DEVELOPMENT OF A SAFETY RISK MODEL FOR THE HIGHWAYS AGENCY ROAD NETWORK

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Abstract

The Highways Agency (HA) operates the network of motorways and trunk roads in England. Following decades of demonstrable improvements in road safety, driven mainly by reactive studies aimed at identifying and treating accident cluster sites, the HA is now moving to a more proactive, risk-based approach to safety management.

To support this, the HA recently commissioned the development of a Safety Risk Model (SRM). This is a computer-based model that aims to address all reasonably foreseeable safety risks associated with the operation, maintenance and improvement of the HA network. This includes safety risks to:

- Road users
- HA Traffic Officers
- Supply chain workers

The paper presents the background to the development and intended use of the SRM, an overview of the SRM itself and some example results and analyses. The paper concludes with observations relating to the main benefits that the SRM has provided to date and a summary of the future aims for its implementation and further development.

1 Introduction

Health and safety legislation in the UK requires that organisations take a preventative and protective approach to managing safety risk. This includes implementing measures in order to prevent risks from occurring, or to reduce their impact if they do occur.

Other sectors (e.g. nuclear, rail) have developed a range of tools and techniques that can be used to support these requirements; these have been in use now for many years and represent established practice that is accepted by safety regulators both within the UK and around the world. However, at present, these techniques are not commonly used to manage risks in the highways sector.

The current approach to safety management on the Strategic Road Network (SRN) tends to be reactive and driven by the bottom-up development of solutions to treat safety problems identified from accident statistics and studies i.e. retrospectively addressing those areas where accidents have already happened. Additionally, efforts to control safety risk tend to focus on only one population at a time e.g. road users *or* Traffic Officers *or* supply chain workers. This means that impacts of risk controls for all populations that could be affected by them may not always be identified.

The Agency faces many challenges ahead, both in fulfilling its new Strategic Plan vision to become “the world’s leading road operator” (with “the safest roads in the world”) and its new ‘Aiming for Zero’ approach to health and safety. In addition to these drivers, the Agency will be managing safety risk on the strategic road network, with fewer incidences of accident cluster sites, increased use of active traffic management, more challenging performance targets and less funding. To reflect this, there is a general view emerging across road safety experts that there is a need to look to an approach to safety management that includes identifying and treating the most cost-effective, known areas of high safety risk <u>before</u> serious accidents occur.

A move to the type of safety risk management practices described above would undoubtedly be an important contribution and an effective tool in support of these aims.

This is the background to the proposed development of an holistic safety risk model.

2 Intended Business Use

The main intended business use of the SRM is to help the HA understand:

- the profile of safety risk for different populations on the strategic road network (SRN),
- the main factors that are driving these risks and

- what proportion of safety risk the HA can control or influence

This understanding will then inform priorities for investment and allocation of resources for managing safety on the SRN, ensuring that efforts are targeted where the HA is likely to have the most impact.

The SRM will also provide the HA with an in-house tool to perform detailed analyses and help understand the potential safety implications of new policies; it will also help identify how specific targets could be achieved i.e. what would need to change and by how much to achieve a specified output.

3 Scope of the Model

Table 1 sets out the safety risks falling within the scope of the SRM.

Population	Safety risks included in the SRM
Road Users	• Driving/riding/walking on the SRN • Breaking down on the SRN
Traffic Officers	• Working on or adjacent to the SRN
Supply chain workers	• Working where live traffic is present • Working on sites, on or adjacent to the operational SRN

Table 1: Safety risks included in the SRM

Safety risks that are out of scope for the SRM are:

- 'Greenfield' construction i.e. new sites/off-line from the operational network
- Supply chain workers driving to work sites
- Unforeseeable Traffic Officer and supply chain worker activities
- Long term occupational health issues
- HA staff driving for work (other than Traffic Officers)
- Terrorist activity
- 'Force majeure' events
- Safety risks not on the SRN (e.g. working in offices)

The SRM has been developed initially to provide **network** level analysis only. However, the model has been designed to allow Regional, Area or route level analysis in the future.

A final important point about the scope of the model is that it has been developed to perform risk analysis *only*; it does not attempt to evaluate the tolerability of any calculated risk levels, or provide any cost-benefit analysis of any identified risk controls. Both of these functions are performed outwith the model, in accordance with established HA procedures for risk assessment and control.

4 Approach to Risk Analysis

The SRM produces measures of collective risk in terms of:

- Fatalities and Weighted Injuries (FWI) per billion vehicle miles (road users)
- FWI per million vehicle hours (road users)
- FWI per 100,000 hours worked (Traffic Officers & Supply Chain Workers)

The SRM also calculates measures of individual risk, in terms of FWI per 100,000 person-hours network exposure (road users, Traffic Officers and Supply Chain Workers).

Within the SRM, an FWI is defined as:

$$\text{(Number of fatalities)} + 0.1 \text{ x (Number of serious casualties)} + 0.01 \text{ x (Number of slight casualties)} \quad (1)$$

This reflects the approximate ratios between the costs of fatal, serious and slight casualties defined in the Department for Transport's (DfT) Transport Analysis Guidance [1]. Whilst this is seen as a defensible starting point for the FWI definition on HA roads, it is acknowledged that further work to validate this could be useful e.g. as completed recently by the UK rail industry [2].

Values of FWIs produced by the SRM are calculated directly from actual accident data; these are then normalised by measures of population exposure to calculate risk.

Different measures of exposure are used for different populations on the SRN. For road users, the SRM measures exposure in terms of the number of:

- Vehicle miles travelled
- Vehicle hours travelled
- Person-hours network exposure

Values of vehicle miles travelled are determined from a combination of HA traffic flow data and data provided by the DfT on the distribution of different vehicle types on different types of road. Values of vehicle hours travelled are then calculated from a combination of the vehicle miles data and published data on the average speeds of different vehicle types on different types of roads. Values of person-hours exposure are then calculated from the vehicle hours data, but taking account of published values of vehicle occupancy.

For workers, the SRM measures exposure in terms of the number of hours worked. These are determined from a combination of HA staff timesheet data (for Traffic Officers) and data provided by the supply chain (for supply chain workers).

5 Model Structure

5.1 Front-end/database structure

The SRM comprises an Excel front-end (SRM Version 1.xls), supported by an Access database ('SRMInputDatabase.mdb'); these platforms were chosen primarily for reasons of end-user familiarity.

The front-end enables users to configure analyses and view results. The front-end also produces standard graphical outputs and stores analysis configuration details, so that they can be re-run at a future date.

The Access database then holds data from a range of external sources that has been imported, cleaned and mapped onto the structure of the SRM, such that the Excel front-end can readily query the data to produce the required results. Data for the SRM is actually formed of four separate databases comprising:

- Road user accident data
- Worker accident data
- Vehicle miles data
- Working hours data

Figure 1 shows a schematic of Excel and Access components of the model.

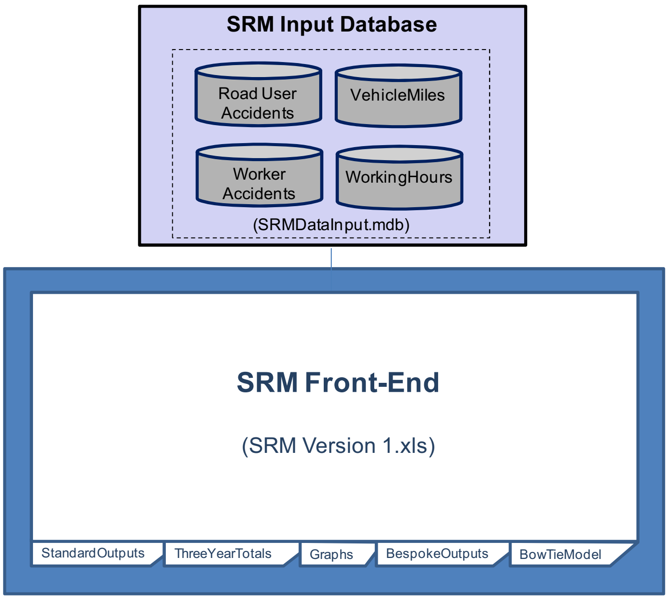


Figure 1 - Schematic of SRM Model

5.2 Model design and functionality

The model essentially supports three types of analyses. The first of these produces 'standard' or 'bespoke' outputs. This type of analysis basically segments the underlying data according to a limited set of pre ('standard') or user-defined ('bespoke') dimensions and presents the results in a standard format.

The second provides bow-tie modelling capability that allows the user to conduct more detailed segmentation of the underlying data.

The third allows the user to apply 'scaling factors' within the bow-tie models, to investigate the impact of changes to the current:

- Frequency of underlying accidents with specific contributing factors
- Distribution of accident sequences
- Average consequences per accident type

This effectively allows users to perform 'what-if' analyses.

5.3 Standard and Bespoke Outputs

The model produces standard outputs and allows the user to perform bespoke analyses against the following dimensions:

- Year (individual years or 3-year totals)
- Road type (Motorways, Dual carriageway A roads, Single carriageway A roads)
- Road user type (Car occupants, Powered Two Wheelers (PTWs), Heavy Goods Vehicles (HGVs), Light Goods Vehicles (LGVs), Buses & Coaches, Cyclists and Pedestrians)
- Worker type (Traffic Officers and Supply Chain)
- Contributing factors (including factors attributable to road users, conditions, vehicle/surroundings and workers; see Appendix 1 for detail)
- Primary accident sequences (including single, two and multiple vehicle accidents for road users and various categories of accidents for workers; see Appendix 1 for detail)
- Consequences (numbers of accidents, fatalities, serious injuries, slight injuries and FWIs and collective risk)

Standard results from the SRM are then automatically converted into graphs for presentation within business reports.

5.4 Bow-tie Modelling

The SRM provides bow-tie modelling functionality for road users and workers: the left hand side of each bow-tie model describes relevant accident causation (contributing factors); the right hand side describes relevant accident sequences and consequences.

The first stage in any bow-tie analysis is to set the analysis 'configuration' parameters; additional parameters included within the bow-tie models that are not supported by the standard or bespoke reporting include:

- Location (carriageway, junction/roundabout/slip road, hardshoulder/lay-by or roadworks)
- Time of day (peak/off-peak, daylight/darkness, dayshift/nightshift)
- Accident 'actors' (e.g. all Road Users, all Car, all PTW, vehicle-person, Car-Car, Car-HGV, Vehicle-PTW, Vehicle-Cycle, Multiple Mixed Vehicle)
- Secondary accident sequences (see Appendix 1 for detail)

The model then allows users to configure both sides of the bow tie dynamically, depending on the size of the underlying population of accidents being studied. For small populations of accidents, the model supports only a limited breakdown of possible contributing factors and accident sequences; for large populations of accidents, the model supports a more detailed breakdown of both sides of the bow-tie.

5.5 What-if Analyses

Figure 2 shows a simplified schematic representation of a what-if analysis, demonstrating the use of the 'scaling' factors within a bow-tie model.

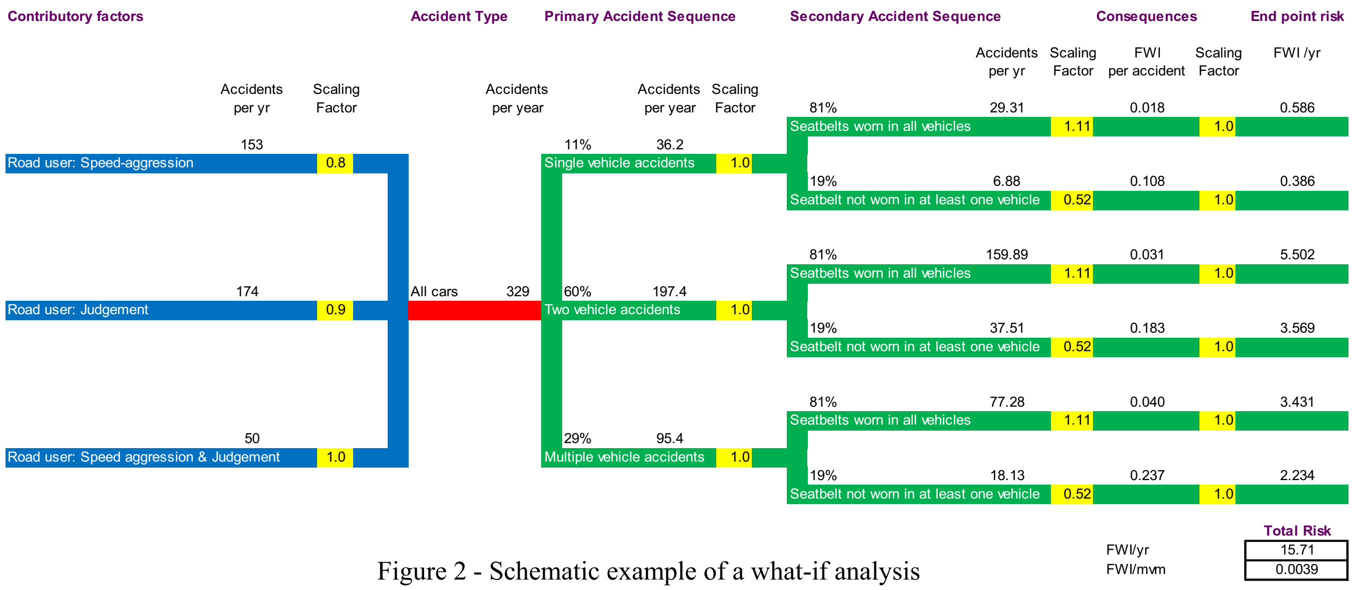


Figure 2 - Schematic example of a what-if analysis

Within Figure 2, scaling factors have been used to represent:

- reduced frequency of the individual contributing factors of 'road user: speed-aggression' and 'road user: judgement (young)' (reduced by 20% and 10% respectively, using scaling factors of 0.8 and 0.9)
- reduced probability of a seatbelt not being worn in at least one vehicle (reduced from 19% to 10%, using a scaling factor of 0.52 plus corresponding scaling factor for the adjusted probability of seatbelts being worn in all vehicles)

The default outputs for the analysis configuration shown are 23.98 FWIs and 0.0058 FWIs/mvm. The results from Figure 2 show that this would reduce to 15.71 FWIs and 0.0039FWIs/mvm *if* the reductions in frequency of the specified contributing factors and probability of not wearing a seatbelt could be achieved. The model does not say how or whether these reductions could be achieved in practice, but simply calculates the outcomes if they *were* achieved.

6 Data

An important aspect of the SRM is the underlying data. This section of the paper describes some of the main data issues encountered as part of the model development work.

6.1 Source data

One of the main aims of the project was maximise the use of existing data, rather than to produce a long wish-list of additional data that the HA would need to collect in order to support the 'ideal' model.

Most of the data sources were internal to the HA, but were managed as separate systems, with separate owners, different 'reasons-for-being' (i.e. unrelated to the aims of the SRM) and often using different terminology and metrics to those adopted within the SRM. The work required to import and clean the underlying data was therefore extensive.

6.2 Data quality issues & solutions

Data issues encountered included:

- Some incidents were captured in more than one data source e.g. accidents involving road users and supply chain workers. The SRM was required to identify these duplicate records and remove any double counting
- Not all model dimensions were captured directly by all data sources; for example, the SRM contains 18 contributing factors for road users, whereas the underlying road user accident data contains approximately 80 contributory factors. This required the road user accident data to be mapped onto the SRM model parameters. The results from the model are very sensitive to this mapping
- Not all model parameters are captured by all data sources; where this is the case, records were classified as 'not known' against the particular model parameter or dimension of interest
- Not all of the relevant or required fields were completed for all records (so-called 'null' fields); where this was the case, a record was classified as 'not known' against the particular model parameter or dimension of interest
- Some model parameters had only very small numbers of incidents recorded against them. Where this was the case, data had to be combined over several years, and the model used an average value for the defined period.

7 Validation

The SRM results need to be trusted if they are to be used to identify safety priorities and inform investment decisions. A key part of the model development process was therefore to validate the model results.

To do this, the model outputs were checked against comparable results published elsewhere in existing HA or DfT documents. This included results for:

- Number of accidents by road type and accident severity
- Numbers of casualties and casualty rates by road type
- Numbers of accidents by severity, collision type and road type
- Numbers of casualties and casualty rates by different customer groups
- Traffic by road type and customer group

The final model showed some variability in terms of collision types. This was attributed to variations in how the accidents were allocated to different collision types within the model, compared with other published analyses.

8 Example Results & Analyses

This section presents a range of example results and analyses produced using the SRM.

8.1 Network-level risk levels

Figure 3 shows one of the standard output graphs from the SRM. This presents the profile of individual risk (FWIs per 100,000 person-hours of network exposure) for road users and workers together.

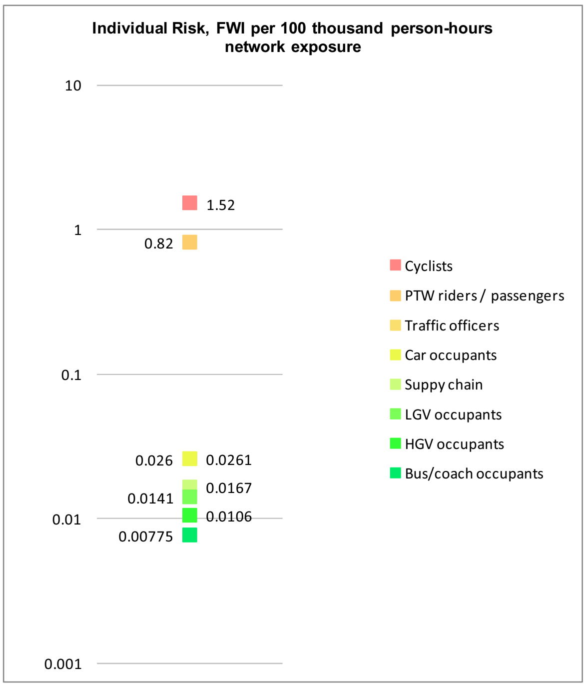
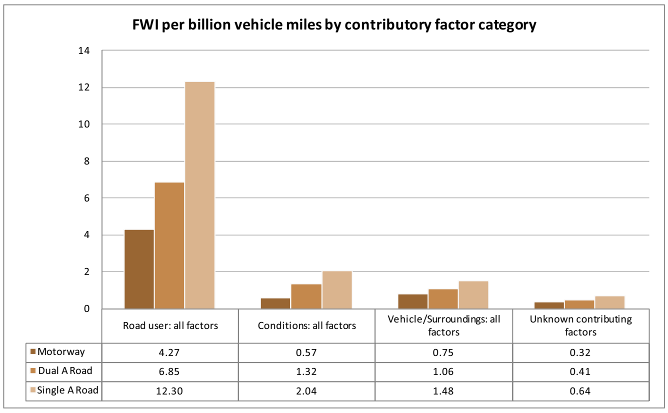


Figure 3 - Example individual risk profile

8.2 Profiles of safety risk

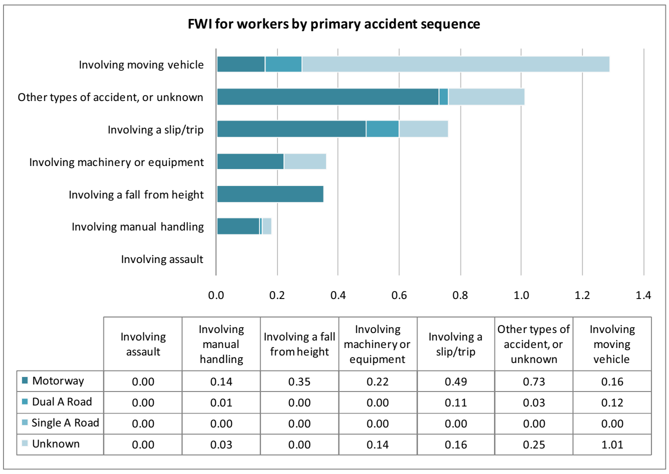
Figures 4 and 5 show example profiles of safety risk produced by the SRM.

Figure 4 shows the profile FWI/bvm for different categories of contributing factor for road users; Figure 5 shows the profile of FWIs for different primary accident sequences for workers



	Road user: all factors	Conditions: all factors	Vehicle/Surroundings: all factors	Unknown contributing factors
Motorway	4.27	0.57	0.75	0.32
Dual A Road	6.85	1.32	1.06	0.41
Single A Road	12.30	2.04	1.48	0.64

Figure 4 - Example safety risk profile for road users



	Involving assault	Involving manual handling	Involving a fall from height	Involving machinery or equipment	Involving a slip/trip	Other types of accident, or unknown	Involving moving vehicle
Motorway	0.00	0.14	0.35	0.22	0.49	0.73	0.16
Dual A Road	0.00	0.01	0.00	0.00	0.11	0.03	0.12
Single A Road	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unknown	0.00	0.03	0.00	0.14	0.16	0.25	1.01

Figure 5 - Example safety risk profile for workers

8.3 Detailed analyses

Figure 6 shows the profile of safety risk for different types of road user on different types of road; this was produced using the 'bespoke' reporting functionality of the SRM.

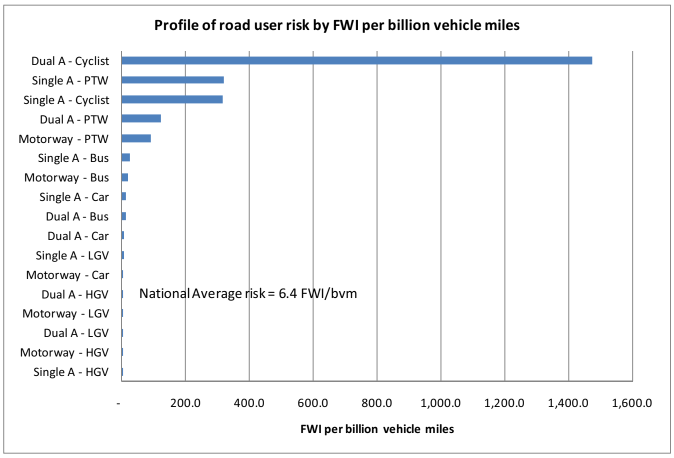


Figure 6 - Bespoke road user risk profile

8.4 HA controls & influence

A final function of the SRM is that it enables the HA to identify what proportion of safety risk on the SRN they can control or influence, either directly (e.g. through their own actions or inactions) or indirectly (e.g. through lobbying of other government departments or Agencies or through supplier contracts).

Table 2 shows some example output.

Contributing Factors	Type of HA control	FWIs associated with factor (% of total FWIs for the population)	
		Road Users	Workers
Road user	Direct	-	-
	Indirect	473.31 (86.3%)	1.13 (26.8%)
Conditions	Direct	80.47 (14.7%)	-
	Indirect	-	0.42 (10.0%)
Vehicle or Surroundings	Direct	49.7 (9.1%)	1.83 (43.5%)
	Indirect	28.89 (5.3%)	-
Worker	Direct	-	0 (0%)
	Indirect	-	0.76 (18.1%)

Table 2: Potential HA control or influence

The figures in Table 2 show the maximum impact that HA could have on the total FWIs on the SRN, if it could eliminate all accidents resulting from that factor; this is an absolute 'best case' scenario as contributory factors are not mutually exclusive. The overriding conclusion from this analysis is that the HA can directly control only a relative small proportion of overall risk on the SRN; the main contribution to risk comes from the behaviour of road users.

9 Conclusions & the Way Forward

9.1 Conclusions

The main conclusions from developing the model are:

- It is possible to produce useful and meaningful calculations of safety risk for highways
- The inclusion of exposure data in risk calculations gives a different picture to the traditional accident/casualty numbers and so provides useful additional insight to inform safety decision making
- The results provided by the SRM clearly demonstrate the extent of HA control and influence on safety risk and helps identify where to focus resources; they also provide useful evidence for discussions with other Agencies
- The development of this type of model provides in-house capability to perform detailed, bespoke analyses, reducing reliance on external consultant support

9.2 Way Forward

Determining the way forward for the model will commence with using it as part of day-to-day business. This has now begun.

Possible next steps for the development of the model then include:

- Regional/Area/Route versions
- Building in risk assessment and cost-benefit functionality

References

[1] Department for Transport, Transport Analysis Guidance, webTAG. Unit 3.4.1. Available at http://www.dft.gov.uk/webtag/ [Accessed 06/06/11]

[2] RSSB, Proposals for the Weighting of Major and Minor Injuries, 2008

Appendix 1

This Appendix provides a detailed list of the contributing factors and accident sequences included within the SRM.

Contributing factors:

Road User	Conditions	Vehicle & Surroundings	Worker
• Alcohol or drugs • Speed or aggression • Fatigue • Illness • Judgement • Inattention, distraction or carelessness • Illegal manoeuvre	• Road adhesion • Visibility • Worksite conditions	• Vehicle defect • Foreign vehicle • Object in road • Pedestrian in road • Roadworks • HA infrastructure defect • HA operations defect	• Alcohol-drugs • Fatigue • Illness • Judgement • Inattention, distraction or carelessness • Non-compliance

Primary accident sequences:

Single vehicle	Two vehicle	Multiple vehicle	Pedestrian	Worker
• Leaves carriageway, hits nearside barrier • Leaves carriageway, hits offside barrier • Leaves carriageway, hits other object • Leaves carriageway, comes to rest • Hits object in carriageway • Comes to rest in carriageway	• Rear end shunt • Head on • Side impact • Side swipe • Other impacts	• Shunts • other	• Vehicle-pedestrian	• Assault • Moving vehicle • Machinery/equipment • Slips/trips • Fall from height • Other

Secondary accident sequences also included in the model are:

- Seatbelt not worn in at least one vehicle
- At least one vehicle greater than or equal to 20 years old (proxy for the likely presence and deployment of in-vehicle safety systems)
- One of more vehicles rollover
- One or more vehicles towing
- Two vehicle accident on hard shoulder, casualties in a single vehicle only