Whole Life Cost-Benefit Analysis for Median Safety Barriers

Task 2 – Structural Consequences

by G L Williams

PPR 277

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Whole Life Cost-Benefit Analysis for Median Safety Barriers Task 2 – Structural Consequences

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by G L Williams (TRL Limited)

Prepared for:	**HA Task Ref No. 3/372/R22; 'Whole Life Cost-Benefit Analysis for Median Safety Barriers'**
Client:	**Safety Standards and Research Department, Highways Agency (Mr Danny Ruth)**

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by G L Williams, TRL Limited

HIGHWAYS AGENCY TASK REFERNCE : 3/372/R22
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TRL Limited has been commissioned by the Highways Agency to identify, investigate and report on incidents in which the breach of a safety barrier has occurred and resulted in damage to an item of roadside equipment. The costs associated with repair, traffic delay, traffic management and any resulting injuries have then been evaluated.

In order to obtain detailed information relating to the damage and costs associated with structural impacts, one area of the Highways Agency's Network, the M25 Sphere, was identified, and details of incidents involving safety barrier breaches and subsequent structural damage were collated. From this list of incidents, the following were selected for further analysis:

- A safety fence in the central reserve was breached by a car, resulting in an impact with a lighting column;
- A safety fence in the nearside verge was breached by an HGV, resulting in an impact with a bridge pier;
- A safety fence in the nearside verge was breached by an HGV, resulting in an impact with a lighting column;
- A safety fence in the nearside verge was breached by a coach, resulting in an impact with a gantry sign support.

In each case, details of damage to the barrier and the item of roadside equipment were collated and the costs associated with restoring the site obtained. As the time for which vehicular access was restricted was known at each incident site, the traffic delay costs were also calculated.

In addition a letter was also distributed to all of the Highways Agency's regional Traffic Operations Departments, their Agents and their Term Maintenance Contractors to obtain their experiences from such incidents.

The report concludes that the costs associated with an incident are highly dependant on the impact parameters surrounding the incident, and the costs associated with the individual costs associated with repairs, traffic delay and the severity of the resulting injuries caused by the incident. Each potential hazard should be assessed on a case-by-case basis and each of these factors quantified using a statistical approach, including the implementation of a risk analysis procedure.

ABSTRACT

TRL Limited has been commissioned by the Highways Agency to identify, investigate and report on incidents in which the breach of a safety barrier has occurred and resulted in damage to an item of roadside equipment. This report identifies four specific accidents and summarises the costs associated with the repair of the safety barrier and item of roadside equipment, traffic delay, traffic management and any resulting injuries.

1. INTRODUCTION

1.1 Background

Early in 1999, there was a series of accidents involving heavy goods vehicles (HGVs) veering to their offside, impacting safety barriers installed in the median, and entering the opposing carriageway. These are referred to as 'crossover accidents' and have caused a number of fatal casualties.

Concern within the Highways Agency about crossover accidents prompted the consideration of replacing normal containment steel safety fences in the median with concrete barriers and/or barriers with a greater level of containment.

1.2 Previous Work

TRL has previously completed three phases to this project, and reports have been produced:

The first phase of the project, TRL unpublished report PR/SE/182/00, examined STATS19 accident data in detail, whilst containing a small amount of information regarding the whole life costs associated with median safety barriers.

Within the second phase, TRL published project report PPR 280, the subject of whole life costing was significantly expanded, and a whole life costing spreadsheet developed.

Within the third phase, TRL published project report PPR279, the whole life costing section was expanded further still, incorporating accident rates, risk factors, and revised costing figures.

1.3 Considerations in Phase Four of the Project

TRL Limited has been commissioned by the Highways Agency to investigate three areas of in-service practicality associated with the replacement of metal median safety fences with concrete safety barriers:
Task 1: The costs associated with the relocation of services in the median;
Task 2: The costs associated with the structural consequences of breaching a safety barrier;
Task 3: The issues surrounding the provision of temporary and permanent signage in a median furnished with concrete barriers.
This report considers the second of these topics.

1.4 Definitions and abbreviations

Definitions and abbreviations used within this report can be located in **Annex A**. In some cases definitions are also included within the main body of the report to aid understanding.

2. SOURCES OF INFORMATION

2.1 The Mouchel Parkman Case Studies – The M25 Sphere

In order to obtain detailed information relating to safety fence incidents and subsequent structural damage, one area of the Highways Agency's Network was identified as being of interest. This was the M25 Sphere. This contains a large proportion of the concrete barrier installed in the median of Highways Agency roads, in the form of the Vertical Concrete Barrier (VCB) and Higher Vertical Concrete Barrier (HVCB). This sector also contains lengths of Tensioned Corrugated Beam (TCB), Open Box Beam (OBB), and Wire Rope Safety Fence (WRSF). The M25 Sphere is currently maintained by Mouchel Parkman.

It was hoped that this study area would contain examples of incidents with a wide variety of safety barrier types to enable a full examination of the differing costs associated with barrier breaches to be examined. However this was not the case once the accident statistics had been examined as TCB was present at all four of the incident sites.

Figure 1: The Case Study Area – The M25 Sphere

2.1.1 Incident Identification

An initial scoping meeting was held between the Highways Agency, TRL and Mouchel Parkman where it was agreed that the following types of accident were of interest to this study:

- Single vehicle;
- Safety fence was breached;
- A secondary impact had occurred to such a degree that additional works were required to repair the damage article;
- Details of the costs associated with the accident were known;
- Details of road closures were known.

From this brief, the following incidents were identified by Mouchel Parkman as being relevant to this project:

Accident Reference Number	Damage 1	position	Damage 2	Approx costs (damage only, no delay costs)	Estimated / final	vehicle
1	safety fence	centre	lamp column	6,030.28	e	car
2	safety fence	nearside	sign	10,483.66	f	car
3	safety fence	nearside	bridge pillar	432,313.90	e	HGV
4	safety fence	nearside	lamp column	6,478.16	f	HGV
5	safety fence	nearside	lamp column	12,852.06	f	HGV
6	safety fence	centre	lamp column	4,917.77	e	HGV
7	safety fence	nearside	acoustic fence	23,390.35	e	lorry
8	safety fence	centre	lamp column	12,789.84	e	HGV
9	safety fence	nearside	bridge pillar	12,200.75	e	HGV
10	safety fence	nearside	gantry	12,944.86	e	coach
11	safety fence	centre	lamp column	4,998.94	f	car
12	safety fence	centre	lamp column	9,760.50	e	lorry
13	safety fence	nearside	chevron sign	9,792.71	f	HGV
14	safety fence	centre	lamp column	7,468.71	e	HGV

Table 1: Incidents in the M25 Sphere in which a safety barrier was breached and a secondary item of roadside furniture was damaged

From this list, the following four incidents were selected for further analysis:

Accident Reference Number	Damage 1	position	Damage 2	Approx costs (damage only, not delay)	Estimated / final	vehicle
1	safety fence	centre	lamp column	6,030.28	e	car
3	safety fence	nearside	bridge pillar	432,313.90	e	HGV
4	safety fence	nearside	lamp column	6,478.16	f	HGV
10	safety fence	nearside	gantry	12,944.86	e	coach

Table 2: Incidents in the M25 Sphere involving structural consequences selected for further investigation

These particular incidents were selected as it was believed that these would demonstrate the costs associated with a variety of different vehicles, impacted objects and location. The incidents would also indicate the variety of costs associated with structural consequences, showing examples of both low and high probability impacts.

Each of the incidents will now be examined in turn and an assessment of the costs associated with each incident presented.

2.1.2 Incident 1 – Median Safety Fence and Lighting Column Strike

Location:	M4 J4-4B Westbound
Action:	M4 Westbound closed at J4
Other traffic impacts:	M4 Eastbound operating as normal
Accident severity:	Serious
Accident description:	The driver of a saloon car collided at speed with the central reserve barrier and subsequently, a lighting column.
Struck Safety Fence:	The central reserve safety fence at the incident location was two parallel rows of single sided tension corrugated beam at 3.2 and 1.6m post spacing (*reported incorrectly as 2.4m in the Mouchel Parkman report*).
Struck Other Object:	Lighting column

2.1.2.1 Damage to the Safety Barrier

Fifty-two metres of fencing were damaged, resulting in the need to replace twenty posts (with concrete foundations) and sixteen beams. The damaged barrier was replaced like-for-like.

2.1.2.2 Damage to the Other Object Hit

The lighting column struck was badly damaged, to such an extent that it had to be cut down and removed from the central reserve. A replacement lighting column was subsequently installed.

2.1.2.3 Economic Cost – Structural Damage Only

The cost to restore the site is estimated by Mouchel Parkman as follows:

Item of Cost	Estimated Cost Incurred
Traffic Management	£ 2,292
Safety Fence	£ 3,032
Lighting Column	£ 5,865
Design and management	£ 1,027
TOTAL COST OF REPAIRS	**£ 12,216**

Table 3: Structural Damage Costs associated with Incident 1

2.1.2.4 Traffic Delay

Traffic Data

Motorway Traffic Viewer (MTV) plots were provided (for M25 Clockwise and Anticlockwise). As may be anticipated, these did not demonstrate any congestion effects on the M25 since the incident affected westbound traffic on the M4 east of the M25. The Highways Agency's TRADS2 database [1] was interrogated to extract automated traffic count (ATC) data for the period of the incident and for average annual traffic on the link.

The M4 closure took place late at night when traffic flows were low. The traffic data showed no increase in levels of traffic flow after the closure was lifted, hence implying that no queuing occurred on the M4 during the incident and its aftermath. The implication is that all traffic that would normally have expected to travel along the M4 was able to divert off the M4 at J4.

By comparing the profiles of normal traffic and that during the closure, it is estimated that **2,735** vehicles were diverted during the repairs.

It is likely that traffic intending to travel along the M4 west of the M25, on being obliged to leave the M4 at J4, would divert along the M4 Spur and along the A4 Bath Road to rejoin the M4 at J5 [normal route 7km at 110kph = 3.8min, diversion 10km at 65kph = 9.2min, additional time = 5.4min].

Similarly, it is likely that traffic intending to travel onto the M25 Northbound, on being obliged to leave the M4 at J4 would again divert along the M4 Spur and along the A4 Bath Road to undertake a U-turn at M4 J5 to return to the M4 at J4B [normal route 4km at 110kph = 2.2min; diversion 10km at 65kph = 9.2min plus a diversion of 4km at 110kph = 2.2min; additional time = 9.2min].

It is also likely that traffic intending to travel onto the M25 Southbound, on being obliged to leave the M4 at J4 would again divert along the M4 Spur and along the A4 Bath Road then take the A3113 to join the M25 at J14 [normal route 6km at 110kph = 3.3min; diversion 8km at 65kph = 4.4min; additional time = 1.1min].

Hence the average delay to road users may be taken to be around **5 minutes** (i.e. ⅓*(9.2+5.4+1.1)).

Delay costs at junctions would have been relatively small at this time of night.

Economic Cost – Traffic Delay Only
The economic cost to road users has been calculated using the value of time as set out in the current version of the Highways Agency's Cost Benefit Analysis (COBA) Manual (DMRB Volume 13) [2]. This is **£9.30/hour** for an average vehicle expressed in 2002 resource prices (i.e. excludes the average rate of indirect taxation – which was 20.9% in 2002).

Number of vehicles affected	Average Delay time (mins)	Traffic delay cost (per min)	**TOTAL traffic delay cost**
2,735	5	£ 0.155	**£ 2,120**

Table 4: Traffic Delay Costs associated with Incident 1

The total traffic delay cost can be attributed to traffic that would have been on the motorway main carriageway. There would also have been minimal delay costs as a result of delays to traffic normally on the diversion route.

Addition of some additional costs during initial confusion and queue clearance at the start of the closure, results in a total traffic delay cost due to this incident of around **£3,000**.

2.1.2.5 Injury costs
The Highways Economic Note No 1, 2004 [3], Table 4c states the following accident cost for a serious motorway accident occurring at night:

Accident severity	Accident location	Accident Time	**TOTAL injury cost**
Serious	Motorway (M4)	Night (Darkness)	**£ 207,552**

Table 5: Injury Costs associated with Incident 1

2.1.2.6 Total cost due to the incident
In summary, the total cost attributable to this incident is as follows:

Item of Cost	Total Cost
Total Cost of Repairs	£ 12,216
Total Traffic Delay Cost	£ 3,000
Total Injury Cost	£ 207,552
TOTAL INCIDENT COST	**£ 222,768**

Table 6: Total Costs associated with Incident 1

2.1.3 Incident 2 – Safety Fence and Bridge Pier Strike

Location:	M25 J9-10A North-westbound
Action:	M25 North-west bound closed at J9 for 38 minutes, then at J8 for 6 hours, 25 minutes. This was followed by more than 3 days of closure to lanes 1 & 2 whilst temporary traffic management (TTM) was installed. During the subsequent assessment and repair to the bridge TTM was in place by means of road marking and temporary vertical concrete barriers. This repair period, lasting some six months, comprised of a lane 1 closure with lanes 2, 3 and 4 operating as narrow lanes under a 50mph speed restriction. Due to initial non-compliance with speed restriction, the HA installed interactive Speedcheck signs to assist in compliance.
Other traffic impacts:	M25 South-east bound operating as normal.
Accident severity:	Fatal
Accident description:	A heavy goods lorry collided with a nearside safety barrier, ran along it impacting a bridge pier, catching fire beneath an overbridge.
Struck Safety Fence:	The nearside safety fence at the incident location was open box beam at 2.4m post spacing.
Struck other Object:	Bridge pier

2.1.3.1 Damage to the Safety Barrier

Approximately sixty socketed posts and thirty-five beams were damaged and required repair. The damaged barrier was replaced like-for-like but with the addition of a crash cushion installed on the approach end. The original barrier length was terminated using a ramped end anchorage.

2.1.3.2 Damage to the Other Object Hit

Severe damage was caused to the bridge support, causing the bridge to be closed to both vehicle and pedestrians. Temporary supports were put into place to enable the M25 to be reopened while a permanent repair was designed and implemented.

2.1.3.3 Economic Cost – Structural Damage Only

The cost to restore the site is estimated by Mouchel Parkman as follows:

Item of Cost	Estimated Cost Incurred
Traffic Management	£ 45,654
Safety Fence and Bridge	£ 307,000
Design and management	£ 67,844
TOTAL COST OF REPAIRS	**£ 420,498**

Table 7: Structural Damage Costs associated with Incident 2

2.1.3.4 Traffic Delay

Traffic Data

Motorway Incident Detector and Automatic Signalling (MIDAS) loop data was obtained in order to evaluate the delays associated with the 150 days of TTM with speed restriction.

On an average day it was determined that **559.45 vehicle hours** delay occurred and that this lasted for 150 days.

Including the initial period of disruption and TTM set-up and operation (without the additional Speedcheck signs in place), the total period for which traffic was affected was **188 days**. For the purpose of this assessment it may be assumed that the above identified delay occurred throughout the 188 days.

The incident itself occurred during the night at a time of low traffic flow. The M25 North-east bound was closed for several hours and traffic diverted. Diversion routing would have been complex and the cost to M25 and other roads difficult to determine.

During the works the users of the TTM appeared to work well and it is not anticipated that significant diversions or use of alternative routes were used.

Economic Cost – Traffic Delay Only
The economic cost to road users has been calculated using the value of time as set out in the current COBA Manual (DMRB Volume 13) [2]. This is **£9.30/hour** for an average vehicle expressed in 2002 resource prices (i.e. excludes the average rate of indirect taxation – which was 20.9% in 2002).

Resulting delays (in vehicle hours per day)	Duration of delays (days)	Traffic delay cost (per hour)	**TOTAL traffic delay cost**
559.45	188	£ 9.30	**£ 978,142**

Table 8: Traffic Delay Costs associated with Incident 2

There would have been some additional cost, both to M25 road users and traffic on other roads during the initial closure and, taking this into account, it may be stated that the total cost to road users would have been around **£1.0M** at 2002 resource prices.

2.1.3.5 Injury costs
The Highways Economic Note No 1, 2004 [3], Table 4c states the following accident cost for a serious motorway accident occurring at night:

Accident severity	Accident location	Accident Time	**TOTAL injury cost**
Fatal	Motorway (M25)	Night (Darkness)	**£ 1,612,383**

Table 9: Injury Costs associated with Incident 2

2.1.3.6 Total cost due to the incident
In summary, the total cost attributable to this incident is as follows:

Item of Cost	Total Cost
Total Cost of Repairs	£ 420,498
Total Traffic Delay Cost	£ 1,000,000
Total Injury Cost	£ 1,612,383
TOTAL INCIDENT COST	**£ 3,032,881**

Table 10: Total Costs associated with Incident 2

2.1.4 Incident 3 – Verge Safety Fence and Lighting Column Strike

Location:	M25 J15 / M4 J4B slip
Action:	M25Clockwise to M4Eastbound slip closed 23:04 to 02:15
Other traffic impacts:	M4 Eastbound operating as normal.
Accident severity:	Slight
Accident description:	HGV lost control and overturned at the merge point of the south to east sliproads and the north to east slip road at junction 15 of the M25, impacting the safety fence and a lighting column.
Struck Safety Fence:	The nearside safety fence at the incident location was single sided tensioned corrugated beam at 1.6m post spacing.
Struck Other Object:	Lighting column

2.1.4.1 Damage to the Safety Barrier

Twenty metres of the fences were damaged, resulting in the need to replace nine socketed posts in concrete footings, six beams and two adjuster beams were. The damaged barrier was replaced like-for-like.

2.1.4.2 Damage to the Other Object Hit

The lighting column was not removed until a period of time after the accident.

2.1.4.3 Economic Cost – Structural Damage Only

The actual cost to restore the site was as follows:

Item of Cost	Final Cost Incurred
Traffic Management	£ 2,292
Safety Fence	£ 2,535
Lighting column	£ 900
Design and management	£ 751
TOTAL COST OF REPAIRS	**£ 6,478**

Table 11: Structural Damage Costs associated with Incident 3

2.1.4.4 Traffic Delay

Traffic Data

MTV plot was provided for the M25 in both directions. This did not demonstrate any congestion effects on the M25 due to this incident.

The Highways Agency's TRADS2 database [1] was interrogated to extract ATC data for the period of the incident and for average annual traffic on the link. No data was available during the period of the incident but average 2002 traffic data was available.

The link road closure took place late at night when traffic flows were low. It is unlikely that there would have been any queuing traffic on the M25.

The implication is that all traffic that would normally have expected to travel along the link road would have continued along the link to join the M4 westbound, making a U-turn at M4 J5 to proceed eastbound along the M4 [additional journey time 6km at 80kph = **4.5min**].

At this time of night delay costs at junctions would have been relatively small.

By comparing the profiles of normal traffic and that during the closure, it is estimated that **361** vehicles were diverted as a result of this incident.

Economic Cost – Traffic Delay Only

The economic cost to road users has been calculated using the value of time as set out in the current COBA Manual (DMRB Volume 13). This is **£9.30/hour** for an average vehicle expressed in 2002 resource prices (i.e. excludes the average rate of indirect taxation – which was 20.9% in 2002).

Number of vehicles affected	Duration of delays (mins)	Traffic delay cost (per min)	**TOTAL traffic delay cost**
361	4.5	£ 0.155	**£252**

Table 12: Traffic Delay Costs associated with Incident 3

This may be attributed to traffic that would have been on the motorway main carriageway.

There would have been minimal delay cost to traffic which would normally travel on the diversion route.

Addition of some additional costs during confusion and queue clearance at the start of the closure, results in a total traffic delay cost due to this incident of around **£500**.

2.1.4.5 Injury costs

The Highways Economic Note No 1, 2004 [3], Table 4c states the following accident cost for a serious motorway accident occurring at night:

Accident severity	Accident location	Accident Time	**TOTAL injury cost**
Slight	Motorway (M25)	Night (Darkness)	**£ 24,404**

Table 13: Injury Costs associated with Incident 3

2.1.4.6 Total cost due to the incident

In summary, the total cost attributable to this incident is as follows:

Item of Cost	Total Cost
Total Cost of Repairs	£ 6,478
Total Traffic Delay Cost	£ 500
Total Injury Cost	£ 24,404
TOTAL INCIDENT COST	**£ 31,382**

Table 14: Total Costs associated with Incident 3

2.1.5 Incident 4 – Verge Safety Fence and Gantry Sign Support Strike

Location:	M1 J6-5 Southbound
Action:	M1 J6-5 closure 11:34 to 17:58
Other traffic impacts:	shorter period closure to M1 J5-6 N/B.
Accident severity:	Serious
Accident description:	A coach collided with the nearside safety barrier and gantry support. The gantry collapsed onto coach and carriageway.
Struck Safety Fence:	The nearside safety fence at the incident location was tensioned corrugated beam at 1.6m post spacing.
Struck Other Object:	Nearside gantry support.

2.1.5.1 Damage to the Safety Barrier

Sixteen metres of the fence was damaged, resulting in the need to replace seven posts, five beams, 3 adjusters and three TCB angled beams.

2.1.5.2 Damage to the Other Object Hit

One of the gantry supports was sheared off at the base and buckled, causing one side of the gantry to collapse onto the bus and carriageway. The gantry will not be replaced as it was scheduled to be removed during scheduled maintenance works.

2.1.5.3 Economic Cost – Structural Damage Only

The cost to restore the site is estimated by Mouchel Parkman as follows:

Item of Cost	Final Cost Incurred
Traffic Management	£ 3,095
Safety Fence and Bridge	£ 2,546
Gantry *(if it were to be replaced)*	£ 106,798
Design and management	£ 80
TOTAL COST OF REPAIRS	**£ 112,519**

Table 15: Structural Damage Costs associated with Incident 4

2.1.5.4 Traffic Delay

Traffic Data

The Highways Agency's TRADS2 database [1] was interrogated to extract ATC data for the period of the incident and for average annual traffic on the link.

Data was available both during the period of the incident and for average 2005 traffic.

By comparing the profiles of normal traffic and that during the closure, it is estimated that **14,772** southbound vehicles diverted due to the incident.

The link road closure took place on a weekday afternoon in the direction opposite to the subsequent afternoon peak and when traffic flows were relatively low. The traffic data downstream of the closure showed traffic on the M1 during the closure period but at a lower level than normal. This implies that some traffic would have rerouted from the M1 at J6 via the A41 to rejoin the M1 at J5, but other traffic rerouted further away and did not rejoin the M1.

Additional time would have been taken for vehicles travelling between M1 J6 and M1 J5 via the A41 [normal route 4km at 110kph = 2.2min; diversion 8km at 80kph = 6.0min; additional time = **3.8min**].

In additional there would probably have been some additional delays at junctions along the diversion route, in particular at M1 Junction 6. This could well have doubled the above link delay time.

Economic Cost – Traffic Delay Only

The economic cost to road users has been calculated using the value of time as set out in the current COBA Manual (DMRB Volume 13). This is **£9.30/hour** for an average vehicle expressed in 2002 resource prices (i.e. excludes the average rate of indirect taxation – which was 20.9% in 2002).

Number of vehicles affected	Duration of delays (mins)	Traffic delay cost (per min)	**TOTAL traffic delay cost**
14,772	7.6	£ 0.155	**£17,401**

Table 16: Traffic Delay Costs associated with Incident 4

The adjacent A41 road would have had sufficient spare capacity available during the time of the incident and hence, this delay cost may be attributed to traffic that would have been on the main carriageway of the motorway. There would not have been high delay costs to traffic normally on this diversion route. Some of this diverting traffic, as noted above, would have used alternative diversion routes which may have been longer but this cannot be determined.

The northbound traffic was also affected with a similar diversion from the M1 J5 along the A41 to rejoin the M1 at J6. This closure period was from 16:05 to 16:50. This delay cost has not been specifically calculated but by pro-rate the southbound cost by time results in a cost to road users of £2,040.

Addition of some additional costs during confusion and queue clearance at the start of the closure and longer diversion routes for some traffic, a road user cost of around **£25,000** results from this incident.

2.1.5.5 Injury costs

The Highways Economic Note No 1, 2004 [3], Table 4b states the following accident cost for a serious motorway accident occurring during daylight hours:

Accident severity	Accident location	Accident Time	**TOTAL injury cost**
Serious	Motorway (M1)	Daylight	**£ 206,404**

Table 17: Injury Costs associated with Incident 4

2.1.5.6 Total cost due to the incident

In summary, the total cost attributable to this incident is as follows:

Item of Cost	Total Cost
Total Cost of Repairs	£ 112,519
Total Traffic Delay Cost	£ 25,000
Total Injury Cost	£ 206,404
TOTAL INCIDENT COST	**£ 343,923**

Table 18: Total Costs associated with Incident 4

2.2 Responses from Highways Agency Maintaining Agents

In addition to the Mouchel Parkman case studies, the Highways Agency's regional Traffic Operations Departments, their Agents and their Term Maintenance Contractors were also contacted regarding were also contacted regarding the costs associated with the relocation of services (with particular reference to a change from steel to concrete safety barriers. The responses received are detailed below:

2.2.1 Email from Neil Duxbury, AmeyMouchel, Area 9, dated 15-12-05

'I have contacted our Structures and Operational teams and the only incident which can be identified is on the M5. The central pier was struck by a HGV. This caused damage to the Barrier, surfacing and Pier. There was an initial cost of £50,500 to make safe the area and a scheme is being progressed to carry out repair work to the pier. This will incur an additional cost of £ 250,000 with some TM costs still to be confirmed.'

2.2.2. Email from Stephen Coe, Highways Agency, Area 2, dated 09-11-05

'There are no records of any central reserve bridge pier strikes within Area 2.'

2.2.3 Email from Roger Wantling, Highways Agency, Area 12, dated 22-09-05

'Costs in relation to damage to central reserve structures behind a safety barrier - From enquiries made with Operations and Area Manager, there appears to be little evidence relating to damage to structures within the central reserve where vehicles have gone the existing crash barrier. Detailed research, therefore, would be required to get a useful definitive answer, which will be time consuming and could be expensive. Accordingly, is it necessary to have this information, especially by the date indicated?'

3. CONCLUSIONS

The following Table summarises the costs incurred by the four incidents investigated:

	Incident Description			
Item of Cost	Incident 1: Median Lighting Column Impact, M4	Incident 2: Bridge Pillar Impact, M25	Incident 3: Verge Lighting Column Impact, M25	Incident 4: Verge Gantry Leg Impact, M1
Total Cost of Repairs	£ 12,216	£ 420,498	£ 6,478	£ 112,519
Total Traffic Delay Cost	£ 3,000	£ 1,000,000	£ 500	£ 25,000
Total Injury Cost	£ 207,552	£ 1,612,383	£ 24,404	£ 206,404
TOTAL INCIDENT COST	**£ 222,768**	**£ 3,032,881**	**£ 31,382**	**£ 343,923**

The four incidents are very different both in the extent to the damage occurring to the structure and in the resulting delays to the travelling public. This therefore indicates that it is impossible to develop an 'average' cost associated with a structural impact and that each incident must be assessed on its own circumstances.

In the case of incidents 1 and 3, the incidents would seem rather similar in their circumstances and, in deed, the cost per metre for the structural damage cost is within a similar ball-park (the costs being £235 and £324 respectively). However in this particular comparison, it is the costs associated with the resulting injuries which are the dominant factor in the differences between the two accidents. In incident 1 the injury is reported as 'serious', the injury being reported as 'slight' in incident 3. Both incidents occurred at night. The severity of the injury is extremely depending on a large number of wide-ranging factors such as vehicle weight, speed and angle at the time of impact, driver health prior to the incident, vehicle type and in-car passive safety devices (such as airbags), driver reaction, seat belt use, etc.

Such a feeling of individuality in costs is supported by the correspondence from the HA maintaining agents.

Several of the accidents occurred at periods of very low traffic flow (late at night) and were cleared up quickly – resulting in relatively small delays and associated costs. The Mouchel Parkman report states that many incidents occur at busier times of the day when motorway traffic flow is operating much closer to capacity. The consequences of such incidents in terms of road user costs (both to motorway users and to those on routes onto which affected traffic is diverted) may therefore be appreciably higher than those in quantified for incidents 1, 3 and 4.

Incident 2 required a much longer repair period, resulting in small delays to individual road users, but as this was to a large volume of traffic (over several months), the result was a high total traffic delay cost.

In each of the incidents examined, a item of roadside furniture or structure has been impacted as a result of an impact by a large car, HGV or coach. In neither case did the metal safety fence at the incident location contain the impacting vehicle, resulting in damage to the secondary object. Given the impact mass of the vehicles, this is not surprising as, in each case, this exceeds that relating to the containment class of the barrier at the incident location (N2 in all cases). Due to the unknown mechanisms of the dynamic impact (such as impact weight, speed and angle), it is difficult to ascertain whether a safety barrier breach and/or secondary, structural impact would have occurred had a concrete barrier been in place at the location of the incident. If a concrete barrier had been in place it is unknown whether a vehicle with a higher centre of gravity, such as a coach or an HGV would roll using the top of the barrier as a fulcrum, resulting in an impact higher up on the item of roadside furniture.

However, this being said, if it is assumed that the containment level of a concrete barrier were sufficient to contain and redirect a vehicle without impacting the item of roadside furniture, the associated cost of repairs would, in each case, be minimal (due to the recognised lack of repair required for concrete barriers) following an impact.

Traffic delay costs would also be reduced as these would only relate to the recovery of the impacting vehicle, and would not be required during the repair to the safety barrier or other damaged roadside equipment. However, the traffic delays associated with such a vehicle recovery from a live or partially closed carriageway are unknown.

One aspect of rigid barriers is their recognised stiffness and hence, the increase in severity when impacted. This has been demonstrated during full-scale impact testing. This may infer that the injuries and hence associated costs attributable to each incident will rise as a result of the impact with the rigid barrier, although the level of such increases is unknown.

Due to the date of the accidents, the circumstances surrounding incidents 1, 3 and 4 are not currently known (due to the date of the incidents) no further judgement can be made regarding the incidents and the likely outcome if alternative barrier containment solutions had been put into place. As incident 2 involved a fatality, the injury cost associated in this case will not rise above that currently included in the calculations.

In summary, the costs associated with an incident are highly dependant on the impact parameters surrounding the incident, and the costs associated with the individual costs associated with repairs, traffic delay and the severity of the resulting injuries caused by the incident. Each potential hazard should be assessed on a case-by-case basis and each of these factors quantified using a statistical approach, including the implementation of a risk analysis procedure.

4. REFERENCES

[1]: 'TRADS2 database', Highways Agency, 2002;

[2]: 'Cost Benefit Analysis (COBA) Manual (DMRB Volume 13)', Highways Agency;

[3]: 'Highways Economic Note No 1', Department for Transport, 2004.

ANNEX A – DEFINITIONS AND ABBREVIATIONS

Term or abbreviation	Explanation
ATC	Automated Traffic Count
Central Reserve	The strip of land (may be grassed) between two opposing carriageways
COBA	Cost Benefit Analysis (as in the Highways Agency's Cost Benefit Analysis (COBA) Manual (DMRB Volume 13).
Concrete Safety Barrier	An installation provided for the protection of users of the highway which is continuously in contact with its supporting foundation.
Crossover Accident	An accident in which one or more vehicle leaves the carriageway on the offside, and enters the opposing carriageway
DMRB	Design Manual for Roads and Bridges
HA	Highways Agency
HGV	Heavy Goods Vehicle
Higher Containment	A safety fence or barrier that has been impact tested to and complies with H1, H2 or H3 containment level requirements in BSEN1317, parts 1 and 2 (see Table 2).
HVCB	Higher vertical concrete barrier - A concrete barrier with a vertical face, 1.2m in height
Median	See 'central reserve'
MIDAS	Motorway Incident Detector and Automatic Signalling
MTV	Motorway Traffic Viewer
Normal Containment	A safety fence or barrier that has been impact tested to and complies with N1 or N2 containment level requirements in BSEN1317, parts 1 and 2 (see Table 2).
OBB	Open box beam safety fence
Safety Barrier	Generic name for a safety fence or a concrete safety barrier
Safety Fence	An installation provided for the protection of users of the highway consisting of horizontal members mounted on posts
STATS19	A reporting system in operation in Great Britain for the collection of information at fatal, serious, and slight accidents; organised by the DTLR.
TCB	Tensioned corrugated beam safety fence
TM	Traffic Management
VCB	Vertical concrete barrier - A concrete barrier with a vertical traffic face, 0.8m in height
Vehicle Restraint System	System installed on the road to provide a level of containment for an errant vehicle
Very High Containment	A safety fence or barrier that has been impact tested to and complies with H4a or H4b containment level requirements in BSEN1317, Parts 1 and 2
WLC	Whole Life Costing
WRSF	Wire rope safety fence