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AN ANALYSIS OF SPEED-RELATED UK ACCIDENTS USING A HUMAN FUNCTIONAL FAILURE METHODOLOGY

Claire Naing*, Alan Kirk*, Pierre Van Elslande, Sylvia Schick***, Julian Hill***
*Vehicle Safety Research Centre, Loughborough University, United Kingdom
**Dept of Accident Mechanisms Analysis, INRETS, Salon-de-Provence
***Medical and Biomechanical Accident Unit, Institute for Legal Medicine, Ludwig-Maximilians-Universität (LMU) Munich

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ABSTRACT

Accidents involving either illegal or inappropriate speeding play a part in a large proportion of accidents involving cars. The types of typical failure generating scenarios found in car accidents where illegal speeding or inappropriate speeding is contributory are compared using the detailed human functional failure methodology developed in the European TRACE project (TRaffic Accident Causation in Europe), funded by the European Commission.

Using on-scene cases from the UK 'On The Spot' database (funded by the UK Department for Transport and Highways Agency), a sample of cases where speed is contributory have been analysed. An overview of speeding cases from the 4,000 in-depth cases available in the dataset is also presented.

The results highlight not only the differences between inappropriate and illegal speeding cases, but also the differences in the functional failures experienced by both the 'at fault' and 'not at fault' road users in both types of speed-related accidents.

The results form a unique base of knowledge for future work on the human-related issues associated with speeding of both types, for all crash participants. Also considered is how new technologies can address speeding accidents.

INTRODUCTION

This paper describes part of an analysis undertaken by the Vehicle Safety Research Centre at Loughborough University, UK, in the EC funded TRACE project (TRaffic Accident Causation in Europe). The work investigated the main characteristics of accidents which involve driving task related factors.

In this study, driving task related factors are defined as being 'directly and causally contributing to the accident occurrence, very specific and detailed, are short-term lasting or dynamic in nature, and refer to the actual conditions of the components'. They can be present in all or part of an overall trip, but will only affect the road user when undertaking a certain part of the driving task. Examples of driving task related factors include speed, weather conditions and risk taking. They are thought to be effects of the wider trip related factors (e.g. alcohol impairment, road geometry, vehicle maintenance), which are in turn effects of background factors (i.e. pre-existing factors that are sometimes sociological such as education, income residence etc…).

From the main types of driving task related factors identified, the factor 'speeding' was chosen to be analysed using data from the UK Department for Transport and Highways Agency joint funded 'On The Spot' (OTS) project, firstly because of the large number of detailed cases available, but secondly because it is possible to identify two separate types of 'speeding' cases. Therefore, an interesting comparison of accidents involving these two types of speeding is possible. The two types of speeding identified are:

- Inappropriate speeding - where a road user in the accident travels too fast for the conditions (e.g. surface, visibility, layout, traffic);
- Illegal speeding – where a road user in the accident travels above the posted speed limit.

Keywords: Inappropriate speeding, Illegal speeding, Human Functional Failure, Causation factors

METHODOLOGY

Two types of analysis are described in this paper:

- A general statistical overview of accidents where either inappropriate speeding or illegal speeding is a contributory factor (frequency and characteristics);
- A detailed case-by-case analysis of a sample of 40 cases where either inappropriate speeding or illegal speeding is a contributory factor using the Human Functional Failure (HFF) methodology developed in the EC TRACE project (Van Elslande et al. 2007).

The On The Spot Database

The data source utilised is the UK Department for Transport and Highways Agency joint funded 'On

The Spot' (OTS) project. There are two investigation teams working on the OTS project in the UK, the Vehicle Safety Research Centre (VSRC) at Loughborough University, working in the Nottinghamshire region and the Transport Research Laboratory (TRL), working in the Berkshire region. The OTS teams attend and investigate, in total, 500 real-world collisions per year on a rolling shift pattern, covering all times and days of the week. The OTS teams investigate all collision types including all road users, all injury severities (from non-injury to fatal) and all road classifications. OTS cases include a wealth of information available to the analyst, as derived from physical examinations and interviews made on-scene followed by detailed analysis of findings and calculations made to reconstruct events and speeds. Both teams work in slightly different road network areas, which collectively are broadly representative of the UK. The study has been running since 2000 and has investigated over 4,000 real world collisions. The detailed methodology has been described elsewhere by Hill et al. (2001 and 2005).

The OTS database includes a number of advanced systems for coding accident causation. The method used in this study to identify speeding-related cases is the 'Contributory Factors 2005' system, which is the same coding system used by the Great Britain national accident data collection system since 2005. All cases in the OTS database have also been coded using this system, including those from before 2005. Each contributory factor can be coded at one of two levels of confidence, either a 'very likely' or a 'possible' cause.

Analysis has focussed on accidents involving at least one passenger car. Therefore, cases including each type of speeding causation factor are selected for analysis from the 3,663 cases involving at least one car currently in the OTS database.

Definitions and Sample Selection: Inappropriate Speeding

The contributory factor 'travelling too fast for conditions' is used to identify cases where 'inappropriate speeding' was causative. The on-scene accident investigators use their expert judgement of the evidence available to them at the scene to determine the likelihood that the road user was travelling too fast for the conditions they were confronted with. The type of 'conditions' included could be the road surface conditions (e.g. wet road, ice, diesel, defective surface), conditions reducing visibility (e.g. rain, fog, vehicle smoke, sun glare, road geometry, roadside objects, other vehicles), high winds and also traffic condition (e.g. traffic flow/speed).

Only cases where inappropriate speeding was recorded as being a very likely cause (rather than just possible) are included in the sample of cases. In order that there is no overlap with the sample of illegal speeding cases, cases are not included if road users were also recorded with illegal speeding (i.e. driving above the speed limit). Therefore, inappropriate speeding is defined as a road user who is not travelling above the speed limit set for the road, but the speed is inappropriate for the road conditions. In the OTS database, 564 cases involving cars are identified, which involved 885 vehicles, including 788 cars.

Definitions and Sample Selection: Illegal Speeding

Cases in the OTS database where 'exceeding speed limit' was recorded as a contributory factor are included in the sample of 'illegal speeding' cases. The on-scene accident investigator will use their expert judgement using the evidence available to them at the scene (e.g. skid marks and vehicle damage) to determine the likelihood that the road user was travelling above the posted speed limit of the road at/on approach to the accident scene and whether this was contributory.

In this sample, cases are included if inappropriate speeding was also a factor. The reason for this is that it is likely that in most cases where illegal speeding occurs, the speed will also be inappropriate for the conditions (i.e. this is denoted by the speed limit itself). As with inappropriate speeding, only cases where illegal speeding was recorded as a very likely cause (rather than just possible) are included in the sample of cases. In the OTS database, 307 cases involving cars are identified, which involved 487 vehicles, including 441 cars.

Statistical Analysis: Explanatory Variables

The explanatory variables listed in Table 1 are included in the general statistical overview to describe the typical characteristics of accidents involving either inappropriate speeding or illegal speeding.

Table 1.
Explanatory variables in statistical overview

Explanatory variables	Values	Analysis level
Intersection	Yes / No	Accident
Manoeuvre	Yes / No	Car drivers
Accident configuration	Single car Car v pedestrian Car v car Car v PTW Car v pedal cycle Car v large vehicle >3 cars only Others involving a car	Accident
Traffic density	Light / Moderate / Heavy / Congested	Accident
Area type	Rural / Urban	Accident
Road class	Motorway / Major / Minor	Accident
Carriageway type	Single / Dual	Accident
Speed limit	<10 / 20 / 30 / 40 / 50 / 60 / 70 mph	Accident
Horizontal geometry	Straight / Bend	Accident
Weather	Good / Poor	Accident
Road surface condition	Good / Poor	Accident
Lighting condition	Daylight / Darkness Dusk / Dawn	Accident
Vehicle type	Car / Van / Truck / Bus / Motorcycle / Pedal cycle / Pedestrian	All road users*
Impact type	Front / Side / Rear / Top / Bottom	Vehicles (no pedestrians)
Age	<25 / 25-44 / 45-64 / >65	All road users*
Gender	Male / Female	All road users*

*Including pedestrians

For both the contributory factors (inappropriate speeding and illegal speeding) and for each explanatory variable analysed, cross-tabulations have been produced to compare the distribution of all cases with only cases where inappropriate speeding or illegal speeding was/was not a causation factor. The results were displayed in tables, such as the example shown in Table 2. It was therefore possible to determine whether accidents involving either causation factor appear to be more likely to occur when a specific type of explanatory variable is present (e.g. more likely on rural roads than urban roads).

Table 2.
Example of results cross-tabulation

Area type	Inappropriate speeding a causation factor?		All cases
	Yes	No	
Rural	-	-	-
Urban	-	-	-
Unknown	-	-	-
All	-	-	-

To determine whether any differences found are significant enough to be a result of the speeding, and not due to chance, two-tailed chi-squared tests (using known-data only) were undertaken to test for statistical significance. A result was significant when $p \leq 0.05$ (i.e. the probability that the results were due to due chance were 5% or less).

In-depth Analysis of Cases Using the Human Functional Failure (HFF) Methodology

To analyse further the type of accidents where either inappropriate speeding or illegal speeding is a contributory factor, an in-depth analysis of a sample of cases involving either inappropriate speeding or illegal speeding has been undertaken using human factors methodologies developed in the EC TRACE project (Van Elslande et al. 2007).

The aim of the HFF methodology is to be able to clearly define the types of functional failures that humans experience in road collisions, using a sequential approach to the driving task which defines five main stages that the road user goes through when undertaking the driving task (perception, diagnosis, prognosis, decision-making and taking action). These failures can occur at any of the stages in the chain and it has been possible to classify five main types of failures that can occur during the driving task, as outlined in Figure 1. In addition to failures occurring at the five main stages of driving, there are also failures which are directly related to the overall capacities of the human which affect the whole functional chain. For example, the loss of psycho-physiological capacities (e.g. falling asleep, loss of consciousness), the alteration of the sensori-motor and cognitive capacities (e.g. alcohol/drug impaired) and the overstretching of the cognitive capacities (e.g. infrequent driving, age) (Van Elslande et al. 2007).

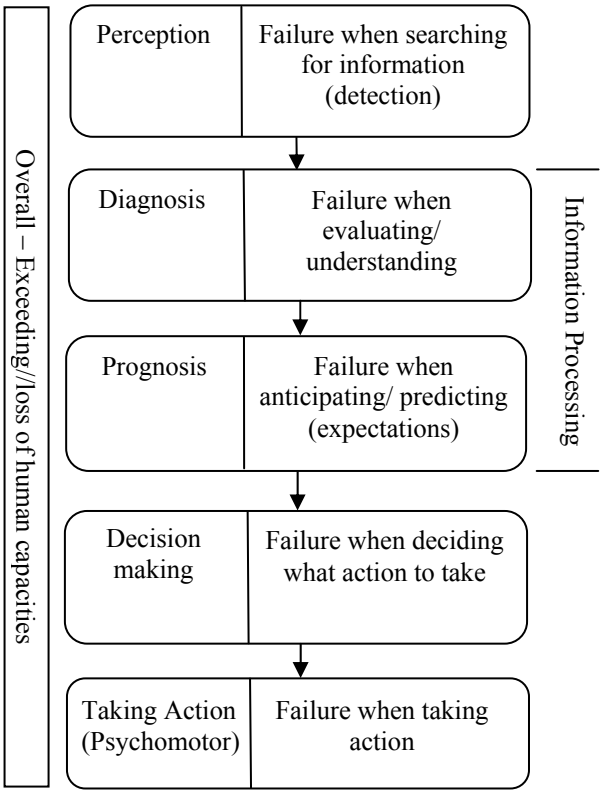


Figure 1: Description of Human Functional Failures (TRACE Deliverable 5.1)

In this methodology, a clear distinction is made between human failures and human factors. Human factors are defined as 'characteristics of the system which have weakened its capacity to function safely', whereas human failures are defined as 'the unwanted outcome of a confrontation of the driver with a task in which a difficulty was met'. Human failures are not defined as 'faults', as failures can also be found for 'not at fault' road users. The aim is to use the failures to identify the limits (physical and mental) of human capacity and therefore be able to understand better the types of countermeasures (i.e. safety systems) that would assist in overcoming these human limitations.

Grids of contributory factors and pre-accident driving situations were also developed as part of the TRACE study, to be used alongside the classification model of human functional failures to determine typical failure generating scenarios in samples of accidents. The grids were developed using current accident causation systems included in existing data collection systems from countries across Europe. See Naing et al (2007) for further details.

Closely related to the pre-accident driving situation is the 'conflict', which is also identified for each road user in each accident analysed. This is defined as the initial conflict that the road user was faced with prior to the accident (e.g. another road user or object in the road). It is possible for a road user to have no conflict (e.g. losing control of vehicle when falling asleep or unconscious, or being distracted by another task or person).

Also, distinctions are made between the road users who are 'primary active' in each accident, and those who are not. In the majority of accidents, the primary active road user is the one who is at the centre of the 'destabilisation of the process', and either intentionally or unintentionally initiate the point at which events start to go wrong (i.e. traditionally 'at fault'). The remaining road users in the accident (i.e. those 'not at fault') are described as 'other road users' in this paper.

To utilise the HFF methodology on OTS cases, detailed recoding of existing cases and in-depth analysis of each individual case was necessary to identify failure generating scenarios in each sample.

The selection criteria for these cases were as follows:

- Cases with injured casualties;
- Cases with an appropriate level of detail to undertake the analysis;
- Cases specifically from the local area so that the investigator's first hand experience of the cases could be utilised, if necessary.

The cases were sourced from the 564 OTS cases where inappropriate speeding was a cause and the 307 OTS cases where illegal speeding was a cause. From the sample of cases which met the above selection criteria, 20 inappropriate speeding and 20 illegal speeding cases were selected, taking care not to introduce any bias into the sample.

RESULTS

Statistical Analysis - Inappropriate Speeding

An overview of the typical characteristics of the 564 accidents where inappropriate speeding was a cause has been undertaken using the list of explanatory variables given in Table 1. Table 3 shows an example of the cross-tabulation results calculated, in this instance area type.

Table 3.
Area type when inappropriate speeding was/was not contributory

% of cases	Inappropriate speeding a causation factor?		All cases
	Yes	No	
Rural	64%	43%	46%
Urban	36%	57%	54%
All	100%	100%	100%

Table 3 shows that the proportion of accidents involving cars on rural roads is larger when inappropriate speeding is a causation factor compared with accidents when inappropriate speeding is not recorded as a causation factor. Statistical testing reveals that the differences in the results are statistically significant ($p \leq 0.05$).

Similar analysis has been undertaken for the remaining explanatory variables listed in Table 1. The results reveal that the following accident characteristics are statistically significantly ($p \leq 0.05$) more prevalent when inappropriate speeding is a cause compared with when it is not:

- Minor roads (UK classification <"A");
- Single carriageway roads;
- Not at an intersection;
- No manoeuvre was being undertaken (i.e. 'going ahead');
- Single car accident (no pedestrian or other vehicle involvement);
- Car drivers;
- Frontal impacts;
- 60mph (97km/h) roads (less prevalent on 30mph (48km/h) or 70mph (113km/h) roads);
- Bend in road;
- Poor weather conditions (e.g. raining, snowing, foggy, windy...);
- Poor road surface conditions (e.g. wet, icy, oil, diesel, defective...);
- Night conditions;
- Light density traffic conditions;
- Drivers under the age of 25 years;
- Male drivers.

Statistical Analysis - Illegal Speeding

The results of the statistical analysis of the 307 OTS accidents where illegal speeding was a cause reveal that the following accident characteristics are statistically significantly ($p \leq 0.05$) more prevalent when illegal speeding is a cause compared with when it is not:

- Minor roads (UK classification <"A");
- Single carriageway roads;
- Not at an intersection;
- No manoeuvre was being undertaken (i.e. 'going ahead');
- Single car accident (no pedestrian or other vehicle involvement);
- Car drivers;
- Frontal impacts;
- 30mph (48km/h) roads (less prevalent on 60 or 70mph (97 or 113km/h) roads);
- Bend in road;
- Night conditions;
- Light density traffic conditions;
- Drivers under the age of 25 years;
- Male drivers.

In-depth Analysis Using the Human Functional Failure (HFF) Methodology - Inappropriate Speeding

From the OTS database, 20 cases have been analysed from the 564 cases where inappropriate speeding was a contributory factor in the accident. There are 6 serious injury cases and 14 slight injury cases, according to the UK police classification system (UK, DfT 2004). There are 46 road users in total, of which 20 are primary active road users (one in each accident) and 26 are other road users. An overview of the vehicle involvement is given in Table 4.

Table 4.
Vehicle involvement - Inappropriate speeding

Vehicle involvement	Number of cases
Single car	4
Car v car	4
Car v PTW	2
Car v pedal cycle	1
Car v truck	1
Car v van	1
3 cars	3
Van v 2 cars	1
Van v 3 cars	2
4 cars	1

Pre-accident Driving Situations and Conflicts

Figure 2 shows the most frequent driving situations for the primary active road users in the 20 inappropriate speeding accidents.

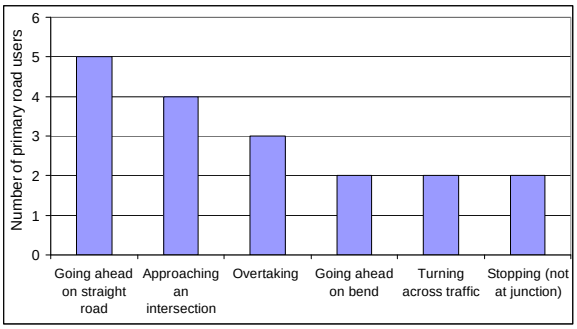


Figure 2: Most frequent driving situations for primary active road users - Inappropriate speeding

Figure 2 shows that the majority of primary active road users are going ahead and not undertaking a manoeuvre at the time of the accident. The most frequent 'conflict' comes from vehicles ahead, travelling in the same direction (either stationary or moving – 11 road users).

For the 26 other road users, the most frequent situation involves the road user being stationary (11 road users), while 7 road users are stopping or starting from stationary in a traffic queue. The most prevalent conflict comes from a vehicle following behind.

Human Functional Failures

Figure 3 shows the main types of human functional failures that occur in the 20 inappropriate speeding accidents analysed.

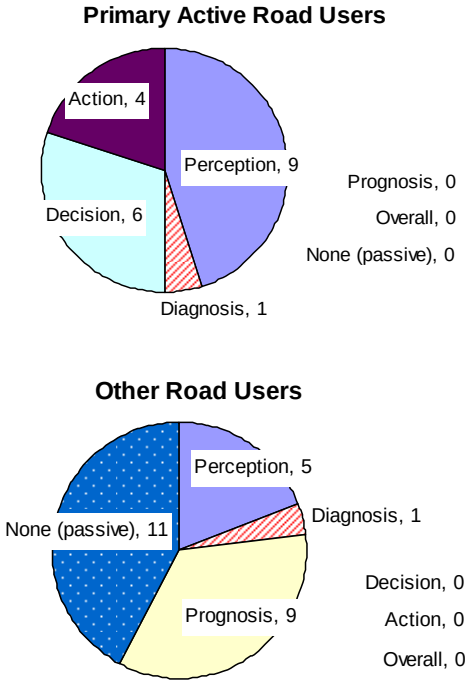


Figure 3: Human Functional Failures for road users in inappropriate speeding cases

Figure 3 shows that for the primary active road user in each accident, the most frequent type of human functional failure is related to a failure in perception (9 road users). When these cases are looked at in more detail, in the majority of cases (7 road users) the road user 'neglects the need to search for information' (i.e. does not search, therefore does not detect a danger).

Of the 26 other road users, 11 do not experience a human functional failure. In other words, they are passive in the accident (stationary). Of the remaining other road users, 8 experienced a prognosis failure - actively expecting another user to take regulating action.

Other Factors Which Lead to the Human Functional Failures Occurring

Table 5 outlines the most frequent (≥3 road users) other factors which are found to contribute to the human functional failures occurring (in addition to inappropriate speeding).

Table 5.
Most prevalent other factors contributing to the HFFs - Inappropriate speeding

Other factors which lead to the human functional failures	Number of road users	
	Primary active	Other
User state - In a hurry	14	3
User state - Right of way status		3
User inexperience - Driving	3	
User behaviour - Distraction within user	5	
User behaviour - Risk taking (vehicle positioning)	11	3
User behaviour – Risk taking ('eccentric' motives)	4	
Road surface condition	7	
Road geometry	4	
Traffic condition – Flow		4
Traffic condition – Speed	5	
Traffic condition - Other road user		14

In Table 5 it can be seen that, for the primary active road user, in addition to inappropriate speeding, other user behaviour-related factors are most frequent in the sample, in particular the road user being in a hurry and the road user 'risk taking – vehicle positioning' (driving too close to the vehicle in front).

For other road users involved in these accidents, it is the behaviour of the other road user(s) (usually the primary active road user) which most frequently contributes to their failure (absence or ambiguity of clues to their manoeuvre or atypical manoeuvre).

In-depth Analysis Using Human Functional Failure (HFF) Methodology - Illegal Speeding

From the OTS database, 20 cases have been analysed from the 307 cases where illegal speeding was a contributory factor in the accident using the selection criterion outlined previously. There is 1 fatal case, 5 serious injury cases and 14 slight injury cases. There are 34 road users in total, of which 20 are primary active (one in each accident), and 14 are other road users. An overview of the vehicle involvement in the sample of cases is given in Table 6.

Table 6.
Vehicle involvement - Illegal speeding

Vehicle involvement	Number of cases
Single car	10
Car v car	4
Car v pedestrian	3
Car v motorcycle	2
6 vehicles (4 cars v 2 vans)	1

Pre-accident Driving Situations and Conflicts

Figure 4 shows the most frequent driving situations for the primary active road users in the 20 illegal speeding accidents.

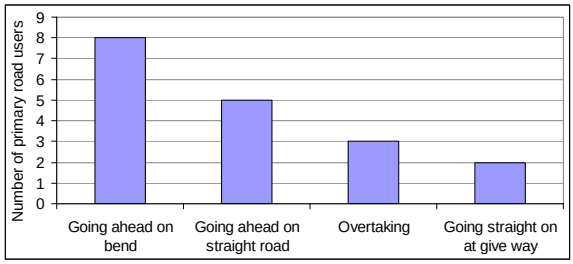


Figure 4: Most frequent driving situations for primary active road users - Illegal speeding

From Figure 4, it can be seen that the majority of the 20 primary active road users are going ahead at the time of the accident and are not at or approaching an intersection. When a manoeuvre is taking place, the road user is overtaking.

For half of the 20 primary active road users in the sample, there is no 'conflict', meaning the road user loses control for reasons which do not involve another road user or object on the road and, as a result, leave the carriageway before a collision. When there is a conflict, it comes from either ahead (oncoming or travelling in same direction) or from the side (from a side road or a pedestrian crossing the road).

For the 14 other road users, going ahead on a straight road is the most frequent pre-accident driving situation (7 road users). The most frequent conflict amongst the other road users involves another road user ahead (7 road users), most frequently travelling in the same direction. However, there are also instances of conflicts from behind (4 road users) and from the side (5 road users).

Human Functional Failures

Figure 5 shows the main types of human functional failures that occur in the 20 illegal speeding accidents analysed.

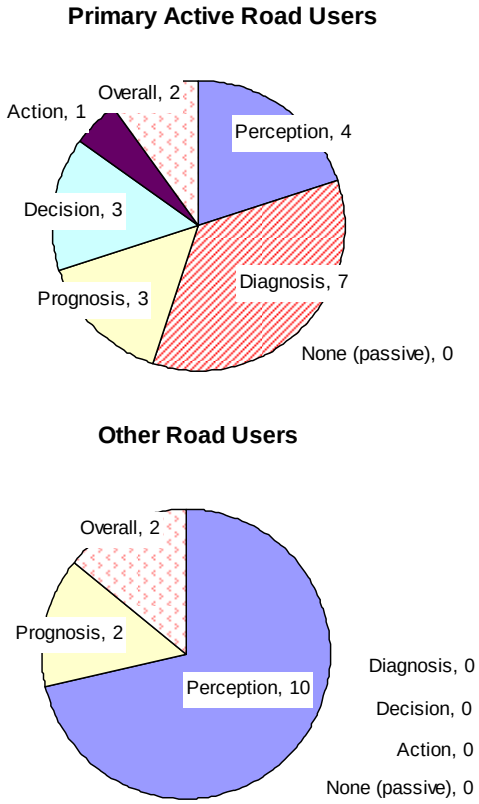


Figure 5: Human Functional Failures for road users in illegal speeding accidents

Figure 5 shows that for the primary active road user in each accident, the most frequent type of human functional failure is related to the diagnosis of the situation (7 road users). When these cases are looked at in more detail, in the majority of cases, the road user makes an erroneous evaluation of a passing road difficulty (6 road users) meaning the road user misjudges the layout (or conditions) of the road ahead (e.g. under-estimating the tightness of a bend or the surface friction on the road).

The most frequent type of human functional failure experienced by the 14 other road users in the sample is a failure in perception (10 road users), with half of these failures involving the road user neglecting the need to search for information.

Other Factors Which Lead to the Human Functional Failures Occurring

Table 7 outlines the most prevalent (≥3 road users) other factors which are found to contribute to the human functional failure occurring (in addition to illegal speeding).

Table 7.
Most prevalent other factors contributing to the HFFs - Illegal speeding

Other factors which lead to the human functional failures	Number of road users	
	Primary active	Other
User state – Substances taken (alcohol)	3	
User state – In a hurry	14	
User state – Right of way status		3
User behaviour – Distraction within user	8	
User behaviour – Risk taking (vehicle positioning)		4
User behaviour – Risk taking (‘eccentric’ motives)	6	
Road surface condition	3	
Road geometry	9	
Traffic condition – Other road user manoeuvre		13

From Table 7, it can be seen that, for the primary active road user, in addition to the speeding, in a hurry is the most frequent type of factor in the sample (14 road users). Road geometry is the most frequently occurring environmental factor in the sample for primary active road users.

For all but 1 of the 14 other road users in the sample, it is an atypical manoeuvre, or the ambiguity or lack of clues to a manoeuvre of other road user(s) (most likely the primary active) in the surrounding environment that contributes to the functional failure.

DISCUSSION

Inappropriate Speeding – Statistical Analysis

From the statistical overview of the 564 cases in the OTS database where inappropriate speeding is a contributory factor, a number of explanatory variables are found to be more likely to be present when inappropriate speeding (i.e. travelling too fast for the conditions) is a cause. A combination of these circumstances could increase the likelihood of an accident occurring when a road user is travelling at an inappropriate speed.

The results give an indication of the type of characteristics more likely to be involved in accidents where inappropriate speeding was contributory. These appear to be high speed limits (60mph, 97km/h) minor rural roads during low density traffic at night when the environmental conditions are poor, involving young, male car drivers going ahead on a bend. This suggests that

the conditions in question - which mean that the driver is driving at an 'inappropriate' speed - could either be the poor weather conditions, poor road conditions, the road geometry (bend) or the night (darkness) conditions. However this also suggests that it can be the posted speed limit itself that is inappropriate for the road conditions (i.e. too high), which leads to the driver travelling at an 'inappropriate' speed.

Inappropriate Speeding – HFF Analysis

The analysis of the sample of 20 cases using the Human Functional Failure methodology finds a number of different accident scenarios where inappropriate speeding is a cause. The 46 road users involved in these cases are split into 2 categories:

- Primary active road users (20)
- Other road users (26)

Primary active road users When bringing the information together to identify typical human functional failure generating scenarios for primary active road users in accidents where inappropriate speeding is a cause, the most frequent scenario involves a perception-related failure (9 road users), in particular a late detection of a vehicle slowing down ahead (in 7 cases). When looking in more depth at the 7 road users who experienced this type of scenario, in all instances, the road user does not detect the slowing/stationary vehicle(s) ahead until it is too late to avoid a collision. The reason given for this lack of detection is that the road user does not feel the need to search for information. In these scenarios, it is likely that this is either due to the stationary/slow vehicle being at an unexpected location (e.g. not at a junction, when a vehicle is turning into a side road or private driveway), or, in the scenarios where the accident does occur at or near a junction, the road user had not expected a traffic queue as far back from the junction as it was, so did not undertake a detection for stationary traffic. Therefore, in these scenarios, the inappropriate speeding is related to the traffic condition (i.e. the sudden change in the traffic speed), rather than the road geometry or surface conditions.

When looking at the other type of factors (in addition to inappropriate speeding) which contribute to these 'failure in perception' accidents, the road user being in a hurry, being positioned too close to the vehicle in front, the sudden slow speed of the traffic ahead and the visibility being impaired by the weather are contributory factors that feature in at least 2 of these 7 accidents. Therefore, this is building up a picture of one type of 'typical scenario' which involves inappropriate speeding as a cause, where the road user approaches unexpected stationary vehicle(s) but does not detect them early enough because it was not expected. In addition, their high (but not illegal) speed, coupled with other factors present, such as the road user being in a hurry to get to their destination, their close positioning to the vehicle in front, the poor visibility conditions and the slowing traffic itself, leads to a collision occurring.

Closely related to the scenarios of these 7 road users, 2 additional road users experience a scenario which involves them not seeing the slowing vehicle(s) ahead due to an internal/external distraction. Although the reason for the non-detection is different, the outcome is the same as with the 7 previously discussed road users.

Other failure generating scenarios which occur in the sample include decision-making failures (6 road users), in particular a scenario related to the intentional risk taking of the primary road user (5 road users). In the sample of cases, this includes a road user overtaking another road user on a curved road during wet conditions, a road user weaving through traffic on a busy dual carriageway road and also a road user overtaking another road user at an intersection just as the second road user is about to turn across traffic (turning right in UK) into a side road. In all of these cases, the road user is travelling under the road speed limit, but it is still too fast to be able to undertake any emergency avoidance when it is needed. Certain risk taking factors are found to be contributory in these accident scenarios, including the road user driving too close to other road users ('vehicle positioning'), and road users thrill-seeking/competing with other vehicles ('eccentric motives'). The road user being in a hurry and also user inexperience are causative in a number of these scenarios.

The final reoccurring type of scenario identified involves a failure when taking action (4 road users). In 2 cases, the road user loses control on a bend with road surface contaminants present, and in both cases it is the combination of this external disruption, the bend and the road user's inappropriate speed that leads to the loss of control. In the third case, the road user loses control on a pool of standing water (aquaplaned) on a straight dual carriageway road. Therefore, it is the sudden wet road surface, coupled with the road user's inappropriate speed that leads to the loss of control. In the final case, the road user is driving a vehicle adapted with hand controls for disabled drivers. The road user accidentally presses the incorrect hand control on approach to a traffic queue, which accelerates the vehicle. Due to the inappropriate (but not illegal) speed at which the road user is approaching the intersection, the road user is unable to regain control of their vehicle and collides with a

number of vehicles in the traffic queue ahead. It could be said that if the road user had been driving at a more appropriate (i.e. slower) speed for the approaching conditions ahead, this would have given the road user more time to regain control after this sudden unexpected 'disruption' in the driving task.

Other road users Bringing the information together to identify typical failure generating scenarios for other road users in inappropriate speeding accidents, the most frequent failure generating scenario is found to involve a prognosis failure (9 road users), in particular, actively expecting another road user behind to take regulating action when braking (8 road users). This scenario is linked to the human functional failure 'actively expecting another road user to take regulating action' (Van Elslande et al, 2007) and often involves contributory factors such as the behaviour of other road users and traffic flow. In this scenario, when a road user starts to brake, they actively expect the (primary active) road user behind to also be able to brake safely. However, due to the vehicle behind travelling too close and also too fast for the traffic condition, the vehicle behind is unable to brake in time to avoid a collision.

Using the HFF methodology, this is seen as not only a functional failure of the primary active road user in terms of their speed and positioning, but also of the non primary active road user, as their expectations of the road user behind and also the 'rules of the road' ('right of way status') mean that they are concentrating on avoiding the road user ahead, and expect the road user behind to avoid them.

This is not implying that road users should also be responsible for avoiding vehicles behind them. On many occasions, it might be beyond human capability to avoid impacting a vehicle ahead and a vehicle behind. However, this has highlighted an area where certain types of safety systems in a vehicle may be able to assist the road user to avoid collisions which a human alone may not find possible to do.

In addition to accident scenarios involving prognosis failures, there are also a number of accident scenarios involving perception failures (5 road users). This failure in detection is due to a number of reasons, including an obstruction to visibility, the road user focussing on only one part of the scene, the road user only undertaking a quick detection of the scene (e.g. due to being in a hurry) or the road user doesn't think there is a need to undertake any detection at all.

Inappropriate Speeding – Possible Solutions

From the analysis undertaken, possible current and future solutions for helping to reduce the type of accidents where inappropriate speeding is found to be a contributory factor could include the following:

- Educating less experienced drivers about the dangers of inappropriate speeding as well as illegal speeding;
- Current in-vehicle technologies such as ABS, brake assist and ESC could help road users who find themselves travelling too fast for the conditions to overcome difficulties they might encounter and avoid possible collisions;
- Advance warnings of the dangers ahead (e.g. of bends in road) at higher risk locations which can also be seen at night will assist road users to travel at a more appropriately safe speed on approach to these high risk locations;
- Signs giving advisory speed limits on approach to high risk locations, although such systems cannot take weather and road surface conditions into account unless equipped with environmental sensors;
- Future solutions such as in-vehicle devices which provide road users with advance notification of the road geometry/surface conditions and hazards ahead and possibly also assist by automatically reducing the vehicle speed on approach to these high risk locations. Full collision avoidance technologies could also be integrated into such systems.
- Further improved definitions of speed limits, considering the road conditions, geometry, traffic conditions etc, which will provide better guidance to road users on the driving limits of the road.

Before implementation, it would be necessary to evaluate some of these potential solutions for their effect on the mental workload of the driver, to determine whether overload could be possible. Field Operation Tests and simulator trials could inform such work. It is also important to more fully understand any risk compensation effects. That is to say any possibilities that driver perceptions of increased safety due to the presence of in-vehicle technologies, such as brake assist, may encourage inappropriate speeding.

Changing attitudes to inappropriate speeding can be expected to have a "knock-on" effect whereby drivers are also less likely to speed illegally.

As the definition of inappropriate speeding is 'travelling too fast for the conditions', conditions which can change, it is clear that the most effective advance warnings systems will rely on the

development of environmental sensors integrated into the highway infrastructure and vehicle to infrastructure communication.

Illegal Speeding – Statistical Analysis

From the statistical overview of the 307 cases in the OTS database where illegal speeding is a contributory factor, a number of explanatory variables are found to be more likely to be present when illegal speeding (i.e. travelling above the road speed limit) is a cause.

These results give a good indication of these characteristics, which appears to be low speed (30mph, 48km/h) minor roads during low density traffic at night (not at an intersection), with a young male car driver going ahead on a bend.

Illegal Speeding – HFF Analysis

The analysis of the sample of 20 cases using the HFF methodology found a number of different accident scenarios where illegal speeding is a causation factor. The 34 road users involved in these cases are split into 2 categories:

- Primary active road users (20)
- Other road users (14)

Primary active road users The most frequent type of failure generating scenario for primary road users in illegal speeding accidents has been found to involve a diagnosis failure (7 road users), in particular an incorrect evaluation of an approaching road difficulty (6 road users). In this scenario, the primary road user is negotiating a bend and it is a single vehicle accident (i.e. no impact with other road user on road). They either have knowledge of the bend ahead and therefore are more complacent than if they were negotiating an unfamiliar bend, or think they will be able to negotiate it faster, and therefore misdiagnose the conditions on this bend on this particular occasion. Or, they are focusing more on the thrill-seeking aspects of driving an unknown bend rather than evaluating the road conditions. In this scenario, it is found that the road user being in a hurry, the eccentric risk-taking motives of the road user and the road geometry (i.e. the bend) are also often contributory to the functional failure occurring (in addition to the illegal speed).

In addition to diagnosis-related failure generating scenarios, perception-related scenarios are also identified in the sample of primary active road users (4 road users). The types of perception failure in each scenario vary, and are shown below:

- A primary road user undertakes a hasty search for information whilst attempting to overtake another road user ahead who is attempting to turn across traffic (turning right in the UK) from a main road into a side road (the road user fails to detect that the vehicle was indicating);
- In two instances, the road user detects a pedestrian crossing the road/slow vehicle ahead too late due to their belief that there is no need to search for information (i.e. encountering a conflict that was not usual at the road location);
- A primary road user who does not detect a vehicle approaching from the side when they are about to cross because they are distracted.

In a hurry and "distraction within user" (i.e. lost in thought), and road surface condition are additional factors to illegal speeding.

Other road users The majority of failure generating scenarios identified for other road users involved in the illegal speeding cases involve a perception failure (10 road users), more specifically the road user neglecting the need to search for information (5 road users). In these cases, the road user does not detect until too late a road user ahead (either another vehicle or a pedestrian). The reason for the lack of detection is either because they do not expect another road user (a possible conflict) to appear at this location or do not expect to encounter slow vehicles ahead at this location, as it is not a crossing or intersection. The main factors which contribute to this failure in this type of scenario include their rigid attachment to the right of way status, their close positioning to another vehicle ahead and the atypical manoeuvre of another road user (i.e. the primary road user).

Scenarios involving prognosis failures are also indentified in the sample (2 road users). One involves the road user failing to expect another road user in an opposing lane to carry out an overtaking manoeuvre in heavy traffic. The other, the road user actively expects a road user behind to also take regulating action when they start to slow down because of slowing traffic ahead. In both scenarios, it was the atypical manoeuvre of another road user that was the main contributory factor to the failures.

There are also 2 cases in the sample which involve a scenario with the 'overall' failure of 'exceeding sensorimotor/cognitive capacities'. In both cases, the main contributory factor for the road user is alcohol impairment and the road user was a pedestrian crossing the road. In the first scenario, the road user is half way across the road just beyond a bend when the primary road user approaches the bend at speed, entering the opposing carriageway where the pedestrian is located. Because of the alcohol impairment, the road user is unable to react at all and a collision occurs. It was decided that due to the alcohol impairment of the pedestrian, that even without the poor visibility due

to the bend, the pedestrian would have been too alcohol impaired to react. In the second scenario, the alcohol impaired pedestrian is trying to cross the road when a collision occurs with the primary road user's vehicle, which is speeding. In this case it was concluded that the pedestrian may have been able to avoid the collision if there had been no alcohol impairment, so the pedestrian's main failure was directly related to the alcohol impairment.

Illegal Speeding – Possible Solutions

From the analysis undertaken, possible current and future solutions for helping to reduce the type of accidents where illegal speeding is found to be a contributory factor could include the following:

- On lower speed limit roads, in particular at night, stricter enforcement of the speed limits;
- Better education of higher risk road users (i.e. those found most at risk of speeding in this study), of the dangers of driving above the speed limit, not only for others, but for themselves;
- Speed limiters in vehicles of the highest risk road users (e.g. young/new drivers; convicted speeders), the limiters working in particular on higher risk roads, especially at night. This would be a focused application of a mandatory Intelligent Speed Adaption system (ISA);
- Educating road users of the increased risk of making errors when driving at high speeds (i.e. not only less time to evaluate their surroundings, but also to detect potential dangers and make correct decisions);
- Advance warning devices (and collision avoidance systems) to help road users avoid a collision with a speeding motorist.
- The introduction of traffic calming procedures, in particular those which are more subtle to the road user, will help to promote a natural reduction in driving speeds.

Comparison between Inappropriate Speeding and Illegal Speeding Cases

As opposed to inappropriate speeding, poor weather and surface conditions are not more likely to be found in accidents where illegal speeding is a cause, which implies that the increased risk of travelling above the speed limit as opposed to just travelling too fast for the conditions, over-rides the risk of the presence of poor weather and conditions.

Whereas rural roads lead to a greater likelihood of an accident occurring when inappropriate speeding occurs, neither rural nor urban roads are more likely to lead to collisions where illegal speeding is causative. However, as with inappropriate speeding accidents, minor roads still have the greater accident likelihood when illegal speeding occurs. Another difference observed between the inappropriate speeding accidents and the illegal speeding accidents is that roads with low speed limits (30mph or 48km/h) are more likely in illegal speeding accidents, whereas roads with high speed limits (60mph or 97km/h) are more likely in inappropriate speeding cases.

When comparing the results of the Human Functional Failure analysis, the illegal speeding accidents most often involve a scenario where the primary road user misdiagnoses the road geometry ahead, either due to over-familiarity or thrill seeking. Whereas in the inappropriate speeding accidents, primary road users are more frequently travelling too fast (and too close) for the conditions and often fail to detect a conflict in time to react.

When comparing the frequent failure generating scenario between both speeding samples for the non primary road users, the first main difference observed is the high number of non primary active road users who do not experience a failure generating scenario in the sample of inappropriate speeding cases compared to the illegal speeding cases, where there are no passive road users. This is mainly due to the stationary road users in the inappropriate speeding cases, who are impacted from behind by the primary road user who is considered to be driving too fast for the conditions (i.e. the erratic traffic flow). Also, the other main difference observed is that for the illegal speeding cases, a scenario involving a perception failure is most frequent, whereas a scenario with a prognosis failure is most frequent in the inappropriate speeding sample. However, both of these scenarios do involve the road user's expectations. In the perception-related failure, the road user fails to detect because they do not undertake any search at all, because they feel there is no need for it at that location (i.e. they're not expecting to encounter a conflict). In the prognosis-related failure, the road user has detected a possible conflict (i.e. another road user in their path), but because they have right of way, they expect the other road user to undertake the avoiding action.

It is interesting to note that in the inappropriate speeding cases, the most frequent scenario for the primary active road user involves a perception failure and for the non primary active road user, the most frequent scenario involves a failure in information processing, whereas in the sample of illegal speeding cases, it is vice-versa.

Future Work

Using the HFF methodology on a larger sample of cases could inform the development and implementation of Intelligent Speed Adaption

(ISA). Whilst the current ISA systems themselves are only concerned with illegal speeding, adaptations utilising advanced warning systems to deal with inappropriate speeding could be of benefit. It would also be interesting to consider that an ISA system may incorrectly reassure a driver that their speed is appropriate, because they know the system is fitted and it hasn't activated, when in fact they are travelling too fast for the conditions. For example, whilst travelling on a rural road with a posted speed limit of 60 mph (97 km/h) but with sharp bends.

CONCLUSIONS

This study finds that the driving task-related factors inappropriate speeding and illegal speeding significantly contribute to accidents occurring with the accident likelihood increasing when specific conditions (e.g. road type, area, road user type…) are present.

The statistical analysis reveals distinct differences in accident characteristics between the two types of speeding. A positive link with high speed limit (60mph, 97km/h) roads, rural roads, poor surface conditions and weather conditions is found when inappropriate speeding is a cause, which is not found when illegal speeding is a cause. However, accidents on low speed (30mph, 48km/h) roads are found to be prevalent when illegal speeding is a cause.

This study also shows that the presence of these two speed-related factors leads to failures at various stages of the driving process, from the initial perception (detection) stage, during information processing (diagnosis/prognosis stage), through to the decision making stage or when undertaking the resulting action. However, as with the statistical analysis, differences in the prevalence of the failures between the two types of speeding are found when undertaking the Human Functional Failure analysis.

For primary active road users, scenarios with a perception-related failure are most frequent in the sample of inappropriate speeding cases and scenarios with an information processing diagnosis-related failure are most frequent in the sample of illegal speeding cases. Whereas for other ('not at fault') road users involved in each type of speed-related accident, the opposite was found to be the case (i.e. information processing prognosis failures in inappropriate speeding cases and perception failures in illegal speeding cases).

These findings imply that different solutions to prevent accidents involving these two types of speeding-related factors are needed. Also, this outlines the importance of ensuring that in future analysis, these two types of speeding-related factors are considered separately, as it has been shown from this work that the failures behind inappropriate speeding and illegal speeding accidents and their characteristics are often not the same.

Road users could benefit from current and future technologies to help avoid travelling at inappropriate speeds, including better advance warning/advisory signage, driver education, and in-vehicle technologies such as advance warning systems. It will be important for future research to monitor the proliferation of in-vehicle systems such as brake assist, ESC and collision avoidance as they may prove able to prevent accidents at speeds currently judged to be inappropriate. However, accidents may not be prevented if drivers continue to drive at inappropriate speeds due to any increased perceptions of safety resulting from these new technologies. Risk compensation as well as any distraction or mental loading aspects of new technologies should therefore be evaluated. It is, furthermore, likely that fully effective warning systems will require a step change in infrastructure (highway sensors and communication systems).

Road users would also benefit from technologies to help avoid travelling at illegal speeds (such as ISA), or being involved in a conflict with a road user who is travelling above the speed limit. In addition stricter enforcement of speed limits at high risk locations (as outlined in this study), improved education to new drivers, speed limiters in vehicles, and advance warning mechanisms to help road users to avoid collisions with speeding motorists would be of benefit.

It has been possible, using the TRACE HFF methodology, to identify a number of typical scenarios that road users are faced with when either travelling too fast for the conditions or above the road speed limit and the failures they encounter. While the current sample is small, and results should therefore be interpreted with appropriate caution, this study has shown the methodology to be a useful tool in accident causation analysis by highlighting the differences between the characteristics of accidents where inappropriate speeding is a cause and accidents where illegal speeding is a cause.

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