can be applied to each road section, without need for iteration. The orange and magenta boxes superimposed on Figure 3 are the PSA grid, dividing the day into fixed 15 minute periods for the purpose of journey time calculations. This grid coincides with the start and end of road sections (including HATRIS links) on the vertical axis, but does not in general coincide with the start and end times of the AIL on each section on the horizontal axis. Overlap of the queue, and its moving ‘change waves’, with the physical section boundaries and PSA time period boundaries, plus the tracks of vehicles moving through the queue at various speeds, create complex and awkward geometrical shapes.

If we consider one road section then we can define the start and end points of the AIL in absolute terms (the whole route can normally be deemed to start at position 0) by the points:

- **P1**: (load start) \( (t_1, x_1) \)
- **P2**: (load end) \( (t_2, x_2) \)

**Line P1P2**: \( x = x_1 + v_L (t - t_1) \)
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where \( v_L \) = AIL’s speed, \( x_1 \) and \( x_2 \) are the start and end positions of the section (distances along the route), \( t_1 \) and \( t_2 \) are the times when the AIL reaches those points.

The shape of the queuing region associated with that section is defined by two further points as shown in Figure 3, a break point \( P_3 \) where the tail of the queue changes speed (which may not be present) and the point \( P_4 \) where the queue dissipates:

**P3**: (break point) \( (t_3, x_3) \) where \( t_3 = t_1 + t_{f(1)} \) and \( t_{f(1)} \) is the time for which extra heavy flow occurs due to the queue upstream, if any – otherwise \( P_3 \) collapses into \( P_1 \).

**Line P1P3**: \( x = x_1 + v_{ab(1)} (t - t_1) \) where \( v_{ab(1)} \) is the left hand tail-wave speed of the queue (note: positive speed means downstream, negative upstream).

**P4**: (dissipation point) \( (t_4, x_4) \) where \( t_4 = t_2 + t_d \) and \( t_d \) is the time taken by the queue (if any) to dissipate – otherwise \( P_4 \) collapses into \( P_2 \).

**Line P3P4**: \( x = x_3 + v_{ab(2)} (t - t_3) \) where \( v_{ab(2)} \) is the right hand tail-wave speed of the queue (note: positive speed means downstream, negative upstream).

**Line P2P4**: \( x = x_2 + v_{bd} (t - t_2) \) where \( v_{bd} \) is the speed of the discharge wave at the front of the queue (note: positive speed means downstream, negative upstream).

It is not necessary to trace each vehicle through the complete queue, nor need the number of vehicles traced be related to actual flows, since what is required is the average delay on each section per vehicle entering the section during a given PSA period. Nevertheless, each such vehicle can meet queuing caused not only by its own section but by one or more sections downstream. The simplest method of calculation is to send a ‘flight’ of simulated trace vehicles through the section starting at regular intervals, and calculate when they enter and leave the various queuing regions. Under heavy queuing, the vehicle is already in the queue at the beginning of the road section (solid blue line). If conditions are favourable, the tail of the moving queue may move downstream (dashed blue line), so the vehicle may join it downstream from the beginning of the road section. Conversely, the exit point from the queue could be within or downstream of the section. However, the travel time must always be truncated so that it takes place within the road section being considered.

A given trace vehicle, arriving freely, is described by a line of the following form:

**TVa**: \( x = x_1 + v_a (t - t_0) \) where \( t_0 \) is the time when the vehicle enters the road section, i.e., position \( x_1 \) corresponding to point \( P_1 \) in Figure 3, and \( v_a \) is the normal speed of traffic. This line may be redundant if the vehicle enters the queue immediately.

Within a queue on the road section, if there is one, the vehicle’s movement is defined by a line of different slope:

**TVb**: \( x = x_q + v_b (t - t_0) \) where \( (t_0, x_q) \) is the point where the vehicle enters the queue and \( v_b \) is the speed of traffic within the queue.

The starting times of trace vehicles can be defined in relation to PSA periods as follows:

\[ t_0 = 6 + .25j + .25i/n + .125/n \]

where \( t_0 \) is in absolute hours, \( j \) is the sequence number of the PSA period (0..55), \( n \) is the number of trace vehicles to be launched in each period, \( i \) is the sequence number of the vehicle in the period (1..n), and the last term is an offset to ensure trace vehicles are launched symmetrically.

Because of the complexity, we do not take into consideration the slight delays associated with passing the AIL or proceeding in denser traffic discharging from a queue, or the slight time saving associated with being in less dense traffic ahead of the AIL.
To determine the actual entry time of a trace vehicle into the queue, we calculate the points at which TVa meets either P1P3 or P3P4. This is best done parametrically, by redefining, for example:

**Line P1P3**: \( x = x_1 + \lambda (x_2 - x_1), \quad t = t_1 + \lambda (t_2 - t_1) \)

If the vehicle path meets this such that \( \lambda \in [0,1] \) then the vehicle would enter the queue along this line. Similarly, we test whether the trace vehicle meets line P3P4. It cannot cross both lines but if it crosses one then it could enter the queue. However, if the valid entry point is before the start of the road section, the actual entry point is the point where the trace vehicle enters the congestion area. Similarly we test for whether and where the trace vehicle exits the queue through P1P2 or P2P4, assuming it moves according to TVb (this of course can be done only once the entry point to the queue is known).

For each intersection of TVx with PyPz, the general formula for the parameter \( \lambda \) is:

\[
\lambda = \frac{(x_0 - x_y) - v_x(t_0 - t_y)}{(x_z - x_y) - v_x(t_z - t_y)}
\]

where \((t_0,x_0)\) is an initial point on the vehicle’s trajectory. If both the numerator and the denominator are zero, then the vehicle’s path is collinear with the queue boundary and \( \lambda \) can be taken as zero. If only the denominator is zero then the vehicle’s path is parallel to the queue boundary so never meets it. In this case, and otherwise if \( \lambda \notin [0,1] \), the lines do not meet. This is represented in the spreadsheet implementation by imposing the value -1. These results lead to binary values for entering and exiting the queue: 0=invalid, 1=valid. An exit point also becomes invalid if it is calculated to precede the entry point. An example of this geometric calculation process is shown in Figure 4.

In the implementation, the entry position of a trace vehicle is fixed as described earlier. The putative queue entry point for the first section is set to this position at the time of entry. If the queue exit point is valid then it becomes the queue entry point for the next section. Otherwise, the current queue entry point is carried forward to the next section. The vehicle exit point is then constrained to the interior of the section being evaluated, and the exit time adjusted *pro rata*. If both the interior queue entry and exit points are valid, the time the vehicle spends in the queue is calculated as the difference between the exit and entry times. Delay is calculated as:

\[
Delay = (t_{exit} - t_{entry}) \left( 1 - \frac{v_b}{v_a} \right)
\]

where the speed-dependent factor means that delay depends on the difference between the free speed and the queuing speed as well as on the time spent in the queue.

When evaluated for a specific road section and trace vehicle start time within a period when a queue is present, this cascaded calculation may generate a delay value *associated with* the specified section and possibly one or more later sections. The sum of these delays is the total delay experienced by the trace vehicle *while on the specified section*. The number of sections whose queues contribute delay depends on the amount of blocking back which occurs. If a flight of trace vehicles is launched, their average delay is calculated. This estimates the average delay per vehicle on the specified section during a specified PSA time period.
Although total travel time is evaluated only delay is kept. This is because normal travel times are available from the AIL route model only at the places and times of its passage. Also there can be slight inaccuracies due to the way the congestion cost calculator works. For example, any queuing caused by a given section is evaluated using the characteristics of that section, including normal free speed, but it may be incurred on a section upstream whose free-flow characteristics are different. Finally, for PSA evaluations, it is necessary to base the estimated journey time affected by an AIL on the distribution of measured normal travel times.
3 Illustration of delay along the route

On a move via the M5 to Hinckley the sixth link is a short (1.6 km) 4-lane section of the M5, leading into a longer 3-lane section. The start and end positions are 52.29 km and 53.90 km, and, as modelled, the AIL enters the 4-lane section at 10:41 or 10.68 hours. The Table below shows the delays experienced by some trace vehicles in PSA time periods 10:30-11:00.

Table 1. Calculated delays to a group of trace vehicles on target link

<table>
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<tr>
<th>Vehicle entry time</th>
<th>Delay from this link</th>
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<th>Total delay (min)</th>
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<tr>
<td>10.675</td>
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<td>10.725</td>
<td>1.62</td>
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<td>0.27</td>
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<td>10.925</td>
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Figure 5 sketches how these delays come about.

The queue on the 3-lane section grows more rapidly than on the 4-lane section, causing its tail wave to move downstream more slowly. The paths of three trace vehicles which experience delay are shown, their undelayed parts in blue and delayed parts in red. The first vehicle, entering the 4-lane section at 10.725 h, passes through queuing caused by the AIL's presence on both sections, but from 10.825 h onward, only the queue caused on the 3-lane section contributes to delay on the 4-lane section.
4 Calculating delay on links just off the route

PSA routes do not merge or fork, but they can touch, so in a few cases a HATRIS link has more than one HATRIS link which could feed traffic into it. However, each HATRIS link forming part of a given route has at most one link on another PSA route which feeds traffic into it. Typically, HATRIS links are major roads, so if there is only one off-route link entering any junction, most entering traffic can be ascribed to it. Also, we assume that off-route through traffic is not delayed by traffic queuing to join the route, even if the link is single-carriageway. It is certainly not always the case that the AIL enters every junction on the main road. For example if it joins a motorway from a minor road, the off-route link will be the upstream motorway link. However, the number of vehicles queuing on the AIL’s route is then likely to be small compared to the capacity of the route downstream of the junction.

While a queue is present at a junction on the AIL’s route, a queue may form on an off-route link joining the route, which can be ascribed to the effect of the AIL. According to the Congestion Cost Calculator model, a queue on the route can develop in two phases. In Phase 1, the demand on the link downstream of the junction is higher than normal due to the queue following the AIL on the link upstream of the junction. In Phase 2, the normal demand on that link, in the presence of the AIL, is enough to cause queuing. For calculation of the off-route queue, there is also a Phase 3 during which the queue on the off-route link discharges (see Figure 6). According to this model, queuing on the off-route link depends only on the presence of a queue passing the junction.

![Diagram of traffic flow](image)

Figure 6. Method of calculating queue and delay on off-route link

The original Congestion Cost Calculator takes a somewhat different approach in that it considers the balance between total demand, including any traffic entering from off-route, and the capacity available on the route. According to this, one would expect the queues from all entry directions to end at the same time, but this is improbable in reality...
since the length of a queue in itself does not determine capacity for traffic entering from the side. Instead, this is usually assumed to be determined by a principle of fair sharing of the available capacity, at least where there is no giving way.

Where the queue passing a junction is modelled as several components ascribed to different route sections downstream, including possibly with gaps in queuing, the pattern of queue passing the junction could be complex, and Phase 3 may be curtailed if it runs into Phase 1 of the next bout of queuing. However, since the queue has a physical stop line at the junction, its shape is simpler than that of a moving queue, and can be calculated by a simple vertical queuing model.

While a queue is passing the junction, the effective capacity is the same as the queuing flow, $q_b$. To share this ‘fairly’ between the on-route and off-route demand, we need to take account of the fact that demand along the AIL’s route is modified by queuing, as defined in the Modelling Report, Section B.7, Equation (21), while that from off-route (O) remains unaltered and is derived from the normal flows (see Modelling Report Figure 10):

$$q_O = q_D - pq_U = q_a2 - pq_a1$$

where $q_U$ and $q_D$ are the normal demands on the upstream and downstream route links ($q_a1$ and $q_a2$ in the Modelling Report) and $p$ is the proportion of traffic turning off the upstream route link.

The effective capacity available to off-route traffic while a queue is present at the junction (Phases 1 and 2), according to the ‘fair sharing’ principle, is given by:

$$\mu_O = \frac{q_O\mu_D}{q_D}$$

where the demand $q_D$ is the elevated demand due to queuing $q_a(1)$ in Phase 1 and the normal or discharging flow $q_a(2)$ in Phase 2, the capacity $\mu_O$ is equal to the downstream queue flow $q_b2$.

In Phase 3, remembering that the demand on the downstream link includes the off-route entering flow, the effective capacity available to off-route traffic is given by a different formula, which allows for any unused capacity in the link and does not involve sharing:

$$\mu_O = \mu_D - q_D + q_O$$

The queue at the end ($t_i$) of each phase ($i$) is calculated by a simple deterministic model, starting at the beginning of Phase 1 with either zero queue or any queue remaining from the previous period of queuing:

$$L_i = \text{Max}[L_{i-1} + (q_O - \mu_O)(t_i - t_{i-1}), 0]$$

The end of Phase 3, $t_3$, is the time when any queue remaining from Phase 2 finally discharges, provided that capacity remains normal. Otherwise it is taken to be the start of Phase 1 of the next period of queuing. The average delay to a vehicle queuing during part of any phase is calculated by assuming that the queue discharges at the capacity rate in that phase only, hence:

$$d_{[i]} = \frac{L_{[i]}}{\mu_{Oi}} \quad \text{(where ‘[ ]’ is equivalent to ‘any part of’)}$$
Finally, the average delay per off-route vehicle is calculated by the time-weighted average of the delays in the parts of the PSA period falling into the three Phases.

This simplified approach avoids the need to consider the density or physical length of the off-route queue, or the speeds of vehicles moving through it, and also ignores any effect related to the finite speed of backward moving discharge waves. Such simplification can be justified by assuming that off-route delays are unlikely to be dominant.
5 Effect of an Abnormal Load on link volumes

Link volumes can change when a queue is present, when volume, as would be measured for example, by MIDAS, can differ from demand. Volume can also vary along the length of a link. As explained earlier, when a queue is present the volume is the queuing flow \( q_b \), and otherwise it is the normal flow on the link \( q_a \), so the effect on volume on on-route links is the difference \( (q_b - q_a) \), which can be positive or negative. It is assumed that flow in a time period is measured at the entry to the link, consistent with the definition of travel time. Only the change in flow in a 15 minute PSA period in which delay is experienced on an on-route link is recorded. This because the full PSA calculation will have its own data on ‘normal’ flows as well as ‘normal’ link travel times. Currently, no flow change is recorded for off-route links.

6 PSA effect estimation by tracing vehicle paths

This method was the first one developed though it is not now recommended because of its computational burden. It requires execution of Generate PSA Impact Table macro. The structure of the link impact calculation is shown in Figure 7. It is important to appreciate that the main model columns are calculating the contributions of queuing deemed to be caused by each section of the AIL’s route, while the blocks shown, which collect these contributions, relate to the one particular route link being analysed, and the associated off-route link if any, and one specified PSA period.

The macro performs a nested loop taking each route section and each PSA time period in turn, inserts the appropriate values in the blue cells at the top, and picks up the red circled results, which are then copied to the appropriate cells in the link delay and flow.
change tables. This calculation is valid only for the starting day and time for which the model is evaluated. HATRIS link and PSA route delays in minutes (per vehicle) are reported in a single worksheet, and flow changes in vehicles (per 15 minutes) in another worksheet with similar format (see Figure 8). The PSA calculation requires distance weighted flow and reference (free flow) journey time in addition to delay for each journey. These are tabulated in the PSA Impact spreadsheet, see Figure 9.

Figure 8. Reporting of vehicle delay and flow change for HATRIS links, routes and PSA time periods

Figure 9. Reporting of trace vehicle impact by PSA routes and time periods
\(Going \ through \ the \ columns \ in \ order:\)

**Route:** the PSA route number with decimal 1 or 2 added to represent the direction.

**Links:** the number of links in the PSA route.

**Day Type:** there are currently 21 day types in HATRIS, including public holidays. Other work (Taylor, 2007) has shown that it is probably sufficient to model only the 7 days of the week, Monday to Sunday being conventionally numbered -1 to -7. Some data are not available for all days, in particular the 21 HATRIS day types combine Tuesday to Thursday, so in practice there are only 5 types of day of the week, with 3 (or -3) chosen to stand in for midweek days.

**Period:** the time when the journey is deemed to begin, to a quarter of an hour (PSA period).

**Distance:** the length of the route in miles.

**FreeFlowTime (FFT or RefJT):** the journey time in minutes assuming the free flow speeds given in the HATRIS data. This is normally the reference journey time against which delay is calculated by the PSA procedure.

**StandardJT:** the journey time in minutes calculated using the speed/flow relationships obtained from HATRIS journey time data for the links (see Taylor, 2007) and the HATRIS average flows for the appropriate time periods as the journey proceeds.

**AffectedJT:** the journey time calculated in the presence of the Abnormal Load.

**DWFStandard:** the distance-weighted HATRIS flow per 15 minutes on the route in the absence of the Abnormal Load, drawn from the appropriate time periods during the journey.

**DWFAffected:** the distance-weighted HATRIS flow per 15 minutes on the route in the presence of the Abnormal Load, which can affect the average flows in the periods by creating queues (the Congestion Calculator uses appropriate flows to calculate normal traffic speeds).

**AILDelay:** the actual delay per vehicle in minutes caused by the AIL, equal to the difference between AffectedJT and StandardJT.

**Uncertainty:** the estimated percentage uncertainty of the whole delay calculation (see next).

Note that a day type is given for both link impacts and route impacts, because the AIL move could take place over two days and so impact on two different day types, but not in the same time period. Worksheets with similar layout give flow changes and percentage uncertainties in delay values (as defined in a later section).
7 PSA effect estimation by projecting link delays

This method is performed automatically using spreadsheet formulae when the macros Generate Profile and Graphs, THIS Route all Combinations and ALL Routes all Combinations are invoked. Macro code is used to collect and write results to an output file, but is far less computationally burdensome than the vehicle tracing method, making it practical to model the full range of AIL types and starting times using a large number of routes. However it does involve a degree of approximation. The method takes the delay caused by the AIL on each link and projects it to the start of any PSA route which shares that link, assuming that PSA reference speed applies on those links of the PSA route not on the AIL’s route, and that travel time any upstream links which are on both the PSA and the AIL’s route is affected by an element of delay. The projected delay on the PSA route is expressed as an average value spread over a number of PSA periods, so no profile information is recorded. Furthermore, when PSA effects are collected, total delay is averaged over all PSA time periods involved. This enables the output to be kept manageable, each move (vehicle type, day and start time) being represented by a set of four numbers, as shown in Figure 10:

![Annotated example of PSA effect output file from Congestion Calculator](image)

To estimate the average PSA effect of AILs, loads of different characteristics are modelled along the PSA routes themselves, with the option of dividing these into segments of a particular road standard. Thus for example, data on the effect of an AIL on a motorway is collected by modelling its progress along one continuous motorway section within a PSA routes while allowing traffic to flow freely elsewhere on the route (by specifying a very high AIL speed which has no effect on traffic), and the same is done for dual-carriageway sections and single-carriageway sections. The results of this exercise are described later, after discussion of the question of uncertainties and time-variation, and of the PSA impact calculation itself.

---

5 The current version substitutes delay (ie JT-RefJT) for absolute journey time, in the results for each AIL move.

---
8 Estimating the uncertainty of delays

One kind of uncertainty in delays and costs arises from the interaction between the timing of an AIL movement and the ambient traffic conditions. Figure 11 shows the profiles of modelled cost-per-mile for different day types and starting times of an actual slow-moving Girder-frame type vehicle occupying 2 lanes.

The very high cost for moves starting around 0900-1000 on a Friday is traceable to a conflict with heavy traffic in the afternoon peak, 5-6 hours after the start, which is higher and starts earlier than on other weekdays. Because the peak in congestion cost is very steep, uncertainty in timings has a much larger effect on cost than where the curves are flatter. To allow for this, the Congestion Cost Calculator produces smoothed profiles based on a user-specified time window (current default 30 minutes). The usual effect is to reduce slightly the height of the peak but to widen it considerably, as shown in Figure 12, so can be considered pessimistic.

![Figure 11. Cost profiles of an AIL move](image1)

![Figure 12. Cost profiles of same AIL move, smoothed with 60 minute window](image2)
Another kind of uncertainty is in the individual delay calculations, whose most sensitive variables are demand, passing capacity and load speed, only the first of which is modelled as inherently variable and then only in a systematic rather than random manner. Ascribing delay to individual road sections along the AIL’s route is complex, so calculating the effect of variations in variables would be equally complex. However, given that the actual uncertainty in the variables in unknown it may be enough to know the approximate magnitude of uncertainty in delay resulting from given uncertainties in the variables. One way to approach this is to analyse the model of a simple queue built up during the passage of a load at speed $v_L$ along a road section length $H$:

$$
L = \left( \frac{q_a \left( 1 - \frac{v_L}{v_a} \right) - \mu c \left( 1 - \frac{v_L}{v_d} \right)}{1 - \frac{k_a}{k_b}} \right) H = \left( \frac{q_a \left( \frac{1}{v_L} - \frac{1}{v_a} \right) - \mu c \left( \frac{1}{v_L} - \frac{1}{v_d} \right)}{1 - \frac{k_a}{k_b}} \right) H
$$

(6)

If we assert that a given proportional change in queue size results in the same proportional change in individual vehicle delay, and assume that the traffic speeds and densities vary little with demand and capacity, then by differentiation the proportional changes in delay and queue resulting from proportional changes in the delay, capacity and load speed can be expressed as:

$$
f_{Dq} = f_{Lq} \approx \frac{f_q q_a \left( \frac{1}{v_L} - \frac{1}{v_a} \right)}{J}
$$

(7)

$$
f_{Dv} = f_{Lv} \approx -\frac{f_v \left( q_a - \mu c \right)}{v_L J}
$$

(8)

$$
where \quad J = q_a \left( \frac{1}{v_L} - \frac{1}{v_a} \right) - \mu c \left( \frac{1}{v_L} - \frac{1}{v_d} \right)
$$

(9)

If it is assumed that $v_a = v_{d}$, equivalent to a ‘flat’ speed/flow relationship in the free-flow regime, then the formulae simplify considerably, also reducing the dependence on speeds:

$$
f_{Dq} = f_{Lq} \approx \frac{f_q q_a \left( q_a - \mu c \right)}{(q_a - \mu c)}
$$

(11)

$$
f_{Dv} = f_{Lv} \approx -\frac{f_v \left( q_a - \mu c \right)}{q_a - \mu c}
$$

(12)

$$
f_{Dv} = f_{Lv} \approx -\frac{f_v \left( \frac{1}{v_L} \right)}{\frac{1}{v_a}}
$$

(13)

---

6 It also affects the duration of queuing and hence the number of vehicles and PSA periods which may be affected, but this is too complex to be analysed by a simple model.
Then if the uncertainties are independent:

\[ |f_D| = \sqrt{f_{Dq}^2 + f_{Du}^2 + f_{Dv}^2} \]  

(14)

It is noticeable in (10-11) that uncertainty in delay is most sensitive to uncertainty in demand or capacity when demand is near to capacity, but in such cases the absolute value of delay may be small and the absolute uncertainty in delay will show less variation. In (12) sensitivity to uncertainty in load speed is magnified when the load speed is much less than the normal traffic speed, as found in previous studies.

As explained earlier in this paper, where queues are extended, ascribing delay to individual road sections is complex because the model works in terms of the queuing and delay caused by the presence of the load on each road section, which can extend onto other sections. However, if these component uncertainties can be estimated, then it may be possible to estimate an uncertainty for the whole route, or to allocate absolute uncertainties to sections pro rata. When overall uncertainty is calculated in this way, assuming independent relative uncertainties of 0.1 (10%) for demand, capacity and load speed, which are also independent between different road sections (this may not be quite true), the profiles of overall relative uncertainty in total delay for the journey shown in Figure 13 result.

![Figure 13. Profiles of relative uncertainty in total delay for the case in Figure 8](image)

The peaks on Saturday at 1800 and Sunday at 1900 are caused by demand and capacity being very similar on one or two sections. However, Figure 8 (earlier) shows that the absolute delays then are very small. For most timings of the move, where congestion cost is substantial, uncertainty hovers around 0.1 or 10%. Note this does not necessarily mean it is always going to be similar to the level of uncertainty in the component variables, yet this may happen where the overall uncertainty is dominated by one section where queuing is heavy.

Assuming again that all uncertainty components are independent, they can be combined in a similar way to components of delay, with \( \sqrt{\text{sum-of-squares}} \) replacing sum, to get figures for relative uncertainty attached to delay estimates.
9 PSA impacts on individual links

The AIL move represented by Figures 9-11 has been partly converted to use HATRIS links. The impact on those HATRIS links modelled (M42 J2 to M40 J15: LM502, LM504, LM468, LM466) and the routes they contribute to (75 direction 1 and 74 direction 2), as calculated by the model for a high-cost departure of the move, on a Friday at 0700, is limited to the afternoon, 16:15-18:00. Figures 14-16 show respectively, delay per vehicle in minutes, relative uncertainty of delay, and change in flow in vehicles, for each PSA time period. Uncertainty is derived assuming an inherent uncertainty in demands, capacities and load speed of 10% (input value = 0.1) and can be expected to vary roughly in proportion to this factor. The model uses HATRIS volume data averaged for the day type for the HATRIS links, and TRADS data for other trunk sections.

Figure 14. Impact of worst-case AIL move on delays on HATRIS links and PSA routes

Figure 15. Relative uncertainty of PSA delay impact, based on data uncertainty of 0.1
The impacts on links relate to PSA periods proximate to the actual impact, but those on routes are graphed against starting time on the route, which may be some time before the impact occurs (though not in this example). The small impact on LM502 is because it is the M42 section upstream of the point where the load joins the motorway, and is therefore an ‘off-route’ link. The greatest impact occurs on the longer M40 section. The uncertainties in impacts tend to be greater than that in the data because partly because of the possible amplifications described in the previous section and partly because they are added vectorially. The 10% uncertainty in the data assumed is arbitrary, not based on any evidence, so the out-turn uncertainties of the order of 20% are only illustrative.
10 Performing the PSA calculation

The algorithm for calculating the PSA value has been detailed by Cottell (2006). It multiplies each sample journey on a PSA route in proportion to the distance-weighted flow associated with it, sorts the multiplied journeys in ascending order of delay relative to the reference (free flow) journey time (which is a constant for the route), and isolates the 10% journeys with greatest delays. The average delay of these journeys is then calculated. The total vehicle-miles travelled by these journeys is also recorded. The overall PSA value for the whole network is the average of the individual route delays weighted by route vehicle-miles and multiplied by ten to give the average minutes of delay to a typical vehicle per 10 miles travelled.

The method conceived to estimate the effect of a one-off AIL move is to model an ‘modified standard day’ and merge this with the historical charts. The impact can then be evaluated in terms of these charts or the average effect on the whole traffic on the HATRIS network. This need be done only for those routes and periods affected by the AIL, as tabulated by the Congestion Calculator for the particular timing of the AIL move (see Section 8 and Figure 9 earlier). The ‘standard day’ not only furnishes typical rather than ideal traffic conditions for the evaluation of the AIL movement, but also provides a control journey unaffected by the AIL, enabling a check on whether this changes the PSA value. If it does then there must be an inconsistency in the data which needs to be resolved.

For example, the standard speed/flow relationships may have be calibrated including some data representing delayed rather than free-flowing traffic, or may have used data from a different year or source from that used in the current PSA value calculation. If there have been very few delayed journeys along the route, it is also possible that random uncertainties in the calculation could put the unaffected standard journey into the slowest 10%, but the effect of the PSA value in that case should be small enough to be ignored. As the PSA value for the whole network is just a flow weighted average of the values for individual routes, the effect of a modified chart can be calculated...
incrementally. However, this cannot be done for ‘modified days’ because it is not possible to know in advance which journeys will fall above the 90th percentile of delay. Therefore each chart which is affected must be recalculated, but there is no need to recalculate the original charts or other unaffected charts.

In Figure 17, the data are represented by blocks, and processes and data transfers by arrows. The processes named in red are required for calculating the network PSA value from start to finish. The processes named in blue are those needed for calculating the impact of one or more AILs. The initial process of organising the HATRIS data, ‘P0’, need not be repeated. The process for calculating the PSA value of a chart, ‘P1’, has to be rerun for the affected charts, then the network PSA value process ‘P2’ has to be rerun. The other processes are ‘RS’ (representative speeds or speed/flow) and ‘CC’ (Congestion Calculator). This whole procedure may be done twice, first with unaffected standard days and then with affected standard days. The efficiency of the AIL impact assessment therefore rests on having data and processes organised as shown, and being able easily to extend individual chart records and recalculate their PSA values, and then being able to recalculate the network PSA value.
11 Implementation in the PSA Value Calculator

In July 2007 Capita Symonds made available their new server and database, making it practical to download the large quantity of data required for calculating the PSA1 Value. SQL queries to the DfTRouteTimes database allow a full set of charts to be downloaded. Because of the large size of the database, a selective query as shown in Figure 18 has been used.

```
SELECT [RouteNumber], [Direction], [JourneyStartDate], [JourneyStartTimePeriod], [TotalTravelTime], [AvgFlow], [RouteWeightingLength], [RefJT] FROM [HATRIS_COPY].[dbo].[DfTRouteTimes] WHERE RouteNumber > '70' and RouteNumber < '81'
```

Figure 18. Example of SQL query used to download charts for a range of PSA routes

Even with this highly selective choice of columns, the size of each file is around 128 MB, and the total set nearly 1.7 GB, although this reduces to under 60 MB when ZIPped™. The files are arranged in relational fashion with each component of each chart in a separate record. It is more convenient to have one complete chart per record. The report files are accordingly reformed into a single text file occupying 90 MB. As this needs be done only once it is done by a simple but efficient DOS-based Fortran program7. This sorts the observations into ascending order of journey time in seconds. Missing or zero observations are excluded so each record may contain up to 53 observations. The current format of the resulting file shown in Figure 19 is not set in stone, but must be observed by any tool which subsequently uses it.

```
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<th>Route</th>
<th>Day</th>
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<th>PSDelay</th>
<th>PSAvehMiles</th>
<th>RefJT</th>
<th>{TravTime}</th>
<th>AverageFlow</th>
</tr>
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<td>31578</td>
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<td>4444</td>
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</tr>
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<td>55 4156</td>
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<td>4181</td>
<td>41 4182</td>
</tr>
</tbody>
</table>
```

Figure 19. Format of combined PSA historical chart file as currently used

The PSA Value Calculator is based on an Excel spreadsheet and VBA macros. First the macro Load Historical Chart Data is invoked. This reads the entire historical chart file into memory an array of nearly 150,000 records, also creating an Index to the file.

---

7 The program also calculates the total vehicle-delay and vehicle-miles for each chart with the aim to save later processing. However, it has since been found that these totals differ from those calculated by the VBA code of the PSA Value Calculator, leading to anomalies in results. For this reason, the PSA Value Calculator now directly compares PSA impact with and without the AIL and does not use pre-calculated totals.
To evaluate *Detailed* PSA Impact records created by the PSA Congestion Calculator, these must be copied into rows below Row 10 in the PSAImpact worksheet (any number of data blocks can be copied, including annotations and gaps with fewer than 10 blank rows may be copied). The macro PSA Impact from Worksheet then goes through the impact records calculating PSA value contributions which are imprinted on the PSACalculator worksheet, modifying the route and network PSA values. This method is very time consuming and can deal only with one start day and time of the move.

After loading the historical charts (see also Section 16 and Figure 33 later), the data for delay effect on PSA routes as generated by the Congestion Calculator must be imported. These may not be ordered by PSA route, so it is advisable to call the Merge Effects with Charts to File macro, which creates a file containing both the original effect data and PSA impact data, sorted by PSA route. When reloaded into the PSA Value Calculator, ‘Yes’ in the ‘Merged’ column of the PSAEffect worksheet confirms that the data have been merged, and subsequent plotting and analysis is much more efficient.

The PSA Value Calculator allows for multiple ‘modified days’, by adjusting the distance-weighted flows of each ‘observation’ so as to retain the original effective number of total days (assumed to be a minimum of 51 including ‘unknown’ days if necessary). Originally, it was proposed that an ‘extra day’ should be inserted, but extra days cannot really occur but only replace normal days. Hence a procedure is used to normalise the chart so that the effect of one or more AIL moves is distributed fairly. This is quite important because many AIL moves occur in series over several weeks, often starting at the same time on the same day of the week. Each modified day ‘loses’ a proportion of its flow to observed days with higher delays, if any, reflecting the idea that an AIL moving on a day where delays were high for some other reason would not contribute further delay (or at least not the delay calculated by the Congestion Calculator). Otherwise it takes a proportion of flow from all observed days with less delay, reflecting that in fact it would replace one or other of those days probabilistically (see Appendix A).
12 Approach to estimating generic PSA impact

In the Work Specification, Task 2 is defined as a study to establish the relationship between Abnormal Load width and speed combinations, defined times, PSA routes and the effect on the PSA value, further summarised to clearly illustrate the impact that width and speed combinations have on different road types. Unless an AIL causes very little impact, it would be misleading to model its effect on only one link, so at least part of the approach is to model whole routes or segments of routes with constant type, i.e., Motorway, Dual Carriageway or Single Carriageway. This can be achieved with a version of the Congestion Calculator able to set up and run through routes and width/speed combinations automatically. In practice it can also model routes specified manually, so the range of options is:

- Manual route definition (selecting links from drop-down list) and Combination/Load details
- Selection of one route, running through all Combinations (22 have been specified)
- Selection of all Motorway, Dual or Single carriageway routes, running through all Combinations
- Selection of all routes in Network file, running through all Combinations

A route in the Congestion Calculator cannot be re-specified if any route of fewer than two links has been modelled, so the automatic route selection is restricted to routes of three or more links. In addition, some link type ‘adoption’ is practised in the process of identifying route segments of consistent type, as follows:

- An isolated link adjacent to Single carriageway links is adopted as Single carriageway
- An isolated link adjacent to Dual carriageway links is adopted as Dual carriageway
- An isolated Motorway segment at either end of a Dual carriageway route is not adopted

In the set of PSA routes used for this work, there are 202 complete routes and 292 segments of three or more links of one road standard. Segments are numbered using an extra digit, for example Route 1 is separated between directions 1.1 and 1.2, and segmented into 1.11-1.15 and 1.25-1.21.

The next issue is how to define the impact. For a single route, combination, day type and start time, the Congestion Calculator, having generated the Model, performs an additional and quite lengthy calculation of the PSA impact by testing the effect of a group of hypothetical trace vehicles entering each link on the AIL’s route during each 15-minute PSA period. Both PSA links on the AIL’s route and PSA links adjacent to the route are assessed. Each AIL move, starting at a particular time, can affect many PSA trace journeys taking place over several hours. The effect on the PSA routes affected is then assessed by chaining. This is as described earlier in Sections 5-8.

The computational cost of this process would be prohibitive for the full set of routes, load combinations, day types and start times, even when the latter are limited as specified to every half hour from 06:00 to 19:30. The total number of cases is in the range 0.9-1.3 million, and the number of individual PSA impacts many times greater. Although generating the Model for a route takes time because columns of formulae have to be propagated, recalculation of the Model for a different load combination, day type or start time is almost instantaneous. One the other hand, calculating the detailed PSA Impact can take 20-30 seconds, so to do all possible cases should involve up to 1 year of continuous computation! Of course this would not be attempted, because the calculation would be recoded in a more efficient language, such as compiled Fortran.

---

8 Not all these routes are used in evaluation of the network PSA value
However, if assessment of all cases is to be attempted using the Congestion Calculator method, in order to build a database for further analysis, what is required is a direct method of estimating PSA impact which can be built into the Model spreadsheet. Such a method can produce only one result, so this has to be representative of all PSA trace journeys along the route which could be affected.
13 Approximate but efficient estimation of delay effect

In addition to the link delay projection method referred to earlier, which is used to estimate generic impacts, the Modelling Report PPR196 (Taylor 2006b, Section E.7) describes a purely formula-based method for estimating the average delay per affected vehicle ascribed to each link of an AIL’s route. This is somewhat relevant because it also involves projection of the period affected by queuing. Delay is ‘ascribed’ because delay caused by the AIL’s passage along the link, and delay experienced by vehicles while they are on that link, are different if heavy queuing leads to blocking back onto upstream links. The effect of the AIL on a trace vehicle’s journey cannot be got by simply adding up the link delays because the vehicle may experience delay only on certain links depending on when it catches up with the AIL’s retinue and whether and when it succeeds in passing it.

The method proposed is first to identify the time period during which trace vehicles are affected by the AIL at some point on their journey, assuming they travel at ‘normal’ link speeds unless queuing, then calculate the average delay they experience. The calculation is an extension of that described in PPR196, see Figure 21. The extension consists essentially of taking account of the ambient traffic which does not meet the queue, either passing ahead of or behind it.

![Figure 21. Method of analysing flows related to queue ascribed to a link](image)

The formulae for calculating the flows which are at some time in the queue are the same as those in PPR196. The following are standard variables used by the Calculator Model:

- $q_a$: ambient traffic flow rate
- $q_b$: flow rate within queue
- $v_L$: speed of AIL
- $v_a$: normal speed of ambient traffic
- $v_b$: speed of traffic within queue
- $v_{bd}$: speed of backward queue discharge wave (typically around 20 km/h)
- $t$: time taken by AIL to travel along link = $H/v_L$ where $H =$ link length
- $t_e$: time at which queue dissipates relative to start time on link
- $p$: proportion of traffic proceeding onto next link of the route

---

9 PPR196 Issue 2, since Issue 1 contains an error.
(A) Ambient traffic flow during affected time range, unaffected by the AIL on this link:

\[ Q_A = q_a (T_a - t_{e(s)}) \]  

(15)

(B) The flow remaining Behind the AIL up to the end of the link:

\[ Q_B = \left(1 - \frac{v_{bd}}{v_b}\right) q_b \max(t_e - t, 0) \]  

(16)

(C) The flow escaping the AIL through the passing Channel:

\[ Q_C = \left(1 - \frac{v_L}{v_b}\right) q_b \min(t, t_e) \]  

(17)

The speed-dependent factors in (15) and (16) arise from geometry when calculating the duration of the lines SP and QR in Figure 21, which represent horizons passed through by traffic moving at speed \( v_b \), destined either to pass the AIL (left) or to remain in the queue until the end of the link (right).

Figure 22. Delay occurring on and off a PSA Route travelled by an hypothetical AIL

The performance of this model is not perfect, but has two main defects: a tendency to underestimate delay probably because it is less successful at dealing with blocking back than the detailed iterative vehicle tracing method used for PSA chart impacts; sensitivity to the range of trace vehicle departure times \( T_a \) over which total delay has to be averaged, which may be greatly extended if a persistent queue is formed on any link as a result of demand being very close to capacity. The significance of averaging period is illustrated by Figure 22, showing how the exact method would ignore delay occurring off the route but would also deliver a shorter affected period to compensate.
Examples of performance on PSA route 75.1, which consists of 22.3 miles of the M42 motorway, are shown in Figures 23 and 24, where the red line is the estimate. Both are for an AIL moving at 12 mph, but Figure 23 is for a width of 4.3m, occupying one lane, and Figure 24 is for a width of 6.1m, occupying two lanes.

The discrepancy at start time 07:00 arises from the second 'defect', as a result of the high volume on one link at the time the AIL passes – note the increase in period duration (grey graph). The distinction between the 'non-zero' (magenta) and 'in range' (blue) delays is again the period over which they are averaged. The detailed PSA Impact results, of course, do not require averaging as they are calculated for each individual PSA period. Looking again at Figure 22, it can be seen that the duration of queuing at the start of the route is given approximately by:
where $R$ is the length of the route and the average queue discharge wave speed $\bar{v}_{bd}$ is around 20 km/h upstream. A rule-of-thumb could be that the assumed affected period $T_a$ should be limited to $1.5 T_{a(\bar{s})}$.

A further problem can emerge for large slow AILs. The Model estimates a queue using the average arrival flow during the period when the AIL is present. However, if a large queue is produced, especially one which propagates upstream, the actual period during which traffic arrives at the queue may be much longer than the AIL’s presence time, and the average flow during that period could be different from that assumed. Usually the flow would be a bit more, or substantially less than that assumed, because queuing tends to occur when the AIL arrives on a link near to a peak, so the true flow could increase in the next hour or two, but will probably fall after that.

In an extreme case a queue formed in the morning peak could persist so long as to be hit by traffic in afternoon peak. This would probably occur only after the queue had propagated a long distance upstream, so the road conditions and the ambient flows would be very different. Also, it is likely that traffic managers would have intervened by then. Technically, it is difficult to allow for this effect because the calculation is circular: the final duration of queuing depends on the demand intercepted, and the demand intercepted depends on the duration. This requires solving simultaneous equations, but where multiple time periods are involved, the ‘equations’ must be calculated by iteration. This is a complicated procedure not practical to implement in a single spreadsheet column. Therefore, experiments have been done to determine how long queuing would actually last given a typical demand profile and various AIL speeds and presence durations. Although in some cases a persistent queue does occur, if it does not then a guide to the duration of queuing is found to be:

$$t_{d_{(\text{max})}} = t + \frac{10}{\sqrt{v_{L \,(\text{mph})}}}$$

This enables an approximate limit on $v_{ab}$ to be set (for values <0, ie upstream):

$$v_{ab_{(\text{min})}} = \frac{v_L t + v_{bd} t_{d_{(\text{max})}}}{t + t_{d_{(\text{max})}}}$$

For queues forming in the reverse direction when an AIL completely blocks a link, a maximum duration of 11h is appropriate, so the minimum (most upstream) queue tail speed is 11/12 of the upstream wave propagation speed, ie around -18.3 km/h.

These adjustments are used to avoid excessive delays being predicted, but they do not work the other way around, so delays could be underestimated for slow loads arriving just before a sharp peak, particularly the morning peak, if the standard model does not predict queuing.
14 PSA impact of AIL on a route or route segment

The PSA Value Calculator is a spreadsheet and macro based tool separate from the Congestion Calculator, whose function is to combine results from the Calculator on the effect of an AIL move with baseline PSA chart data to calculate the effect on PSA values.

Figure 25. Comparison of Congestion and Value Calculator outputs for route segment 1.12
The PSA Value Calculator takes as input a set of pasted data and/or two text files:

- A set of PSA Impact records copied and pasted (pref. by value) from the Congestion Calculator
- The complete set of baseline Chart data derived from the HATRIS database
- A file of PSA Effect data from the Congestion Calculator as described in the previous Section

The output can be any or all of:

- Tabulation of the aggregate result of the inserted PSA Impact data by route and for network
- A graph of PSA Value impact for a selected route or route segment, all days and start times
- A file of Merge values produced by combining Chart and Effect data

A file of aggregate PSA delay and flow changes based on the whole Effect data set. The first type of input and output has already been described earlier in Section 12. This section deals with the second type of output. The third type of output is described in the next Section. Having loaded the Chart and Effect files, the user selects the PSAEffect worksheet and selects a route number and a width/speed combination from drop-down lists. The route number can be the number of a segment of a whole PSA route, so that only that part of the route which is of a particular consistent standard (eg Motorway) is analysed. The program then calculates the all-day impact on the PSA value for the whole PSA route, for each day type, as a function of the start time of the AIL’s presence on the route segment. Figure 25 shows two graphs, the upper being the Cost profile generated by the Congestion Calculator and the lower the PSA Impact graph produced by the Value Calculator. Although superficially similar there are differences and of course the quantity assessed is quite different, in the latter case considerably dependent on baseline Charts embodying delays from all causes throughout a whole year.
15 Analysis of model runs to estimate generic impacts

The third type of input and output listed in the previous Section can be used to derive a guide to average or typical impacts of Abnormal Loads of various dimensions on road sections of different type and length. Figure 26 shows extracts from the three types of file involved.

The baseline Chart file (upper) contains PSA route journey times in seconds and distance weighted flows in vehicles per 15 minutes, consistent with the approach used by the Highways Agency. Each record contains the chart of up to 53 observations for one route, day type and PSA time period, where time periods run from 0 representing 00:00-00:15 to 95 representing 23:45-24:00.

Each record of the Effect file generated by the Congestion Calculator (middle) contains the journey time for a whole PSA route traversed either in full or in part by an AIL of the type indicated, on a particular day type, joining the route at a specified time, ranging from 06:00 to 19:30 in steps of 30 minutes (ie PSA periods 24 to 78 in steps of 2). If the route segment traversed is some way down range, an AIL can affect PSA periods before its joining time. This is reflected in the Congestion Calculator by starting the model route earlier than the specified joining time, as described earlier in Section 13. The first two fields in each record indicate whether a whole route (of unspecified standard), or a route segment (of particular standard) is described. Whichever it is, the assessment is conducted for the whole PSA route, because this is the unit for which Chart data exist.

The format of the Merge impact file output by the Value Calculator (lower) is similar to that of the input Effect file, but reports the whole-day aggregate average 10% slowest PSA time delay (seconds) and distance-weighted flow (veh/15 min) for the specified route and day type followed by the changes in these quantities associated with an AIL move of the specified type joining at each of the ‘effect’ times. The PSA Value in any instance can be calculated by the following formula:

$$ PSA\_Value = 0.26816667 \times \frac{\text{sumTD (seconds)}}{\text{sumDWVF (veh/15m)}} $$(21)

where the factor performs conversion to units of minutes/10 miles per vehicle.

The potential size of the Merge file for a given road standard is around 200 route segments x 22 AIL combinations x 7 days x 28 start times, ie 862400 data points. To get a ‘typical’ impact value, it appears reasonable to:

- Analyse for each AIL combination separately
- Aggregate over all routes, but consider the effect of segment length on results.

Concerning time dependence, to reduce the amount of analysis we may reasonably attempt to:

- Aggregate together all weekdays, and both weekend days, or all day types if possible
- Aggregate some or all start times together, at least for the purpose of generic prediction.

Start time aggregation is perhaps risky, bearing in mind how much the impact of an AIL can vary during the day, but does allow some interesting results. Figure 27 is an example of relative impact on the PSA Value, for PSA Motorway segments traversed by a wide (5m-6.1m) AIL moving at 4 mph, as a function of segment length, while Figure 28 shows how the network PSA impact of a fleet of large loads on all PSA Motorway segments varies with day of the week and move start time.
Figure 26. Sample screenshots of Chart, Effect (input) and Merge (output) files
Figure 27. Whole-day PSA impacts of a large slow AIL on PSA Motorway segments, with idealised trend

Model may not be realistic here, as travel would exceed legal maximum driving time of 9 hours.

Figure 28. Example of effect of day of week and start time on network PSA impact (2 lane, 12 mph)
Figure 27 shows considerable scatter, but there does not appear to be any significant difference between weekdays and weekends. Figure 28 shows that PSA impact varies with time broadly in line with the pattern of traffic flow but magnifies differences because only the longest delays contribute.

In Figure 27 there appears to be nearly linear increase with segment length up to about 40 miles, beyond which the impact flattens off or declines. This effect is also noticeable for wide 12 mph loads. One possible explanation for the falling off of impact is the damping effect of equations (18, 19), and the necessity that slow loads which spend many hours on the network and encounter peak traffic will eventually move into periods of reduced traffic flow, reducing the average impact over their whole journey. Assuming linearity, slopes of PSA impact against distance travelled can be estimated by regression. Plotting the slopes for Motorway segments as a function of AIL speed for each width results in Figure 29, which appears to show a consistent pattern from which average impact of slower loads (much less than 25 mph) could be predicted very simply. Although impact is broadly proportional to the number of lanes occupied, it is much more sensitive to AIL speed, so much so that it would be difficult to establish a simple formula.

Quicker moving loads, 25 mph and above show this pattern weakly if at all, and above 35 mph not at all, and therefore slopes calculated for them may not be reliable. Hence mean impacts may be preferred, though that these are independent of distance travelled may seem paradoxical. Estimated slopes and means for Motorways are given in Table 2.

![Figure 28. Motorway aggregate impact estimator slopes as a function of AIL characteristics](image)

Results of a similar analysis for Dual-carriageways are given in Figure 30 and Table 3. For Dual-carriageway segments, there is little difference between AILs occupying 2 lanes or 3 lanes because relatively few links are 3-lane (ignoring the fact that a 9m AIL might not be able to fit into a 2-lane road). Therefore, it may be advisable to use the Motorway figures for 3-lane Dual carriageways.
Table 2. Slopes (PSA impact/mile travelled) and means (PSA impact) for PSA **Motorway** segments. Impacts are whole day (periods 24-79) on the relevant PSA route only. Light Italic values may not be reliable.

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Slopes</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Lane</td>
<td>2 Lane</td>
</tr>
<tr>
<td>4</td>
<td>0.003136</td>
<td>0.031993</td>
</tr>
<tr>
<td>12</td>
<td>1.64E-05</td>
<td>0.000133</td>
</tr>
<tr>
<td>25</td>
<td>3.67E-07</td>
<td>6.41E-07</td>
</tr>
<tr>
<td>30</td>
<td>2.16E-07</td>
<td>3.68E-07</td>
</tr>
<tr>
<td>35</td>
<td>2.07E-07</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>3.16E-07</td>
<td>2.13E-07</td>
</tr>
<tr>
<td>60</td>
<td>5.93E-08</td>
<td></td>
</tr>
</tbody>
</table>

Figure 30. Dual carriageway aggregate impact estimator slopes as a function of AIL characteristics

Table 3. Slopes (PSA impact/mile travelled) and means (PSA impact) for PSA **Dual-carriageway** segments. Impacts are whole day (periods 24-79) on the PSA route only. Light Italic values may not be reliable.

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Slopes</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Lane</td>
<td>2 Lane</td>
</tr>
<tr>
<td>4</td>
<td>0.134042</td>
<td>0.188134</td>
</tr>
<tr>
<td>12</td>
<td>0.008479</td>
<td>0.011508</td>
</tr>
<tr>
<td>25</td>
<td>0.000108</td>
<td>0.000157</td>
</tr>
<tr>
<td>30</td>
<td>4.01E-05</td>
<td>6.29E-05</td>
</tr>
<tr>
<td>35</td>
<td></td>
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<td>40</td>
<td>1.89E-06</td>
<td>7.56E-06</td>
</tr>
<tr>
<td>60</td>
<td>2.77E-06</td>
<td></td>
</tr>
</tbody>
</table>
For Single-carriageway links, Figure 31 and Table 4, there is no difference between the impacts of AILs of different width (the passage of a 3-lane-wide load is hypothetical anyway). This because a Single carriageways are modelled as S2 standard, and since the calculation considers only the PSA route which is being travelled, the impact on the reverse direction is not included. Therefore, the impact of an AIL which blocks both directions of a single carriageway road should be duplicated in the reverse direction.

The slopes and means obtained can be used to estimate generic PSA impact, and have been incorporated in the PSA Value Calculator for this purpose. In each instance the impact calculated is that of one AIL of the specified type travelling a specified distance or one continuous segment of the specified road standard on any one PSA route on any one day starting at any one time. For a particular PSA route, given the aggregate delay and distance-weighted flow values for that route derived from the historical charts, this impact can be converted from PSA value to the equivalent additional aggregate delay (the effect on flow cannot be estimated). Any number of aggregate extra delays from an arbitrary fleet of AIL moves can then be summed and the network PSA impact estimated.

![Figure 31. Single carriageway aggregate impact estimator slopes as a function of AIL characteristics](image)

Table 4. Slopes (PSA impact/mile travelled) and means (PSA impact) for PSA Single-carriageway segments. Impacts are whole day (periods 24-79) on the PSA route only. Light Italic values may not be reliable.

<table>
<thead>
<tr>
<th>Speed (mph)</th>
<th>Slopes</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Lane</td>
<td>2 Lane</td>
</tr>
<tr>
<td>4</td>
<td>0.028711</td>
<td>0.028711</td>
</tr>
<tr>
<td>12</td>
<td>7.39E-05</td>
<td>7.39E-05</td>
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<tr>
<td>25</td>
<td>8.27E-06</td>
<td>8.27E-06</td>
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<tr>
<td>30</td>
<td>6.86E-06</td>
<td>6.86E-06</td>
</tr>
<tr>
<td>35</td>
<td>1.36E-07</td>
<td>2.09E-05</td>
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<tr>
<td>40</td>
<td>2.38E-07</td>
<td>2.38E-07</td>
</tr>
<tr>
<td>60</td>
<td>5.04E-12</td>
<td>9.38E-11</td>
</tr>
</tbody>
</table>
The results deemed ‘not reliable’ above have been identified after plotting slopes on a logarithmic scale, which shows that slope values decline roughly exponentially with AIL speed until about 35 mph, after which they ‘wander’. On the positive side, this means that the slopes can be used up to about 35 mph, beyond which PSA impact can be expected to be negligible anyway. Conversely, mean values for slow moves cannot be relied upon because their impacts depend strongly on distance travelled. Application of the generic formulae embedded in the PSA Value Calculator is illustrated in Appendix B.
16 Cautions and provisos

A number of issues regarding data and results have arisen during this work.

- The number of lanes on some HATRIS links is uncertain
- Flow data for some HATRIS links is missing in the data set used
- Model validation has proved difficult (see below)
- All PSA routes have been used though some may be excluded from official figures
- PSA routes may not be representative of actual journeys made by AILs
- Only the impact of an AIL move on the PSA route it travels along is considered
- Delay effect of AIL on each PSA route is averaged over the PSA periods affected
- There is considerable scatter in PSA impact values and weak relationship to distance travelled
- The reason for the ‘break distance’ effect in impact of slower AILs is uncertain.

There have been substantial problems with the Congestion and PSA Value Calculator software, though it is hoped that these have now been overcome. Problems with the Congestion Calculator stem from its complexity and having no benchmark against which to verify its results. These have mostly affected the longest and slowest and the quickest journeys, where arguably the software was applied beyond the conditions for which it was designed. For AILs travelling at higher speeds, a problem arose in the queuing calculation when the speed of the AIL was close to that of ambient traffic. This has now been corrected. The most persistent problems have arisen from the difficulty of reconciling long slow journeys covering several days in the model with the cyclic nature of PSA analysis, where to keep the amount of output from over 684,000 individual models manageable, the delay effect has to be averaged over a single time period deemed to occur on the starting day. Although there is some evidence, there are no clear rules for how multi-day trips should be treated.

The PSA Value Calculator has also suffered from the volume of data and the lack of a benchmark, but it was also found that the aggregate time delay and distance-weighted flow components pre-calculated for the historical PSA charts disagreed with ones calculated by the PSA Value Calculator. The differences appeared to be random, and resulted in some negative delay impacts. When these were suppressed they distorted the results. In the latest analysis, the PSA Value Calculator calculates all charts both with and without the effect of the AIL, so the impacts, ie differences, obtained are true, and no results have had to be suppressed. The discrepancy is believed to come from differences in precision between Visual Basic for Applications (VBA), which is used in the PSA Value Calculator, and Fortran 95 which was used to process the historical charts. Finally, the quantity of data has pushed analysis in Excel to the limits.

Attempts to validate the Congestion Model using traces of AILs on MIDAS/MTV, as opposed to data collected for moves monitored individually, have met with little success. This is believed to be because the direct effect of these relatively low-impact AIL moves is obscured by flow breakdown in the elevated-density traffic following the AIL, when it reaches a point where capacity is reduced (a ‘seed point’ rather than a true bottleneck). This effect can occur some time after the AIL has passed, but becomes evident only when visualised through MTV (see Appendix B).
17 Conclusion

This report has described the methods and results of the extended Congestion Calculator for estimating the PSA impact on an Abnormal Load on PSA routes, in the form of 'modified days' to be added to those PSA charts affected. Combined with tools for calculating the PSA Value for each chart, route or for the HATRIS network as a whole, this enables an estimation of the impact of one or more Abnormal Load movements on the PSA Value to be performed efficiently.

PSA impact magnifies congestion effect, which is already highly sensitive to AIL speed, so the impact of a very slow AIL (4 mph) is estimated to be one or two orders of magnitude greater than that of a typically slow AIL (12 mph), although the prevalence of very slow AILs on the HATRIS network, particularly on motorways, is questionable. Despite its sensitivity, PSA impact shows a certain consistency, and appears to be predictable, within a wide range of uncertainty, and the results may be applied to individual movements.

Estimating the effect of all AIL movements which take place on the network during a typical year requires realistic more realistic routes as well as data on the number of movements and the distribution of their types and journey lengths. This work is expected to be reported elsewhere.

Acknowledgements

The work described in this report was carried out in the Transportation Division (Network Performance Group) of the Transport Research Laboratory. This work is funded by the Highways Agency. The author is grateful for guidance and comments by the Project Sponsor Chris Cottell and Rob Jones of Highways Agency, and Glen Wiedman and colleagues at Capita Symonds. Thanks are due to the following TRL staff: Paul Emmerson for Technical Review, Dr Barbara Frith for advice concerning the HATRIS/MADJ data and the PSA method, Francis Dickinson for assistance with access to Capita Symonds’ server and downloading of data, and Nathan Bourne for developing an enhanced tool to visualise the HATRIS network.

References


Appendix A: Adding ‘modified days’ representing AIL move to PSA chart

The principle is that the AIL moves on a typical or ‘standard’ day of which the existing distribution of journey times in the historical chart (for the route, day type and time period affected) is representative. In practice, the modified journey cannot literally be an ‘extra day’ because there is only a certain number of days available in the year. This is particularly important if the impact of a series of AIL moves is being evaluated. AILs often move in several successive weeks on the same day of the week starting around the same time. To deal with this rationally, and symmetrically for any number of AIL moves, the following normalisation procedure is applied.

1. Sort original days in order of journey time or delay.

2. If there are fewer than 51 days in the chart, implying missing information, fill the chart with ‘phantom’ days at the low journey time end, making a total if \( n \geq 51 \).

3. Divide the day sequence into a set with journey times greater than the modified day and a set with journey times less than the modified day (see Figure). Count the number of days, not the total distance-weighted flow, in each set. This is because the movement of an AIL is an ‘all-or-nothing’ affair.

4. If there are \( j \) days out of \( n \) with journey time greater than the modified day, assume that the fraction \( j/n \) of the modified day’s flow is absorbed by the days with greater delay. This reflects the notion that an AIL moving on those days would not create significant extra delay to traffic already held up by an incident or pre-existing congestion.

5. ‘Discount’ the flow of each day in the set with journey time less than the modified day by a proportion reflecting the remaining fraction \( 1 - j/n \) of flow introduced by the modified day, distributing the discount equally to all days in the set. This reflects the notion that the total flow should be unchanged apart from the marginal modification caused by the AIL on the day of its move, while retaining all the information about the original journey time distribution.

6. Insert the modified day into the set as an additional day measurement with the fraction \( 1 - j/n \) of its original distance-weighted flow.

7. Repeat for further modified days, from step 3.

8. Evaluate total delay and distance-weighted flow for the 10% ‘slowest’ vehicle-miles, in the standard manner.
It has been found that this process can result in small reductions in total ‘10% slowest’ delay, or changes in ‘10% slowest’ vehicle-miles, which lead to a reduction in PSA impact. Scrutiny of the calculation reveals that this can result from a small adjustment to the total flow in the chart. As explained above, the method has been designed to preserve the number of days, not the total flow, which could be redistributed from other PSA periods by the delaying effect of the AIL. While such results are not inconsistent, they are not thought to make a reliable contribution to overall calculations.
Appendix B: Estimating PSA impact generically

Using the relationships found in the Section 15, the **PSA Value Calculator** enables the PSA Impact of one or more generic AIL moves to be estimated at Route or Network level. ‘Generic’ means the route is not explicit, but defined in terms of the PSA route segments of various standards and lengths which it affects.

The estimation is done on the **PSACharts** worksheet of the PSA Value Calculator, as illustrated in Figure 32. This is separate from and independent of other evaluations including from detailed PSA impact data, whose results appear in Columns G-I of the worksheet, or graphing of merged data. To enable generic impact estimation, the PSA Value Calculator has embedded the slopes and break distances described in the previous Section, so it requires the type of AIL, and the distance it travels on each road standard on each particular PSA route. Individual PSA routes have to be selected, even though the impact formulae are generic, because the contribution to aggregate delay and hence to network impact depends on the historical aggregate delay and flow applying to that route.

In this example, the impact of a girder-frame move along six PSA motorway segments is estimated. On the first four routes cases the whole-day impact has been calculated according to the road standard and the segment length. For example, moving 24.5 miles along Route 1.2 increases the PSA value on that route from 3.22 to 3.24. On the fifth route the generic calculation has been overridden by a manually input value (+2) whose net effect is reduced by the factor 6.33 (the number of days in the week weighted for difference between weekdays and weekends). On the sixth route the generic value has been scaled by a factor entered as negative (-1.5). In all cases Column J contains
the resultant PSA value for that route, which may be compared to the baseline value in Column F.

For each route, the increase in PSA value translates into an additional amount of vehicle-minutes delay. Although a change in vehicle-miles could occur this is not calculated. The overall effect on the network PSA value is got by adding the additional vehicle-minutes to the reference total. In this case it is not visible to two decimal places.

Repeat moves can be handled approximately by using the multiplier function of Column K. However, this does not perform any adjustment for multiple ‘modified days’ affecting the same charts.

Dependence on route number arises not as a result of the generic formulae, which are common to all routes, but as result of the rate of delay on each route, which varies as indicated by the values in Column F. AIL moves which stick to the HATRIS network can probably be decomposed into PSA route segments, but this may in practice not be more useful than evaluating the route directly. The generic analysis is useful to give a idea of the scale of effect, but since it is based on rather artificial routes, is not a substitute for an analysis using realistic AIL routes and actual annual mileages by various AIL types.

The generic formulae can be applied directly on a network basis. For example, based on records for 2004-2007, large 12 mph AILs (eg girder-frames) are estimated to travel about 1460 miles annually on the HATRIS network. Accepting that it is meaningful to model them along the 206 PSA routes, and given the proportions of mileage in HATRIS which are 43% Motorway, 36% Dual, and 21% Single-carriageway, their estimated aggregate impact on the whole network works out at about 0.006 minutes per 10 vehicle miles.
Appendix C: Congestion Model validation

The PSA impact for an Abnormal Load value will be correct only as far as the delay estimated to be caused by the AIL is correct. Another scheduled part of this work was to validate the Congestion Calculator using data for actual moves monitored through MIDAS detectors and MTV speed plots. In practice few of these moves caused large queues, with notable exceptions like the Stafford-Seaforth cases, which were 5.9m wide and occupied two lanes, with police escort, and travelled between J14 and J16 of the M6 on Saturdays 15 and 22 May 2004 (under Special Order 38/10/327). Flows observed on the day, by limited sample counts, were not reliable enough to distinguish between the days, so have been set equal to avoid bias. Passing capacities were also difficult to establish, for the same reason. These data and results are summarised in Table B1, and the modelling of the moves is discussed more fully in Taylor (2006).

Table B1. Observed, modelled or estimated values for the Stafford-Seaforth M6 moves

<table>
<thead>
<tr>
<th>Date</th>
<th>Link</th>
<th>Start</th>
<th>End</th>
<th>Ambient flow</th>
<th>Pass capacity</th>
<th>Queue length</th>
<th>Delay v-h</th>
</tr>
</thead>
<tbody>
<tr>
<td>15/05</td>
<td>J14-15</td>
<td>845</td>
<td>940</td>
<td>2446</td>
<td>3350</td>
<td>1236</td>
<td>1080</td>
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<tr>
<td></td>
<td>J15-16</td>
<td>940</td>
<td>1036</td>
<td>3162</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22/05</td>
<td>J14-15</td>
<td>913</td>
<td>1005</td>
<td>3139</td>
<td>3350</td>
<td>1236</td>
<td>1260</td>
</tr>
<tr>
<td></td>
<td>J15-16</td>
<td>1005</td>
<td>1051</td>
<td>3910</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Congestion Calculator has a facility to take account of delay caused by additional queuing when heavy traffic which has been following an AIL hits a bottleneck. Quite severe ‘knock-on’ of ‘consequential’ queuing was indeed observed in the Stafford-Seaforth cases, long after the time and well downstream of the point that the AILs left the motorway.

Where lesser moves caused significant queuing, ie with clearly visible speed drop on an MTV plot indicated by lighter regions, this was often not the direct result of the AIL’s presence, but appeared to result from the heavier-than-normal traffic following the AIL undergoing flow breakdown on hitting ‘seed points’ where capacity was locally reduced. ‘Seed points’ are often associated with diverges and merges. The conventional wisdom up to now has been that flow breakdown is a probabilistic phenomenon which can occur randomly in any traffic stream which has temporarily exceeded normal maximum flow, as in heavy merging traffic. However, in practice flow breakdown seems to occur repeatedly at the same points, suggesting it is more strongly related to road geometry. This view is gaining strength – see for example Wilson (2007).

Capacity can be reduced by road works, leading to a similar effect. This occurred in the case of the move shown in Figure B1.

This AIL was travelling from Chepstow to Dishforth along the M42 around 1700 (right hand thinner trace) on 23 February 2004 (Special Order 38/10/242). This AIL was only 2.55m wide so occupied only one lane, and was also quick moving with an average speed around 34 mph. Unfortunately, there were road works on the M42 at the time. Plots of speed on the actual day, taken from MADJ, show a substantial drop in average traffic speed from around 110 km/h to around 80 km/h between J3a to J6 (Figure B2), and the general speed drop is also visible as a pale ‘fog’ on the MTV plot.

The major apparent discrepancy between the Congestion Calculator results given in Table B2 and the MTV picture occurs on the J6-7 section where there appears to be no queue at all. A closer look at the Calculator results shows the ‘queues’ predicted are moving at quite high speeds.

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10 This always occurs where the tail of the queue behind the AIL moves downstream, which is almost invariably the case for quick-moving Loads and often the case even for large slow-moving Loads.
Figure B1. MTV plot of SO move travelling along the M42 (thinner trace on right)

Figure B2. Speed and flow breakdown following passage of the AIL on M42 J4-5
When traffic is moving at such high speeds, it is difficult to discern a queue in the normal sense. Nevertheless, traffic speed behind the AIL is reduced, and density increased, resulting in delay, but the effect is hardly more than would be produced by an ordinary HGV.

Table B2. Initial Congestion Calculator estimates for Chepstow-Dishforth move on M42

<table>
<thead>
<tr>
<th>Section of M42</th>
<th>J2-3</th>
<th>J3-3a</th>
<th>J3a-4</th>
<th>J4-5</th>
<th>J5-6</th>
<th>J6-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADJ average volume (veh/h)</td>
<td>3575</td>
<td>3453</td>
<td>4100</td>
<td>4557</td>
<td>5192</td>
<td>5536</td>
</tr>
<tr>
<td>Average traffic speed (km/h)</td>
<td>110.7</td>
<td>108.1</td>
<td>94.0</td>
<td>90.8</td>
<td>75.6</td>
<td>100.8</td>
</tr>
<tr>
<td>Speed in queue (km/h)</td>
<td>84.4</td>
<td>83.5</td>
<td>76.9</td>
<td>76.0</td>
<td>67.5</td>
<td>80.7</td>
</tr>
<tr>
<td>Queue size (vehicles)</td>
<td>0</td>
<td>0</td>
<td>21</td>
<td>77</td>
<td>299</td>
<td>373</td>
</tr>
<tr>
<td>Queue tail speed (km/h)</td>
<td>-</td>
<td>-</td>
<td>50.3</td>
<td>43.3</td>
<td>26.8</td>
<td>-4.1</td>
</tr>
</tbody>
</table>

The model cannot account for the all the queuing seen in Figure B1. While the narrow streak up to J2 represents about the right speed according to the grey scale, the blocks of queuing before J3a (diverge) and on the J4-5 section appear to be dependent on local bottleneck effects, albeit triggered off by the passage of the AIL. On the J6-7 section there is a just visible lightening which could be consistent with a drop in speed from about 60 mph to 50 mph – the ‘queue’ caused by the AIL.

The problem with local bottlenecks is that, depending on where the detectors which contribute to the databases are located, they may not be picked up by the HATRIS flows, and may not show up at all under normal conditions. Flow breakdown also has a ‘snowball’ effect where an initial minor drop in speed is magnified as it propagates upstream. This is evident in Figure B2 and Table B3, where flow drops from 4557 veh/h on J4-5, and J3a-4 is also affected (red figures).

Table B3. MADJ flows measured on M42 sections during passage of the AIL in Figure 34

<table>
<thead>
<tr>
<th>Section of M42</th>
<th>J2-3</th>
<th>J3-3a</th>
<th>J3a-4</th>
<th>J4-5</th>
<th>J5-6</th>
<th>J6-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum flow in day</td>
<td>5071</td>
<td>4647</td>
<td>4661</td>
<td>4748</td>
<td>5221</td>
<td>5552</td>
</tr>
<tr>
<td>Flow when AIL is passing</td>
<td>3575</td>
<td>3571</td>
<td>4100</td>
<td>4557</td>
<td>5221</td>
<td>5536</td>
</tr>
<tr>
<td>Minimum flow after AIL passed</td>
<td>3655</td>
<td>3571</td>
<td>3966</td>
<td>4310</td>
<td>5192</td>
<td>5536</td>
</tr>
</tbody>
</table>

Where consequential flow breakdown is responsible for most of the queuing, it creates a serious problem for validation, because the mechanism is poorly understood and the effect impossible to predict without very detailed knowledge of the seed points in the network. As a result, it has not been possible to carry out validation as planned. This could be seen as raising a question about the value of modelling, but in practice the Congestion Calculator can still be expected to give realistic predictions for the heaviest AILs, and the problem of consequential queuing may be soluble through better calibration of link capacities, which would also contribute to better prediction of other delays.
Estimating the Impact of Abnormal Loads on the PSA Value

Abnormal Indivisible Loads (AIL) range from vehicles slightly larger than HGVs to massive transporters specialised for heavy loads like electricity transformers. The HA is responsible for authorising the largest and heaviest movements under Special Order regulations. To help meet the DfT’s PSA network delay target, the HA needs to know their likely impact, and the possible benefit of managing routes and schedules. The report describes a project to extend the modelling already implemented in the ‘AIL Congestion Calculator’ spreadsheet program, and to apply it to estimating impact on the PSA value. Modelled delays of simulated AIL moves on specified routes are first translated into a profile of impacts on all the PSA measurement routes affected. Then a new program, the ‘PSA Value Calculator’, merges ‘modified days’ representing the AIL moves with reference charts of measured journey times on the PSA routes, and uses a standard procedure to calculate the impact on the network PSA value. The report also describes a modelling exercise leading to estimation of the generic PSA impact of a range of AIL types on primary route segments of different type and length, which can be used to estimate the impact of one or more AIL moves.

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