Causation patterns and data collection blind spots for fatal intersection accidents in Norway

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Abstract - Norwegian fatal intersection accidents from the years 2005-2007 were analysed to identify any causation patterns among their underlying contributing factors, and also to evaluate whether the data collection and documentation procedures used by the Norwegian in-depth investigation teams produces the information necessary to perform causation pattern analysis. A total of 28 fatal accidents were analysed. Details on crash contributing factors for each driver in each crash were first coded using the Driving Reliability and Error Analysis Method (DREAM), and then aggregated based on whether the driver was going straight or turning. Analysis results indicate that turning drivers to a large extent are faced with perception difficulties and unexpected behaviour from the primary conflict vehicle, while at the same time trying to negotiate a demanding traffic situation. Drivers going straight on the other hand have less perception difficulties. Instead, their main problem is that they largely expect turning drivers to yield. When this assumption is violated, they are either slow to react or do not react at all. Contributing factors often pointed to in literature, e.g. high speed, drugs and/or alcohol and inadequate driver training, played a role in 12 of 28 accidents. While this confirms their prevalence, it also indicates that most drivers end up in these situations due to combinations of less auspicious contributing factors.

In terms of data collection and documentation, information on blunt end factors (those more distant in time/space, yet important for the development of events) was more limited than information on sharp end factors (those close in time/space to the crash). A possible explanation is that analysts may view some blunt end factors as event circumstances rather than contributing factors in themselves, and therefore do not report them. There was also an asymmetry in terms of reported obstructions to view due to signposts and vegetation. While frequently reported as contributing for turning drivers, they were rarely reported as contributing for their counterparts in the same accidents. This probably reflects an involuntary focus of the analyst on identifying contributing factors for the driver legally held liable, while less attention is paid to the driver judged not at fault. Since who to blame often is irrelevant from a countermeasure development point of view, this underlying investigator mindset needs addressing to avoid future bias in crash investigation reports.

INTRODUCTION

All fatal crashes in Norway are analyzed in depth by multidisciplinary crash investigation teams organized by the Norwegian Public Roads Administration (NPRA). The teams collect data from on-the-scene and/or on-the-site investigations (including the data from the police investigations) and produce a report of each crash. For the purpose of this study, reports and related data from all fatal crashes in Norway in the period 2005 – 2007 was obtained.

From the total of 559 fatal crashes occurring in these three years, all intersection crashes (28 in total) were retrieved and analysed. The analysis of these 28 crashes was carried out with a dual purpose. The first aim was to identify any causation patterns among their underlying contributing factors. The second aim was to evaluate whether the data collection and documentation procedures used by the Norwegian in-depth investigation teams results in the information necessary to perform causation pattern analysis.

The data available for each crash varies in scope; for some crashes only the final report was available (usually a 5-10 page document), whereas for other crashes various protocols filled out by the investigators while investigating were also available. As will be further discussed below, the extra information available from these protocols sometimes (but not always) is very valuable, not in the sense that information unavailable in the main report is brought to light, but in the sense that it can be used to eliminate theoretically possible contributing factors which are not addressed in the main report.

All 28 crashes involved two vehicles except one, which involved three. Somewhat surprisingly, only 3 of the crashes are car-to-car crashes. In the other 25 there is a large mass difference between the involved vehicles, as at least one of the vehicles is either a light vehicle (e.g. a motorcycle) or a heavy vehicle (e.g. a truck). When conjuncted with the fact that intersection accidents is one of the most common car-to-car accident types, one immediate reflection is that the forces generated in intersection crashes are low enough to leave car drivers alive.

An overview of the number and type of vehicles is given in Table 1. In that table, there is also a listing of to which extent each vehicle type was turning or going straight through the intersection.

Table 1: Vehicle types involved in the 28 fatal intersection crashes

Vehicle size		**All**	**Turning**	**Going Straight**
Small	Motorcycle	17	0	17
Medium	Passenger car or similar	30	26	4
Large	Truck (with or without trailer)	10	2	8
Total		**57**	**28**	**29**

In Table 1 it is noticeable that all smaller vehicles, e.g. the motorcycles, and most of the large vehicles (8 of 10) were going straight through the intersection, while most medium sized vehicles were on a turning path. Turning drivers of medium size vehicles thus obviously have problems with motorcycles going straight. The reasons for this will be further discussed in the analysis.

METHODOLOGY

Details on crash contributing factors for each driver in each in-depth case file were first coded using the Driving Reliability and Error Analysis Method (DREAM 3.0) [1]. All coding was performed by the first author of this paper. An underlying assumption of the coding was that each driver has his/her own reasons for failing to adapt to the driving situation. Causation information was therefore coded separately for each involved driver; resulting in one schema of contributing factors, or causation chart, per involved driver.

A strength of the DREAM method is that it allows for aggregation of the individual causation charts produced in the first step of the analysis, something which provides a foundation for analysis of patterns among crash contributing factors. In this analysis, the 57 individual causation charts from the 28 crashes were aggregated based on whether the driver was about to turn or was going straight trough the intersection. The reason for this grouping was that it was hypothesised that crash contributing factors may be different for turning drivers and drivers going straight. If this holds, it would constitute valuable input for countermeasure development.

The DREAM methodology

DREAM is an adaptation to the traffic safety domain of the Cognitive Reliability and Error Analysis Method (CREAM) [2]. DREAM was developed in the FICA project at Chalmers University of Technology [3] to help provide condensed overviews of crash contributing factors on a case by case basis, as well as to facilitate aggregation of case causation data into aggregated causation patterns, or causation charts. It was also used in the project SafetyNet [4-5]. For a discussion of how to create and interpret aggregated causation charts using DREAM, see Sandin [6-8].

DREAM contains a classification scheme with a large number of factors that can be used to code crash causation information. The scheme distinguishes between observable effects due to loss of control (called phenotypes) and the contributing factors which bring those effects about (called genotypes). Phenotypes are expressed in the general dimensions of time, space and energy, and consist of the following:

Table 2: Phenotypes in DREAM 3.0

Phenotypes	*Specific phenotypes*
Timing	Too early action; Too late action; No action
Speed	Surplus speed; Insufficient speed
Distance	Too short distance
Direction	Wrong direction
Force	Insufficient force; Surplus force
Object	Adjacent object

The genotypes include contributing factors both at the sharp end (close in time/space to the crash) as well as at the blunt end (more distant in time/space, yet important for the development of events). In DREAM version 3.0 which was used here, genotypes are divided into 16 main categories, each belonging to one of four main groups: Driver, Vehicle and Traffic environment and Organisation (see Table 3).

Table 3: Genotypes in DREAM 3.0

GENOTYPES (B-Q)

HUMAN (B-F)

Driver

B: Observation
Missed observation (B1)
Late observation (B2)
False observation (B3)

C: Interpretation
Misjudgement of time gaps (C1)
Misjudgement of situation (C2)

D: Planning
Priority error (D1)

E: Temporary Personal Factors
Fear (E1)
Inattention (E2)
Fatigue (E3)
Under the influence of substances (E4)
Excitement seeking (E5)
Sudden functional impairment (E6)
Psychological stress (E7)

F: Permanent Personal Factors
Permanent functional impairment (F1)
Expectance of certain behaviours (F2)
Expectance of stable road environment (F3)
Habitually stretching rules and recommendations (F4)
Overestimation of skills (F5)
Insufficient skills/knowledge (F6)

TECHNOLOGY (G-M)

Vehicle (G-I)

G: Temporary HMI problems
Temporary illumination problems (G1)
Temporary sound problems (G2)
Temporary sight obstructions (G3)
Temporary access limitations (G4)
Incorrect ITS-information (G5)

H: Permanent HMI problems
Permanent illumination problems (H1)
Permanent sound problems (H2)
Permanent sight obstruction (H3)

I: Vehicle equipment failure
Equipment failure (I1)

Traffic environment (J-M)

J: Weather conditions
Reduced visibility (J1)
Strong side winds (J2)

K: Obstruction of view due to object
Temporary obstruction of view (K1)
Permanent obstruction of view (K2)

L: State of road
Insufficient guidance (L1)
Reduced friction (L2)
Road surface degradation (L3)
Object on road (L4)
Inadequate road geometry (L5)

M: Communication
Inadequate transmission from other road users (M1)
Inadequate transmission from road environment (M2)

ORGANISATION (N-Q)

Organisation

N: Organisation
Time pressure (N1)
Irregular working hours (N2)
Heavy physical activity before drive (N3)
Inadequate training (N4)

O: Maintenance
Inadequate vehicle maintenance (O1)
Inadequate road maintenance (O2)

P: Vehicle design
Inadequate design of driver environment (P1)
Inadequate design of communication devices (P2)
Inadequate construction of vehicle parts and/or structures (P3)
Unpredictable system characteristics (P4)

Q: Road design
Inadequate information design (Q1)
Inadequate road design (Q2)

DREAM also includes a link system which specifies possible interactions between contributing factors. When case information on causation is coded into a chart, the link system ensures that the description of how one contributing factor leads to another is not arbitrary. The link system basically limits the range of possible factor interactions to those currently supported by scientific knowledge, thus restricting and guiding the coding of causation information. The inherent structure in the link system also makes it possible to aggregate causation information from multiple case studies in a structured, and principally semi-automated fashion, reducing the number of subjective judgements necessary to identify a pattern of contributing factors for a group of crashes. Naturally, the link system can be updated as new knowledge is gained.

RESULTS AND DISCUSSION

In the figures below, the total number of times a contributing factor occurs is represented by the number in brackets within each box. Note that DREAM allows attribution of, for example, multiple planning failures or multiple missed observations to a single driver. Some contributing factors can therefore exist more than once per chart, which means their frequency of occurrence can exceed the number of aggregated charts (i.e. the number of drivers).

For visual guidance when looking for patterns, the factor frequency numbers are indicated through box border thickness as well. For links between boxes, the number of times a link occurs is not written out, but indirectly represented through the thickness of the connecting arrows.

Note also that for simplified reading, all detailed information which motivates the choice of each phenotype and genotype in the individual charts has been removed from the aggregations below. However, in the analysis, that information is of course used. For interested readers, the full analysis for each accident can be found in the final project report where the analysis was carried out [9].

Turning drivers

The aggregated causation charts for all turning drivers are shown in Figure 2. As can be seen, the most prominent causation patterns for the turning drivers seem to be *Misjudgement of situation* due to *Missed observation.* This in turn is brought about by various obstructions to view (mostly related to infrastructure elements), as well as by *Driving related distracters outside vehicle* (linked through *Inattention*) and *Expectance of certain behaviours.*

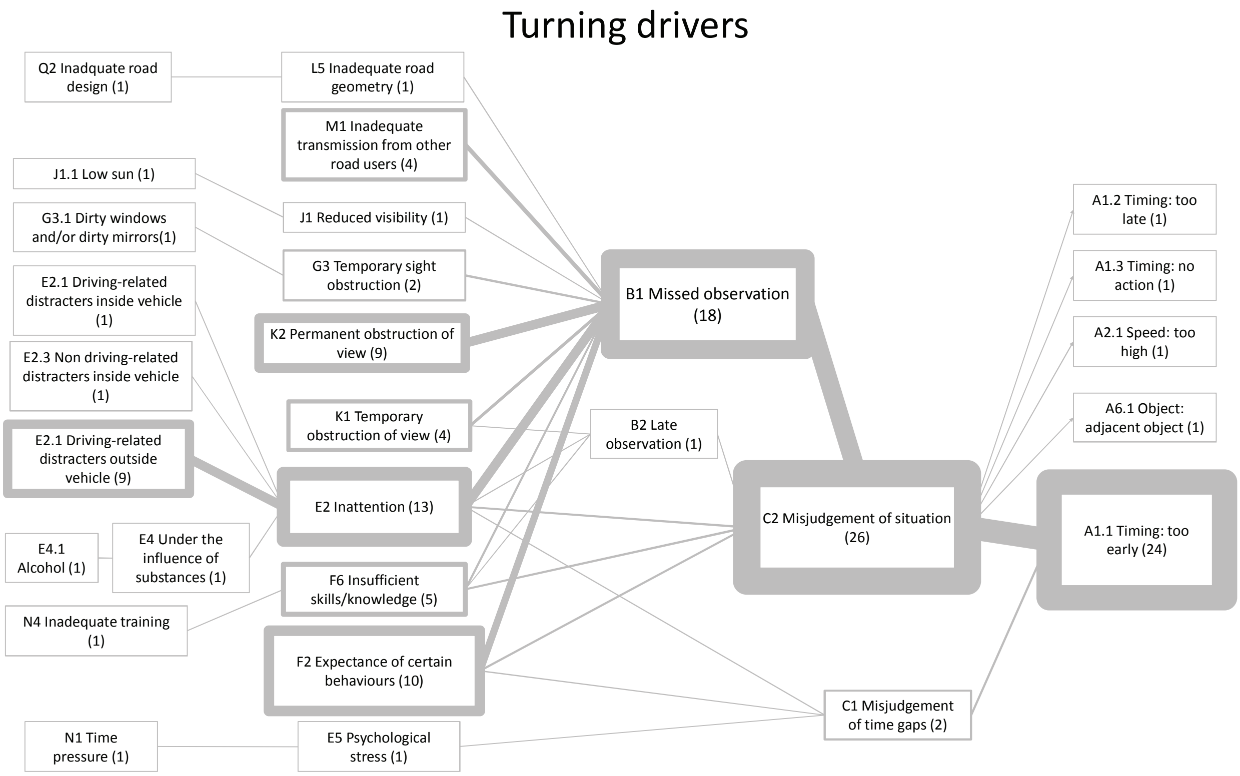

Figure 1: Aggregated causation chart for all 28 drivers who were performing a turning manoeuvre prior to the crash

The high frequency of *Missed observation* as a contributing factor possibly reflects the fact that the task of identifying and responding to a conflict vehicle in an intersection usually rests with the turning driver, since the driver going straight more often has the right of way. Because of that responsibility, sight limitations are more debilitating for turning driver performance, and hence more likely to be reported as a contributing factor.

The large portion of *Expectance of certain behaviours* here mainly refer to turning drivers not adjusting their regular intersection scanning pattern to accommodate vehicles travelling at speeds well above the speed limit. The fact that these speeding vehicles invariably are motorcycles could be taken to indicate that car drivers do not speed in the same way motorcyclists do. However, a perhaps more plausible account for this has to do with the human visual attention selection processes.

As discussed at length in recent research on attention, there are two main ways in which driver attention can be captured. One is the way in which a stimuli, such as another vehicle, can be said to stand out in relation to its surroundings, i.e. its *saliency*. When attention is directed towards an object because it somehow stands out, this is referred to as *bottom-up* driven attention capture. For example, the colour red if often used on warning signs and lights, because it normally stands out in relation to the surroundings. The other way a stimuli can capture attention is through *top-down* selection, meaning that a driver is proactively selecting, or being partial to, certain stimuli, not because they stand out from a sensual point of view (though they may of course do so), but because they provide important cues for how the traffic situation will develop[1]. For example, if a driver is about to turn left in an intersection, the turn indicator of a vehicle coming from the opposite direction may be less salient than its headlights. The turning driver will nevertheless focus on that turn indicator, to find out whether the other vehicle is turning or going straight (in which case the driver must yield right of way).

When a turning driver expects any other vehicles to keep to the speed limit, while another vehicle in fact is speeding, this in practice can be said to disable the top-down selection process. The "threat horizon" which the turning driver thinks is relevant and therefore actively scans is in effect too small. This means that the only way for the conflict vehicle to capture the turning drivers' attention is through bottom-up attention selection, i.e. by standing out in relation to its surroundings. Since a motorcycle is much less salient than a car (smaller, less intense headlights) it will not stand out in relation to its surroundings the same way a car does. In the crashes analysed here, it seems like the motorcycles do not make it above the saliency threshold for bottom-up driven detection before it is too late. Several turning drivers describe their experience of the speeding motorcycles as "suddenly it was just there". While this cannot be true from a physics point of view, it matches quite well with what the theory of attention selection predicts.

In the above overview of turning drivers it is noticeable that the contributing factor *Under the influence of substances* is almost entirely absent. Only in one instance has *Alcohol* contributed to the turning driver's misjudgement of the situation. In terms of other factors often cited as prominent contributors to fatal accidents, speeding (*Speed: too high*) only occurs once, driver fatigue is entirely absent, and *Inadequate training* occurs only once. This could mean that either the accident investigators have failed to identify instances where these factors have contributed, despite their elsewhere noted association with fatal crashes, or that turning drivers are not the ones for whom these factors contribute. This will be further discussed below.

Other noticeable "missing" factors are *Time pressure* and *Psychological stress*, as well as indications of secondary task engagement, e.g. *Non-driving related distracters inside vehicle* occurs only in one instance. Again, this could either mean that the accident investigators are missing something, or that the turning drivers are not subject to these contributing factors. On the other hand, the frequency of *Driving related distracters outside vehicle* indicates that there is often some other traffic element involved in the traffic situation which the driver has to attend to, i.e. the driving task for the turning driver is often relatively complex.

Drivers going straight

The aggregated causation patterns for drivers going straight are shown in Figure 2. Here, drugs and alcohol seem to be more prominent contributing factors than they were for turning drivers. There are 5 instances where substance abuse has contributed to the accident (mainly *Alcohol*). In terms of the other "high profile" factors, speeding occurs in 8 instances (*Speed: too high*) and *Inadequate training* in 3 instances, while driver fatigue is again absent.

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[1] Note that this does not necessarily involve effort or conscious awareness. Routine driving, such as lead vehicle following, is often handled effortlessly, even if it involves some proactive and context-dependent attention selection, due to "implicit" expectations on how the situation will develop.

In other words, for drivers going straight, the accident investigations show a larger display of factors commonly referred to as typical contributors to fatal crashes. In terms of numbers, a closer reading reveals that some of the factors overlap for particular accidents (i.e. the same driver was both speeding and intoxicated in some accidents). All in all, high speed, drugs and/or alcohol and inadequate driver training played a role in 12 of 28 intersection accidents, and the affected driver in 10 of those 12 cases is the driver going straight.

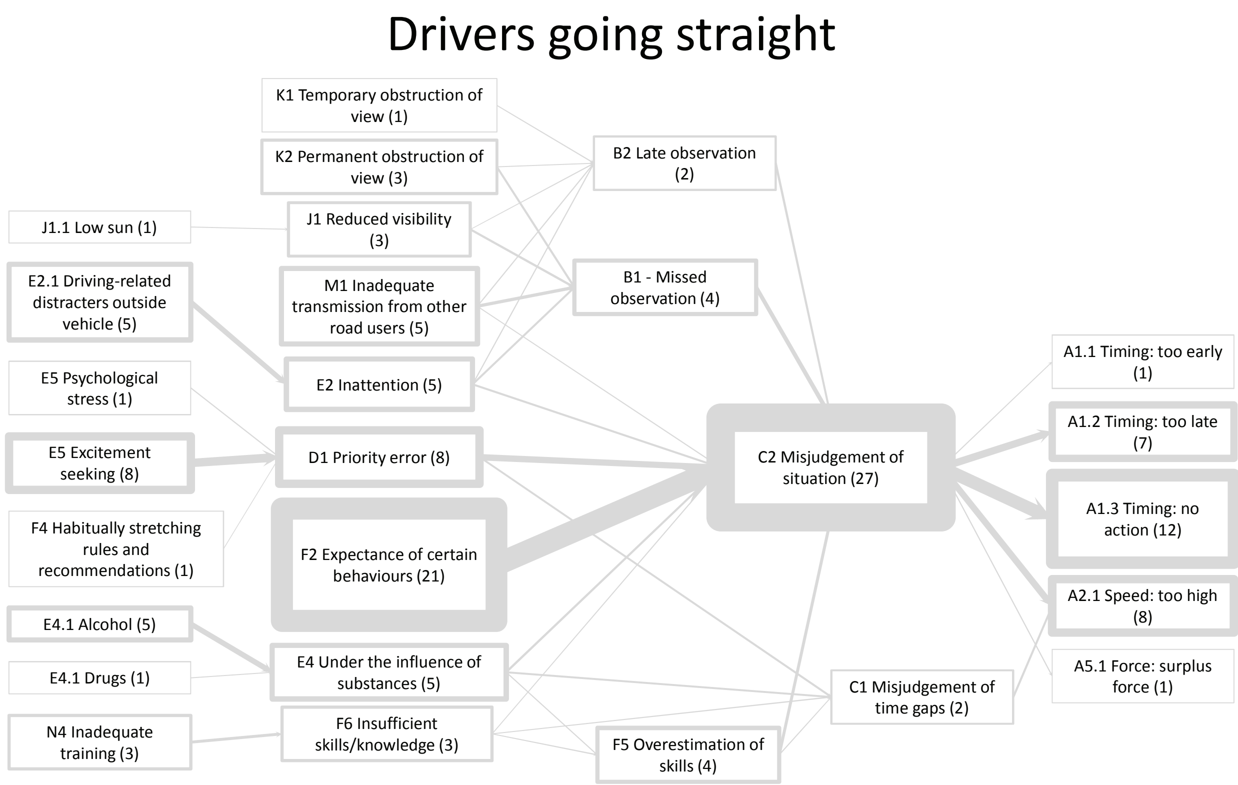


Figure 2: Aggregated causation chart for all 29 drivers who were planning to go straight through the intersection

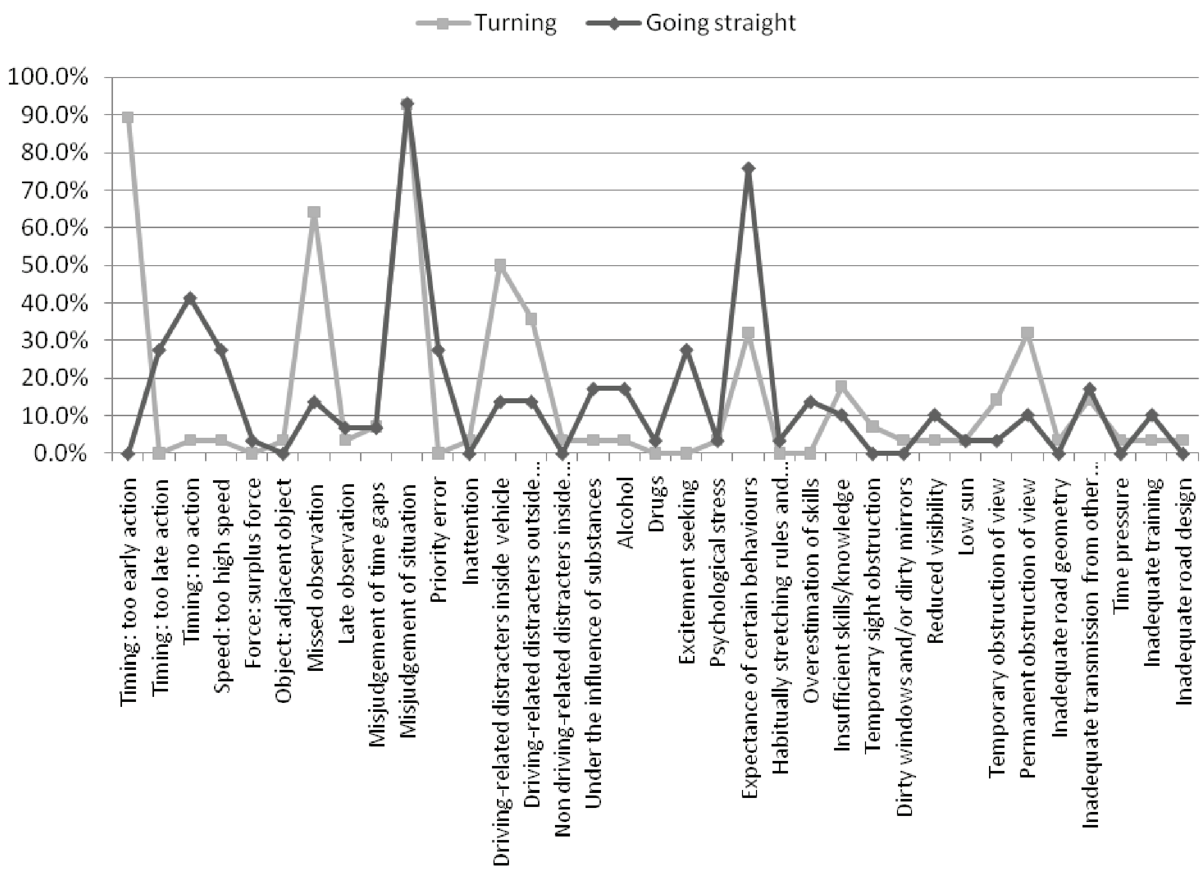
A large number of planning related failures are also present for drivers going straight. Something which stands out is the high frequency of planning failures due to *Expectance of certain behaviours*. Again, this could reflect the fact that drivers going straight more often have the right of way and therefore expect turning vehicles to yield. As discussed above, this assumption is supported by the fact that various obstructions to view are more often reported as a contributing factor for turning drivers than for drivers going straight.

It is worth noting that the group of drivers going straight contains all 17 MC drivers involved in the 28 fatal crashes. These MC drivers are also overly represented when it comes to contributing factors such as *Excitement seeking* and *Alcohol/Drugs,* as well as *Overestimation of skills* and *Insufficient skills/knowledge.*

Data collection and quality

In Table 4, the occurrence percentage for each contributing factor identified for drivers going straight and drivers turning is shown. The percentage was calculated by dividing the total number of times a factor is present in each group with the total number of drivers in that group. For example, 25 instances of *Timing: too early action* for the 29 turning drivers give a presence percentage of 89.3 %. This table provides some interesting general insights into the data collection procedure for the 28 crashes.

Table 4: Chart describing the percentage of occurrence for each identified contributing factor (of those applicable in the analysis) for turning drivers and drivers going straight respectively



A general observation is that there are overall fewer contributing factors coded for drivers going straight than for turning drivers. This probably reflects an underlying but involuntary mechanism in the accident investigations, which is that the analysts are more likely to provide deeper and fuller explanations for why the turning driver gets into trouble, as compared to the driver going straight.

An example which illustrates this asymmetry is the number of reported obstructions to view due to signposts and vegetation. Since there are part of the traffic environment, i.e. the infrastructure, one would assume that any blockage in lines of sight is reciprocal, i.e. if driver A cannot see driver B, the reverse should also be true. However, while such obstructions to view are frequently reported as contributing for turning drivers, they are rarely reported as contributing for their counterparts in the same accident.

The reason why analysts have this focus on identifying contributing factors for turning drivers (albeit involuntary) is quite likely connected to the fact that the turning driver is usually the one who is legally held liable for the accident. Since the driver going straight normally has the right of way, it is easy to conclude that it was not his/her fault. From that it is easy to come to think that the lions share of investigation effort should be put on the driver at fault, since that driver is the one who needs accident countermeasures the most.

Now, it is true from a physics standpoint that if two vehicles are on a colliding path, it will almost always be easier for one of the vehicles to perform the avoidance manoeuvre necessary to prevent a collision. However, it is far from clear that this vehicle necessarily contains the driver at fault; it is a kinematic relationship between moving masses rather than a moral relationship between operators. Put slightly differently, who to blame is in a majority of cases irrelevant from a countermeasure development point of view. Underreporting of contributing factors for one of the parties involved based on moral reasoning about guilt thus hinders rather than helps countermeasure development. This underlying investigator mindset would need addressing to avoid future bias in reported information.

It can also be seen that in the general perspective, the information on blunt end factors (those more distant in time/space, yet important for the development of events) contained in the accident reports is more limited than information on sharp end factors (those close in time/space to the crash). A likely explanation for this phenomenon is that the analysts, while certainly being professional crash investigators, not always reflect on the influence of blunt end factors on the event they are analysing. As there is no common methodology which explicitly describes the relevant scope of possible contributing factors, the analyst may view blunt end factors as part of the circumstances under which the event took place rather than contributing factors in themselves. This points to the importance of having an explicit, and in the analyst group anchored, analysis method which clearly defines the scope of possible contributing factors and influences to be controlled for in accident investigation. This in particular holds if the investigations are to yield results on blunt end factors.

On a more detailed level, there seem to be certain discrepancies between the investigation teams in terms of how data collection is managed. The data available per accident varies in scope; for some accidents there is just the final report available, whereas for other accidents the files include various protocols filled out by the investigators. The extra information available through the protocols outside the main report sometimes (but not always) did hold valuable extra information for the analysis performed here. Valuable should here be taken not to mean that it brings new information to light which is unavailable in the main report. In that sense, the final reports overall are good at compiling the relevant information from the other documents. However, the main reports are written to describe inclusions rather than exclusions, i.e. reasons for why certain factors are thought to contribute are included, but reasons for excluding other possible factors are left out. In this regard, the extra information in the other protocols could sometimes be used to discard certain possible contributing factors, for which their established absence certainly made a difference in terms of how the accident causation process was reconstructed.

In the discussion above on noticeable “missing” factors such as driver fatigue and secondary task engagement, two possible explanations were offered. One was that the accident investigations have failed to identify instances where these factors have contributed despite their assumed association with traffic accidents, and the other was that these factors simply do not contribute. This dispute is not easy to settle, because it requires in-depth knowledge of the investigation procedure, which questions the analysts ask, and how systematic they are in trying both to prove the presence of possible contributing factors as well as to disprove the presence of other factors.

The DREAM methodology used here contains a number of genotypes which can be used for coding contributing factors, but which never were applied in the analysis of the 28 crashes. Since DREAM has been put through extensive validation work and corroboration with other researchers’ findings on possible crash causes, there is reason to further investigate why many of the genotypes available in DREAM did not get applied in the analysis. One possible explanation is that the information necessary for coding those genotypes usually is acquired through detailed driver interviews, something which is inherently impossible for at least one of the subjects involved in a fatal crash. Also, the Norwegian in-depth investigation teams rarely conduct their own driver interviews, rather they rely on information from the police conducted interviews. Here it can be hypothesised that the crash survivors are not always completely forthcoming when describing crash circumstances to the police. However, it is also possible that the full set of genotypes is not necessary for fatal crashes. This is a topic for future studies.

CONCLUSION

This study indicates that turning drivers to a large extent are faced with perception difficulties and unexpected behaviours in relation to the conflict vehicle, while at the same time trying to negotiate a demanding traffic situation. Drivers going straight on the other hand have less perception difficulties. Instead, their main problem is that they largely expect turning drivers to yield. When this assumption is violated, they are either slow to react or do not react at all. Contributing factors often pointed to in literature, e.g. high speed, drugs and/or alcohol and inadequate driver training, played a role in 12 of 28 accidents. While this confirms their prevalence, it also indicates that most drivers end up in these situations due to combinations of less auspicious contributing factors.

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