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Analysis of road crashes and effectiveness of countermeasures using Indian in-depth crash data

To evaluate the potential of large-scale introduction of Advanced Driver Assistance Systems in the Indian vehicle fleet

Master's thesis in Automotive Engineering

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MASTER’S THESIS IN AUTOMOTIVE ENGINEERING

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Application of Driving Reliability and Error Analysis Method (DREAM) on RASSI data to evaluate the potential of large-scale introduction of Advanced Driver Assistance Systems (ADAS) in the vehicle fleet or infrastructure in India

Master's thesis in Automotive Engineering

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Abstract

Road accidents are one of the major causes of deaths in India for people in the age group 5-24 years. More than 50% of the deaths occurring in Indian roads involve Vulnerable Road Users. Active safety systems are meant to prevent or mitigate the crashes. In order to evaluate and prioritize active safety systems or Advanced Driver Assistance Systems (ADAS) that suits best to the type of crashes that occur in India, crash causation mechanisms are identified by analyzing Indian in-depth crash database using the principle of Driving Reliability and Error Analysis Method. The presence of crash causation mechanism patterns could be used to identify the most frequent and common crash contributing factors. The analysis of the Indian in-depth accident database, Road Accident Sampling System India, it is observed that a single system might not address majority of the crashes. Instead some of the ADAS like Forward Collision Warning, Driver State Monitoring, Breath Alcohol Ignition Interlock devices and infrastructural improvements are suggested that could potentially avoid or mitigate a few major crashes based on the observations from a random sample of 500 crashes out of 3167 crashes. If all of the proposed systems and infrastructural improvements are adapted, about 54% of the crashes could be potentially avoided.

Keywords: Active safety, crash analysis, DREAM, RASSI, effectiveness

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Ashwij Madhusudan Rao, Göteborg, October 2020

Contents

List of Acronyms and Abbreviations

ACC Adaptive Cruise Control
ADAS Advanced Driver Assistance Systems
AEB Autonomous Emergency Braking

CREAM Cognitive Reliability and Error Analysis Method

DREAM Driving Reliability and Error Analysis Method
DSM Driver State Monitoring

EBA Emergency Brake Assist
ESC Electronic Stability Control

FCW Forward Collision Warning

HUD Head-Up Display

LCDAS Lane Change Decision Aid System
LDW Lane Departure Warning
LKAS Lane Keeping Assistance System

M2W Motorized Two-Wheeler
M3W Motorized Three-Wheeler

NDD Naturalistic Driving Data

RASSI Road Accident Sampling System India

TSD Traffic Sign Detection

URU Unprotected Road User

VRU Vulnerable Road Users

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Introduction

1.1 Background

In India, road crashes are one of the major causes of deaths for people in the age group 5-24 years [1]. About 480,652 crashes have occurred resulting in 150,785 deaths in 2018 [2]. A mixed traffic consisting of high speed vehicles and Vulnerable Road Users (VRU), viz. motorcyclists, cyclists and pedestrians, in addition to unsafe road infrastructure and poorly safety rated vehicles are responsible for higher fatality rates and among the people dying on roads, approximately 50% are VRU [2, 3].

Adequate infrastructure, traffic regulations like maximum speed limits, enforcing use of seat-belts while driving, helmets while riding a motor bike and bicycle and no driving after consumption of alcohol, better crash-worthy vehicles have proven and resulted in a large reduction of societal burden of and number of crashes in developed countries [4]. India is trying to follow these methods and regulations, however the enforcement level is at a much lower rate.

Crash-worthiness refers to engineering features of vehicles or infrastructure that reduces the crash severity. On the other hand, crash prevention refers to engineering that is aimed to prevent a crash from occurring. If a system or a method that could prevent or reduce the risk of a crash then it is far more effective than a system that is equally crash-worthy [5]. It is better to introduce the systems or methods that can prevent crashes together with the improvement principles mentioned above.

Active safety systems like Autonomous Emergency Braking (AEB), Electronic Stability Control (ESC) and Advanced Driver Assistance Systems (ADAS) like Adaptive Cruise Control (ACC), Forward Collision Warning (FCW), etc. are some of the systems that are designed to prevent or mitigate the crashes [6]. A combination of passive safety and active safety technologies have a higher potential in reducing fatalities [7].

However, it is very important to understand crash causation mechanisms in order to prioritize the development and use these active safety systems. A proper understanding of how crash occurs will guide to identify a countermeasure that could possibly avoid the crash. This can be done by analysing in-depth accident database [8, 9]. A systematic crash investigation is important as investigator can visualize the entire sequence of events that lead to a crash [10]. In-depth databases, in general, will have the needed information for understanding the crash causation mechanism, the crash contributing factors and the relation between them [11]. The databases could be analyzed in different ways to conclude at one or more factors that have lead to the event of crash [12]. There are various methods to analyze crashes viz. Driver Behaviour Questionnaire (DBQ), Driver error and incident causation factors, Car-Driver model, etc. [13, 14]. One of them is Driving Reliability and Error Analysis Method (DREAM).

With the application of DREAM to in-depth crash database, most common crash contributing factors could be inferred. These most common contributing factors guide policymakers, and vehicle or safety system manufacturers to prioritize large scale introduction of countermeasures (vehicle safety or improvements in infrastructure) in order to prevent or mitigate majority of crashes.

India is a vast country with versatile terrain that has roads ranging from very narrow to expressways, a very high penetration of Motorized Two-Wheeler (M2W) and corresponding crashes, poor infrastructure, high congestion, etc. Hence, for the purpose of analysis in this work, database being used is the Indian in-depth data, Road Accident Sampling System India (RASSI).

Before practically deploying a system and testing its effectiveness, it is convenient and quicker to analyze it virtually. A lot of sophisticated software packages are available in the market to analyze active safety systems in different vehicles. However, these packages need information about the road infrastructure and vehicle conditions. In order to get a holistic view of effectiveness of a system, simple rules could be applied on the database to evaluate the potential benefits of proposed countermeasures [7].

Various measures could be implemented in order to improve the traffic safety in India and of course, currently there are many regulations and guidelines in place. However, the number of crashes and fatalities are extremely high. Lots of investments on traffic infrastructure are being made by Government of India [15]. Also, in cooperation with companies and organizations around the world, steps are being taken to reduce road crashes. A recent step towards it is equipping a few buses with sensors and instruments required for Naturalistic Driving Data (NDD) studies in India according to the project- the Safe and secure transport corridor by SITIS (Sweden-India Transport Innovation and Safety Partnership) [16].

In this project, RASSI data is analyzed using the principle DREAM to identify the crash causation mechanisms and major crash contributing factors. The identification would help in prioritizing use of the existing active safety systems or guide system developers in concept generations. In addition to the identification of countermeasures, they are evaluated for estimating the potential benefits.

1.2 Objectives

The main objective of this master thesis is to contribute to the reduction of road crashes by identifying common crash causation mechanisms and explore the potential of large scale introduction of ADAS in the vehicle fleet or infrastructure in India.

In order to do this, DREAM is used. The analysis helps to identify different factors or actions of human, vehicle and infrastructure that causes the crashes. Identifying these causes will help either to develop the infrastructure or will lead to identify the appropriate ADAS needed in order to prevent or mitigate the crashes. Further, the potential benefits of using the proposed changes would be analyzed.

The following questions will help to achieve the objectives:

- What are the major crash contributing factors that are responsible for the high number of crashes on Indian roads?
- What can be done to avoid or mitigate the crash?
- Can any of the active safety systems be used as an effective countermeasure for this problem?
- How effective would the suggested systems potentially be?

1.3 Limitations

The following are the limitations that might affect the generalisation of results:

- The RASSI data is collected only in 5 cities and hence it may not represent entire India
- Since the project has a time frame, analysing all available crashes is not feasible
- The analysis done in this project is not weighted; it is based on the 500 randomly sampled cases

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Theory

This chapter explains theories and principles that formed the basis of this project. The details of the database used, DREAM principle, aggregation and a brief information on ADAS can be found here.

2.1 Road Accident Sampling System India

The Road Accident Sampling System India (RASSI) is an Indian in-depth road accident database which is funded by a consortium of automotive vehicle manufacturers and suppliers in India. RASSI collects accident data in and around five cities: Coimbatore, Pune, Ahmedabad, Kolkata, and Jaipur. The RASSI data includes in- and post-crash data together with some information about pre-crash phase. Based on information collected from police record and on spot investigation, crash contributing factors for the crashes are coded into the RASSI database. RASSI collects information on over 700 variables for human, vehicle, road and environmental factors associated with crashes, making it the most comprehensive crash data collection in India [17].

Whenever a crash occurs within the jurisdiction of RASSI cities, the crash investigation team gets notified by local police, highway patrols, road operators or other emergency services. Then the team goes to the site and does a thorough investigation of the crash location by looking at tire marks, debris in the surrounding and a detailed vehicle inspection. In addition to this, the research team will be driving around at different places to collect information of non-reported crashes. The interviews of crash participants are done and the injury coding will be done for further analysis.

For the RASSI project, basic criteria to be met for investigating a crash are:

- A crash must involve at least one motorised vehicle
- Crash spot has to be on a public road within the study area

Further, for a crash to be eligible to be included in the RASSI database, the following criteria are also to be met:

- The crash spot should be identifiable by any of:
  - Known final rest positions (photographs, etc.)
  - Vehicle trajectories (skid or brake marks, etc.)
  - Other evidence (debris, damaged fixed objects, eyewitness)

  ;

- The crash spot should also yield measurements of the road, skid marks, and any other evidence
- Vehicles should be examined to obtain data such as direct damage details, crush profile, intrusions, contacts, and safety system use
- Make and model of all the vehicles involved in the crash should be known
- In case of pedestrian, bicyclist or M2W crashes, the other vehicle should be available for inspection
- The vehicles with highest injury severity must be available for inspection for all other crash types

Once all the parameters are coded as per RASSI coding manual by crash investigators, crash data will be verified for the quality and a crash reconstruction will be carried out [18].

2.2 Driving Reliability and Error Analysis Method

DREAM is based on a cognitive method called Cognitive Reliability and Error Analysis Method (CREAM) [19]. CREAM was developed to analyze accidents in process domains and DREAM is an adaption of it to suit the road traffic domain. Using DREAM, one can classify and store various information that has possibly contributed to the crash with evidence. However, DREAM cannot straight away provide the crash causation mechanism. Instead, it is the analyzer who infers the most common crash contributing factors from DREAM charts. Further, the series of events that leads to the crashes are noted. This will facilitate system developers to identify different phases of the crash or crash contributing factors that have to be addressed in order to prevent or mitigate crashes. The current and most recent version of DREAM is Version-3.2 which has addressed the short comings of previous versions. DREAM was mainly developed to support the development of ADAS.

DREAM has three main components; an accident model, a classification scheme and a procedural description to analyze crashes. An accident model is an abstract conceptual representation of the occurrence and development of a crash [20]. In simpler words, an accident model defines how human and all other contributing factors collectively resulted in a crash. These models are holistic and would accommodate all tiny details to represent a crash.

DREAM is built on an accident model that is based on Man, Technology and Organization triad. In particular, Man corresponds to Driver, Technology corresponds to Vehicle and Organization corresponds to traffic environment. Driving is considered as a complex function due to the difficulty involved in driving like skills required, continuous monitoring, understanding and adapting to the continuously changing safety margins [21]. Safety margin is the minimum distance between comfort zone and the point at which control is lost [22]. There is a limit to people's capability to quickly adopt to changing situations due to the variations in perception and action capacities [23]. Thus a driving task that fails to manage this complex task goes beyond control and leads to a crash.

DREAM classification scheme has four elements; Phenotypes, Genotypes, Links and

Stop rules. The Phenotypes or critical events are used to classify the moment when driver lost control from a sort of physics perspective. The Genotypes or contributing factors are used to classify all information that relates to why the control was lost. The Links are logical reasons that actually connects genotypes to phenotypes and/or genotypes to genotypes. The stop rules determine when an analysis is finished. The final outcome of this analysis is a DREAM chart from which the analyzer can infer the main crash contributing factor that has lead to the critical event [24]. The Table 2.1 shows the overall grouping of the phenotypes and the genotypes currently considered in DREAM. The listed parameters are very general in nature and the more specific parameters can be found in the DREAM manual that has been used in this work.

Table 2.1: Overall grouping of genotypes and phenotypes in DREAM

Genotypes			**Phenotypes**
Driver	**Vehicle**	**Organization**	
Observation	Temporary HMI problems	Organization	Timing
Interpretation	Permanent HMI problems	Maintenance	Speed
Planning	Vehicle equipment failure	Vehicle design	Distance
Temporary Personal Factors		Road design	Direction
Permanent Personal Factors	**Traffic environment**		Force
	Weather conditions		Object
	Obstruction of view due to object		
	State of road		
	Communication		

As mentioned earlier, DREAM comprises of all the three constituents (man, technology and organization) and it is not possible to describe a crash with sequence of steps in a hierarchy. Instead, a network is required.

The DREAM Links are the possible connections between different phenotypes and genotypes or genotypes and genotypes. This is mainly done in order to relate the crash contributing factors. To bring in an uniformity in coding and also with the results of previous works, the DREAM Links are such a way designed now to guide the analyzer in a right direction and also it sets a boundary for the crash contributing factors.

Since the Links connects genotypes and phenotypes, this forms an endless loop if there is no criteria so as to end the analysis. Also these stopping rules tries to bring the uniformity in coding among different analyzers. The following are the Stop rules used in DREAM

- Specific genotypes always end the link.
- If there exists no general or specific genotypes that link to the chosen consequent, the analysis stops.
- If none of the available specific or general genotypes is relevant for the chosen consequent, the analysis stops

The above procedure has to be carried out for each crash event individually including all the collision partners and the DREAM parameters have to be stored. The information from the interviews and other documentation in the in-depth database are required to confirm every genotype. Also, the analyzer has to note that the analysis is to identify where and what has led to the crash and not to blame someone [24, 25]

The chart does not necessarily conclude on what has caused the crash. Instead, it is more of a systematic classification of the various crash contributing factors that are available to the analyzer.

The Figure 2.1 shows a DREAM chart for a crash where the driver has performed no action to avoid the crash. The situation was misjudged by the inattentive driver as a result of missed observation of the object due to permanent obstruction to view and also the driver was expecting other road user to behave in a particular way. In Figure 2.2, the driver has performed an action much earlier by misjudging the situation due to a missed observation of the object due to permanent obstruction of view.

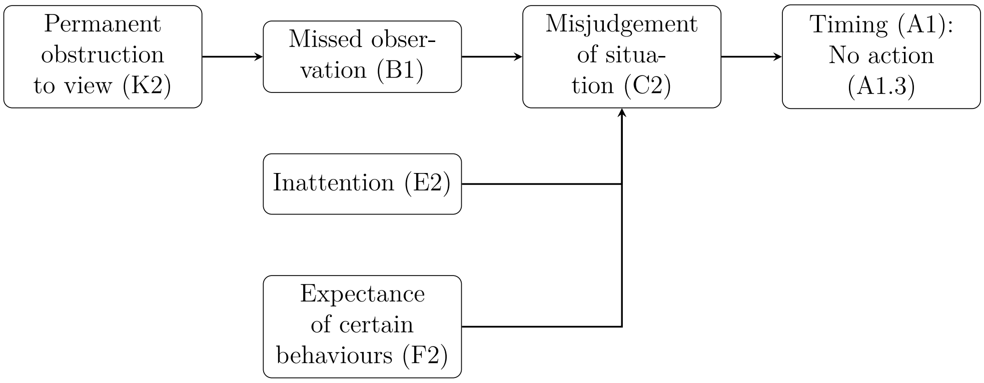

Figure 2.1: An example of a DREAM chart with phenotype: Timing-No action

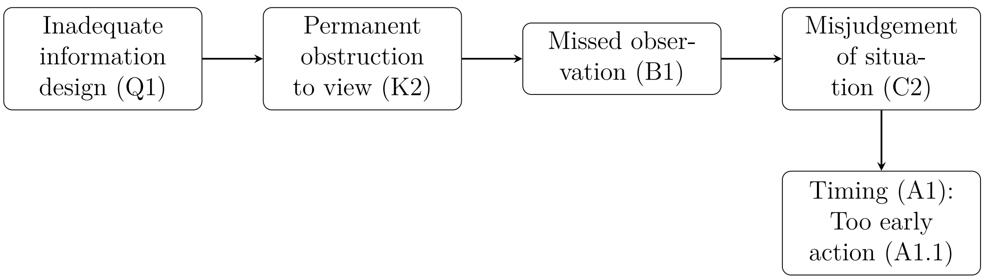

Figure 2.2: An example of a DREAM chart with phenotype: Timing: Too early action

2.2.1 Aggregation

The aggregation is a procedure where individual DREAM charts are added cumulatively based on a certain condition. The analyzer has to aggregate individual DREAM charts into a single DREAM chart in order to identify the most common crash contributing factor. In simpler words, the superimposing of individual DREAM charts can be called as aggregation.

Though there are no prescribed methods to aggregate, it has to be done based on the context that has to be analyzed. However, commonly used principles for aggregation as per the DREAM manual are:

- Cause based aggregation: a cause is selected based on the frequency of occurrence and all cases with this cause are aggregated
- Context based aggregation: all crashes in a particular context are aggregated
- Trajectory based aggregation: all crashes that were the results of a particular type of pre-crash trajectory are aggregated
- Event based aggregation: Any particular event prior to the crash is noted and all cases with this event are aggregated.

Further, the aggregation can be done for the crashes in different perspectives i.e. the aggregation can be done either as a whole or in each crash participant's perspective. Also, a combination of the above principles and different perspectives could be used. In this way, the analysis has to be carried out for individual crashes and later aggregated based on a condition. The DREAM parameter with highest frequency becomes the frequent or common crash causation factor, and other common and repeated genotypes connecting this factor indicates a pattern of crash causation mechanism [26]. Finally, with the identified crash contributing factors and causation mechanism, one could think of developing a system that directly or indirectly addresses the crash contributing factor and in turn prevents or mitigates occurring of such crashes [8, 9, 12, 24, 27].

The Figure 2.3 is the aggregated DREAM chart for the examples shown in Figures 2.1 and 2.2. In these two examples, it is seen that the situation is misjudged and the observation is missed by the driver. Permanent obstruction to view is responsible for this. The numbers above the arrow represents the frequency of occurrence of that particular crash contributing factor in these two crashes considered.

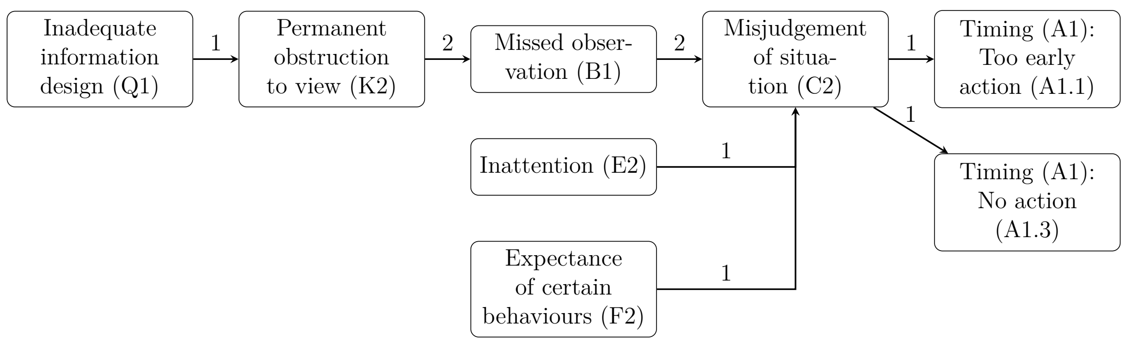

Figure 2.3: An example of an aggregated DREAM chart

2.3 Advanced Driver Assistance Systems

The vehicle systems that sense and monitor conditions inside and outside the vehicle in order to identify potential dangers to the vehicle, occupants, and/or other road users, and automatically intervene to help avoid or mitigate potential collisions are called active safety systems. The intervening might be alerts to the driver, vehicle system adjustments, and/or active control of the vehicle subsystems (brakes, throttle, suspension, etc.) [28].

Active safety systems can be either designed with a purpose to improve safety or to provide comfort to the driver in the form of assistance or both. The active safety systems that provide comfort to the driver can be termed as Advanced Driver Assistance Systems (ADAS). The ADAS can be mainly considered into two categories; warning systems and intervention systems.

2.3.1 Warning Systems

The systems that warn the driver regarding an on-coming risk or that needs driver's attention are called warning systems. Forward Collision Warning (FCW), Lane Departure Warning (LDW), Driver State Monitoring (DSM), Traffic Sign Detection (TSD), etc. are few of the warning systems that are in application today [29].

2.3.1.1 Forward Collision Warning

Forward Collision Warning (FCW) is an ADAS that detects a potential collision with a vehicle ahead and alerts the driver. This could be in the form of a visual warning in the Head-Up Display (HUD) or auditory or both. Some of the systems also provide alerts for pedestrians or other objects.

2.3.1.2 Lane Departure Warning

Lane Departure Warning (LDW) is an ADAS that monitors vehicle's position within the driving lane and alerts driver as the vehicle approached or crosses lane markers. This warning can be auditory or haptic.

2.3.1.3 Driver State Monitoring

Driver State Monitoring (DSM) is an ADAS that observes driver actions to estimate if they are not engaged in the task of driving. Some systems may monitor eye movement and/or head position. Usually the warnings are auditory, haptic or both.

2.3.1.4 Traffic Sign Detection

Traffic Sign Detection (TSD) is an ADAS that detects the traffic signs and notifies the driver about the sign in the dashboard and for example if the driver exceeds the speed limit then it warns the driver.

2.3.1.5 Lane Change Decision Aid System

Lane Change Decision Aid System (LCDAS) is an ADAS warns the driver against collisions that may occur due to a lane change manoeuvre. It is a supplement to supplement for rear and side view mirrors.

2.3.2 Intervention Systems

The systems that gets deployed at critical situations to avoid or mitigate a crash not necessarily with the intervention of the driver are called intervention systems.

2.3.2.1 Adaptive Cruise Control

Adaptive Cruise Control (ACC) is an ADAS that is an enhancement of the cruise control which also assists the acceleration and/or braking to maintain a driver-selected gap to the vehicle in the front.

2.3.2.2 Lane Keeping Assistance System

Lane Keeping Assistance System (LKAS) is an ADAS that provides steering support to assist the driver in preventing the vehicle from departing the lane. Some advanced systems also assist to keep the vehicle centered within the lane.

2.3.2.3 Emergency Brake Assist

Emergency Brake Assist (EBA) is an ADAS that provides additional braking force when the brake force by the driver is insufficient to avoid a collision by using the information provided by sensors in the longitudinal direction and brake pedal.

2.3.2.4 Autonomous Emergency Braking

Autonomous Emergency Braking (AEB) is an ADAS that detects potential collisions with a vehicle ahead, provides collision warning, and automatically brakes to avoid a collision or mitigate the severity of impact. Some systems also detect pedestrians or other objects.

3

Materials and Methods

This chapter briefly explains materials used and methodology followed in this project for handling the data, application of DREAM, aggregation criteria, identification of crash contributing factor and crash causation mechanism, solution to address it and the steps followed in analyzing the potential benefits of the proposed solution.

3.1 Data

The RASSI data made available for this project had 3167 crashes that were collected, investigated and coded by trained professionals. These 3167 crashes nearly represents 7,150,000 crashes in India. Each case has several contributing factors being coded so that it includes all the road users, defects or faults in the vehicles and infrastructure.

An open source software RStudio based on R programming language was used for data manipulation and visualization. The Figure 3.1 shows the share of three main contributing factors for the crashes: Human, vehicle and infrastructure. Human was responsible for more than 93% of crashes. Infrastructure contributed for about 53% and vehicles were responsible for about 10% of the crashes.

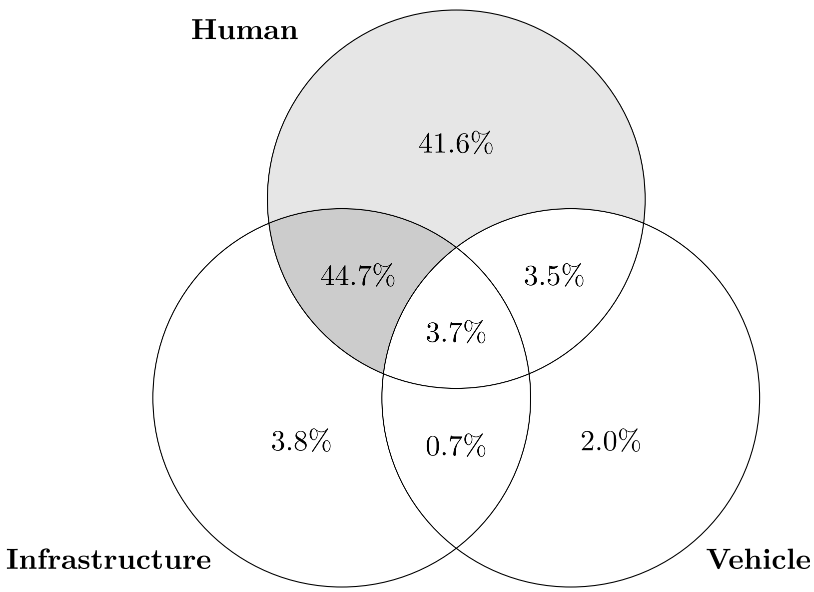

Figure 3.1: Venn diagram for contributing factors with N=3162 crashes

All the crashes that are considered for analysis are based only on the first event i.e, even if one more crash is resulted after the collision with first partner, only the first crash will be analyzed. Analyzing all the available cases is tedious and not in the scope of this project. Hence it was decided to analyze only 500 crashes using DREAM. These 500 crashes are divided equally in five groups that includes majority of types of crashes occurring in India as shown below:

1. car to VRU
2. commercial vehicle to VRU
3. M2W to VRU
4. commercial vehicle to car
5. single vehicle crash

On filtering all the RASSI qualified crashes, 3162 crashes remained; 2 crashes were coded incorrectly and 3 crashes were not qualified. Then the crash partners in the RASSI data were assigned with a string value 'pedestrian', 'bicycle', 'M2W', 'Motorized Three-Wheeler (M3W)[1]', 'passenger car', 'commercial vehicle' and 'object' corresponding to the body-type coded. Using the appended crash partners, merging of the rows is done to obtain crash partner 1 and 2 in the same row. A new string value is assigned to each crash based on the values of collision partners. This step is done in order to obtain the above mentioned five groups. The Table 3.1 shows the number of crashes present in these different groups.

Table 3.1: Number of crashes in different groups

Group	Number of cases
Single vehicle crash	1087
Commercial vehicle to VRU	611
Passenger car to VRU	464
Passenger Car to Commercial vehicle	288
M2W to VRU	235

Using the syntax 'sample' in R, a random sampling is done to obtain 100 cases each in the above groups and these cases are considered for further analysis using DREAM.

3.2 Application of Driving Reliability and Error Analysis Method

3.2.1 AutoDREAMing

For analyzing a crash, the DREAM chart has to be prepared for each road user. Quite often, the analyzer has to refer the DREAM manual in order to obtain the parameters required to create the DREAM charts. Further, even if the sample size is 500, the process of application of DREAM to individual cases will be tedious as well as repetitive. Therefore, a software is required for speeding up this process.

[1]Example: auto rickshaw or tuk-tuk

AutoDREAMing is a software that is developed to minimise the look-up to the DREAM manual. The interface has a starting point where all phenotypes are listed. The analyzer has to select one of this phenotypes based on his conclusion from the information present in the RASSI database. After this, in the subsequent cards (tile with possible genotype), the analyzer has to select corresponding genotype. The Figure 3.2 shows the web interface of the tool wherein phenotype and genotypes are selected for a particular case. Once, the selection of all genotypes are completed, the data can be saved with corresponding case number. In this analysis, to differentiate between different collision partners, an underscore followed by 1 or 2 is suffixed to the case number. Once this case number is added, the tool will request for 2 files to be inputted. The 2 files, 'Element Year' and 'Nodes' either new files or the previously used could be inputted. Soon, 2 more files named the same would be downloaded from the system with the DREAM parameters written. These files would serve as a database that would be the input to DREAM-AT tool. More information on how to install and use AutoDREAMing is in the Appendix A.1.

Figure 3.2: A snapshot from the web interface of AutoDREAMing tool

3.3 Aggregation of Driving Reliability and Error Analysis Method Charts

After completion of DREAM charts for all the crashes, the aggregation of charts has to be done to identify the common crash contributing factors and the crash causation mechanism. This will help the analyzer to determine the factors that are repeatedly leading to the critical events and guidelines could be sought for from this. The Figure 2.3 shows the aggregated DREAM chart. The crashes are to be filtered based on the criteria that is being laid to aggregate as mentioned in the section 2.2.1. Once the filtering is done, the aggregation can be done quickly using DREAM-AT tool.

3.3.1 DREAM-AT

DREAM-AT is a tool that is developed in Chalmers which can be used for easier and quicker aggregation of DREAM charts [30]. When the three files (Element Year, Nodes and Node Type) are inputted together to this tool, all the cases that have been analyzed and stored as DREAM parameters could be seen as entries in the tool. Now selecting the aggregation option and selecting the required cases based on the analysis criteria, a new aggregated DREAM chart is created. For a better visualization, the crash contributing factors with frequencies higher than a certain frequency could be selected.

In this project, the aggregation is done based on the following criteria:

- Overall (All 500 cases are aggregated to visualize the crashes and contributing factors look)
- Overall aggregation w.r.t. all vehicles except for VRU
- Overall w.r.t. VRU
- Single vehicle crash w.r.t. all vehicles except for VRU
- Single vehicle crash w.r.t. VRU
- Passenger car to VRU w.r.t. Passenger car
- Passenger car to VRU w.r.t. VRU
- Commercial vehicle to VRU w.r.t. Commercial vehicle
- Commercial vehicle to VRU VRU
- M2W to VRU w.r.t. Motorbike
- M2W to VRU w.r.t. URU
- Crashes involving Passenger cars and Commercial vehicles
- Crash location- Urban area (inclusive of semi-urban area)
- Crash location- Rural area
- Traffic flow- Divided road
- Traffic flow- Undivided road

3.4 Identification of Common Crash Contributing Factors and Crash Causation Mechanism

The common crash causation factors are those DREAM parameters (genotypes) with the highest frequencies of occurrence. Other genotypes following this genotype in numbers and also related to this must be noted. This will help to identify the causation pattern. It is the analyzer who has to look into the aggregated DREAM charts and identify the most common crash contributing factors that have highest frequencies and brings logical connection among them. This observed pattern in crash causation mechanism and the common contributing factors will help in deciding where to implement a system or strategy that possibly breaks the chain or network of crash causation factors.

3.5 Identification of Countermeasures

The result of aggregation enables the analyzer to identify the common crash contributing factors and crash causation mechanisms that lead to the crashes. If the factors that lead to the crashes are of known type, like a rear end collision, then the available active safety systems could be considered to be used by tuning them to the Indian driving conditions. But if the causes for the crashes are not very commonly known then there is a need to explore an active safety system or suggest some other changes in infrastructure or regulations that might prevent or mitigate the crashes.

3.6 Rules for Potential Benefits of Countermeasures

To understand the effectiveness of a new system incorporated, the computer simulations helps. Since the Naturalistic Driving Data for Indian roads is not available, evaluation of the suggested system through simulations is quite challenging. Instead, simple rules are considered to evaluate the suggested countermeasures in this project. This will help to identify the number of crashes avoided if the active safety systems or the suggested changes in the infrastructure were in place. With this data, the ideal effectiveness of the proposal could be determined [7].

In evaluating the suggested countermeasure following rules were laid:

- Countermeasure: All divided roads with positive median barrier
  Rule:
  - Crash scenario: head-on collision
  - Traffic flow: Not divided, divided without positive median barrier and one way
- Countermeasure: FCW
  Rule:
  - Crash scenario: front-rear collision
  - Ego vehicle: M2W, passenger car, commercial vehicle

  - Collision partner: all vehicles
  - General area of damage: front
- Countermeasure: FCW for crashes with pedestrians
  Rule:
  - Crash scenario: front-rear collision
  - Ego vehicle: M2W, passenger car, commercial vehicle
  - Collision partner: pedestrian
  - General area of damage: front
- Countermeasure: Breath Alcohol Ignition Interlock Device
  Rule:
  - Crash scenario: crashes occurred due to consumption of alcohol
  - Ego vehicle: M2W, passenger car, commercial vehicle
- Countermeasure: Driver State Monitoring System
  Rule:
  - Crash scenario: crashes occurred due to the distracted driver
  - Ego vehicle: M2W, passenger car, commercial vehicle

Filtering of RASSI data based on the above conditions would give the number of crashes that are potentially avoided if the suggested systems were used. The crashes that are not avoided even if these systems are in use are the remaining crashes that should be of interest for researchers for further development in the future.

4

Results

This Chapter covers the results from this master's thesis project. The outcome expected in this project is to identify the causation mechanisms of crashes in India and to suggest suitable active safety system or infrastructural changes that would help to prevent or mitigate the crashes. Also, the results of the evaluation of potential benefits of proposed changes in infrastructure and deployed ADAS is presented.

4.1 Initial findings from Road Accident Sampling System India data

4.1.1 Entire data

RASSI data has details of crash contributing factors based on driver, vehicle and environment. When this information is accumulated for all the available crashes in the database, the following plots are obtained.

The Figure 4.1 shows the overall distribution of crash contributing factors that are coded by RASSI. For a better readability, the factors with a frequency of occurrence less than 2% are not plotted. Of all crash contributing factors, undivided road accounts for majority of the crashes.

The Figure 4.2 is the distribution of crash contributing factors that are dependent on human (driver or pedestrian). Excessively speeding for a given condition is the main human responsible crash contributing factor. For a better readability, the factors with a frequency of occurrence less than 2% are not plotted.

The Figure 4.3 shows the distribution of vehicle dependent crash contributing factors. Vision obstruction due to vehicle interiors is the major vehicle related crash contributing factor.

The Figure 4.4 is the distribution of infrastructure related contributing factors. Factors with the frequency of occurrence greater than 2% are plotted. Undivided road is the infrastructure related major contributing factor.

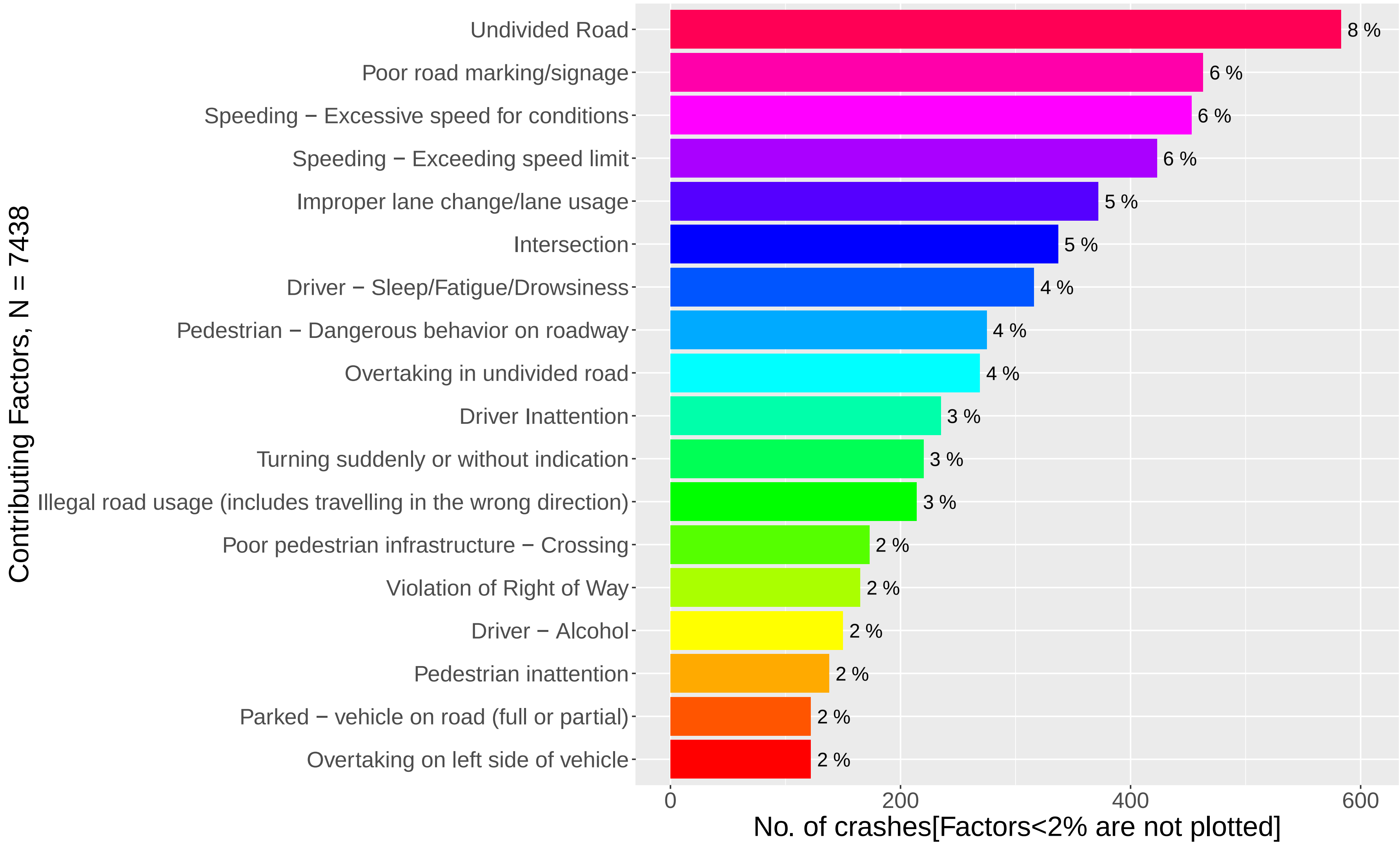

Figure 4.1: All contributing factors as available in RASSI data with N=3162 crashes

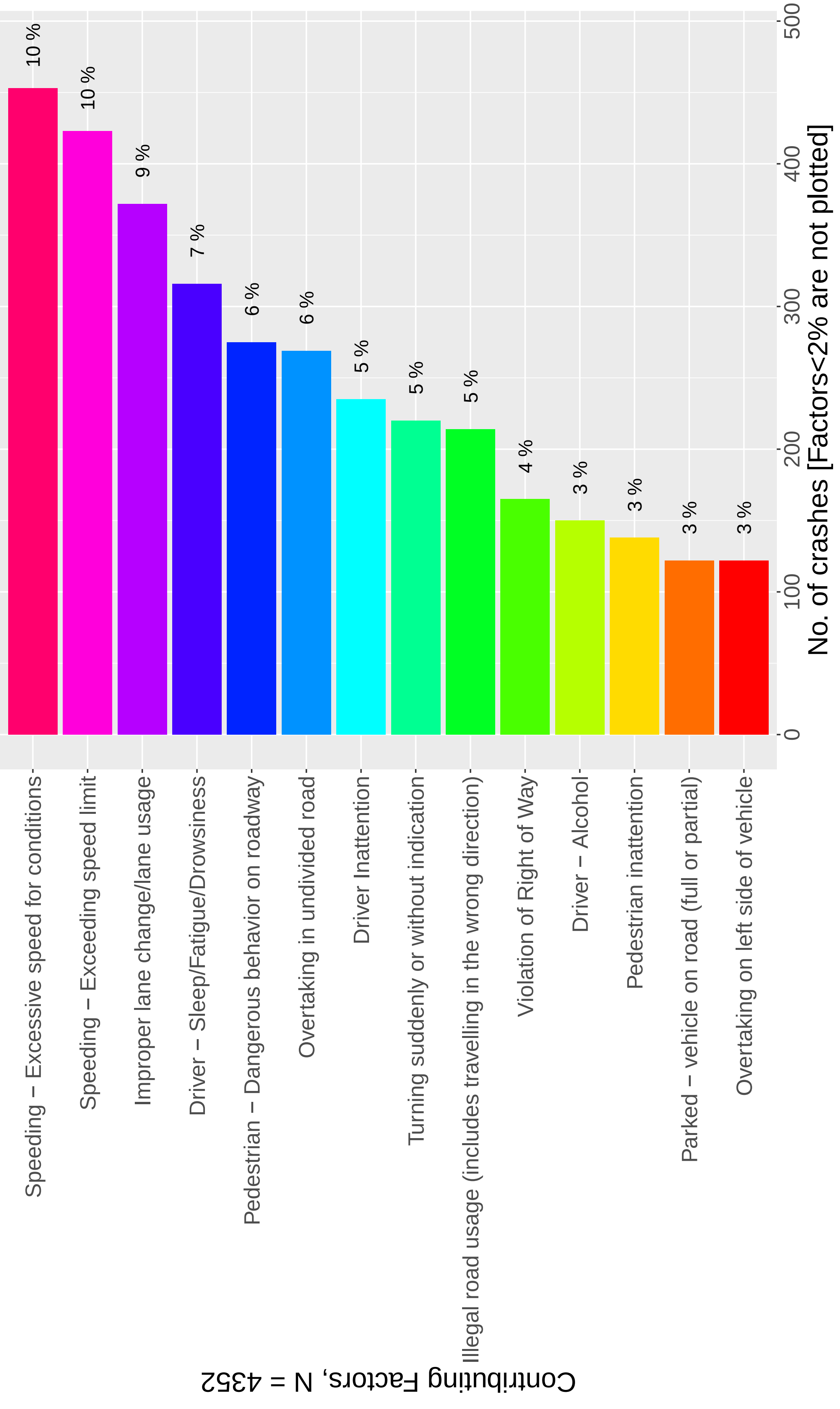

Figure 4.2: Human dependent contributing factors as available in RASSI data with N=3162 crashes

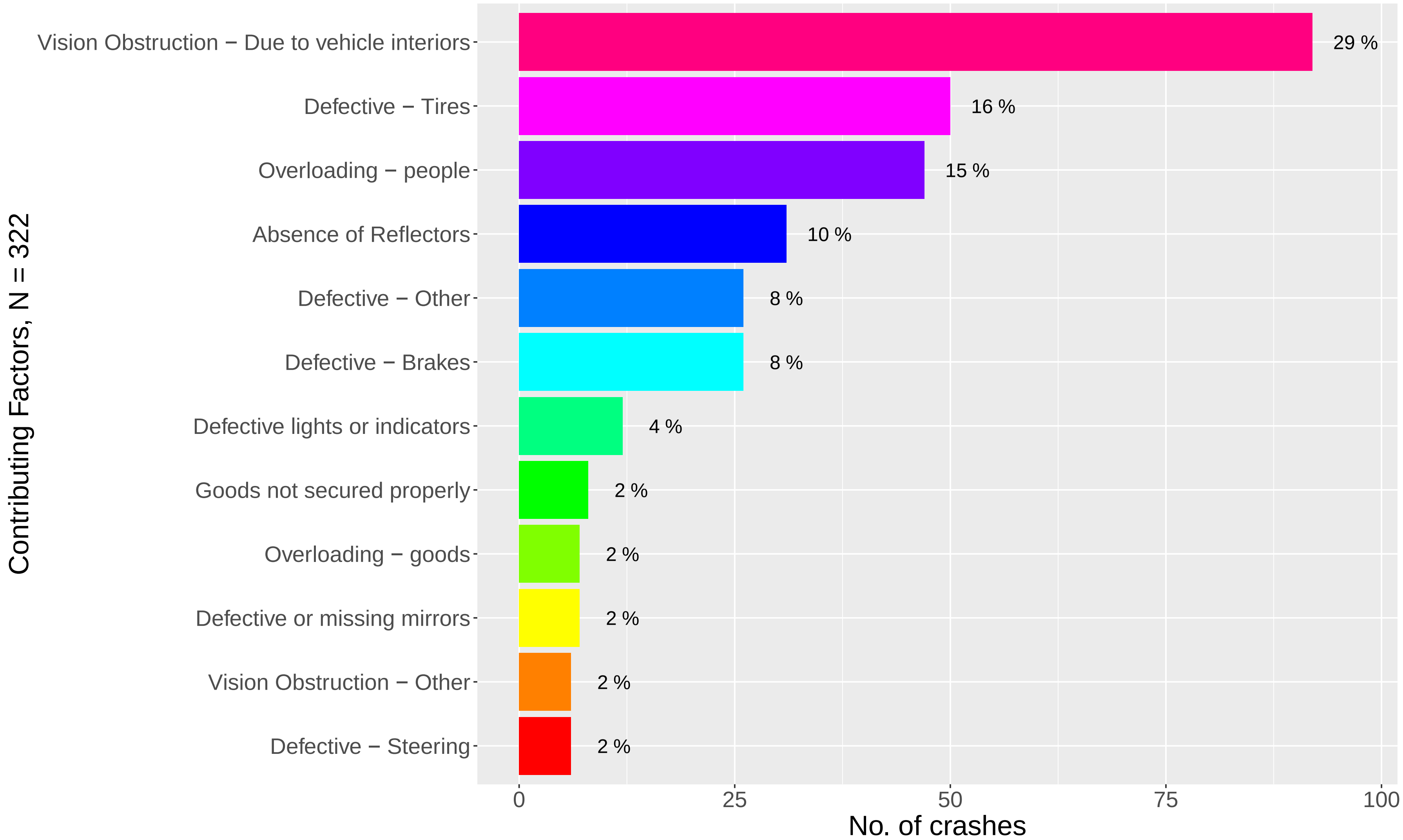

Figure 4.3: Vehicle dependent contributing factors as available in RASSI data with N=3162 crashes

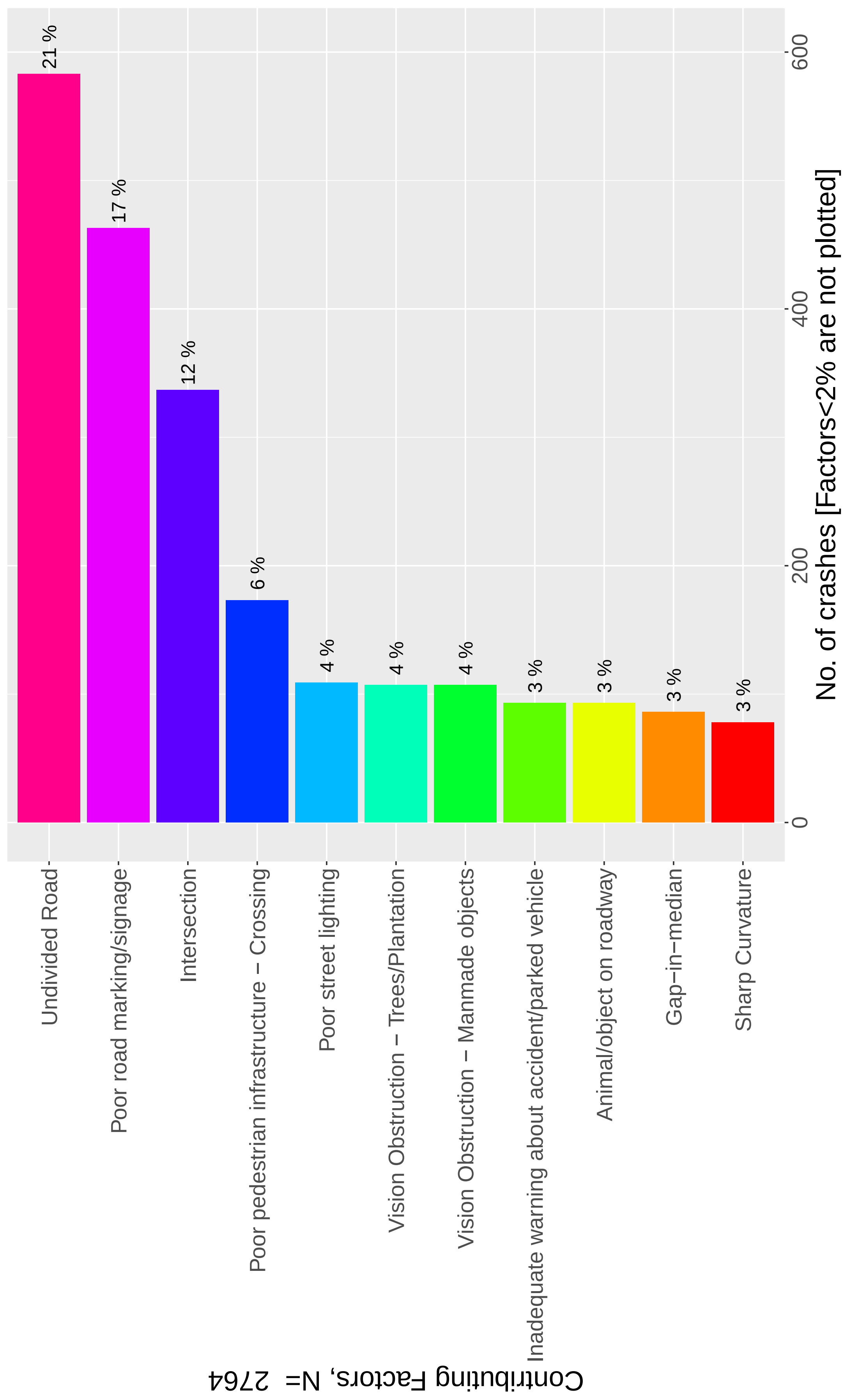

Figure 4.4: Infrastructure dependent contributing factors as available in RASSI data with N=3162 crashes

4.1.2 Sampled data

The 500 randomly sampled crashes from the RASSI database that has been used for DREAM analysis in this project are plotted in the same way as the entire data in Section 4.1.1. This gives an overview of distribution of crash contributing factors based on driver, vehicle and environment in the sampled data.

The Figure 4.5 shows the overall distribution of crash contributing factors in the sampled RASSI data. For a better readability, the factors with a frequency of occurrence less than 2% are not plotted. Of all contributing factors, undivided road accounts for majority of the crashes similar to the entire data set.

The Figure 4.6 is the distribution of crash contributing factors that are dependent on human in the sampled RASSI data. Pedestrian dangerous behaviour on roadway is the main human related crash contributing factor unlike the entire data set. For a better readability, the factors with a frequency of occurrence less than 2% are not plotted.

The Figure 4.7 shows the distribution of vehicle dependent crash contributing factors in the sampled data. Vision obstruction due to vehicle interiors is the major vehicle related crash contributing factor which is similar to the entire data set.

The Figure 4.8 is the distribution of infrastructure related contributing factors in the sampled data. Factors with the frequency of occurrence greater than 2% are plotted. Even in the sample, undivided road is the infrastructure related major crash contributing factor.

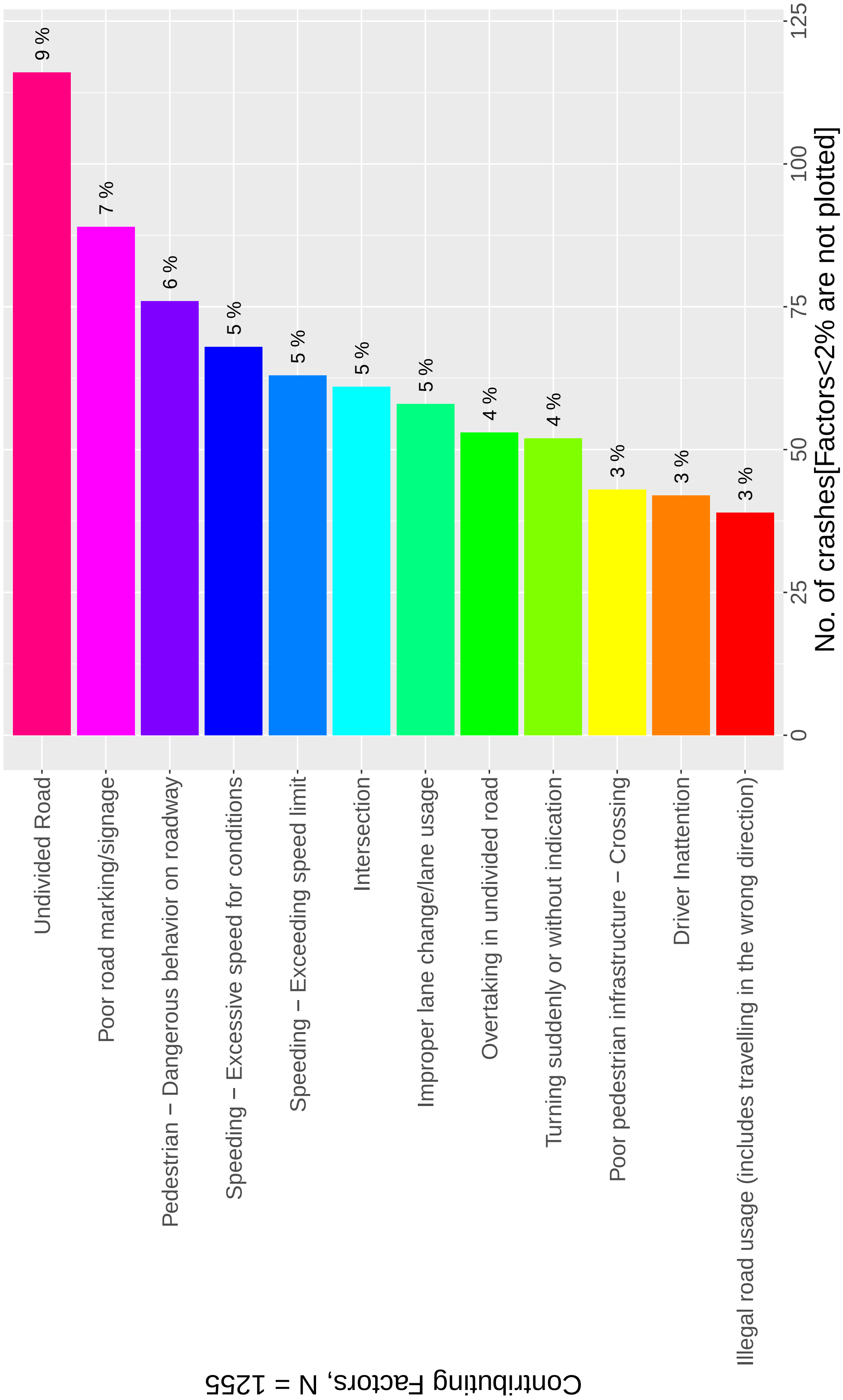

Figure 4.5: All contributing factors from sampled RASSI data with N=500 crashes

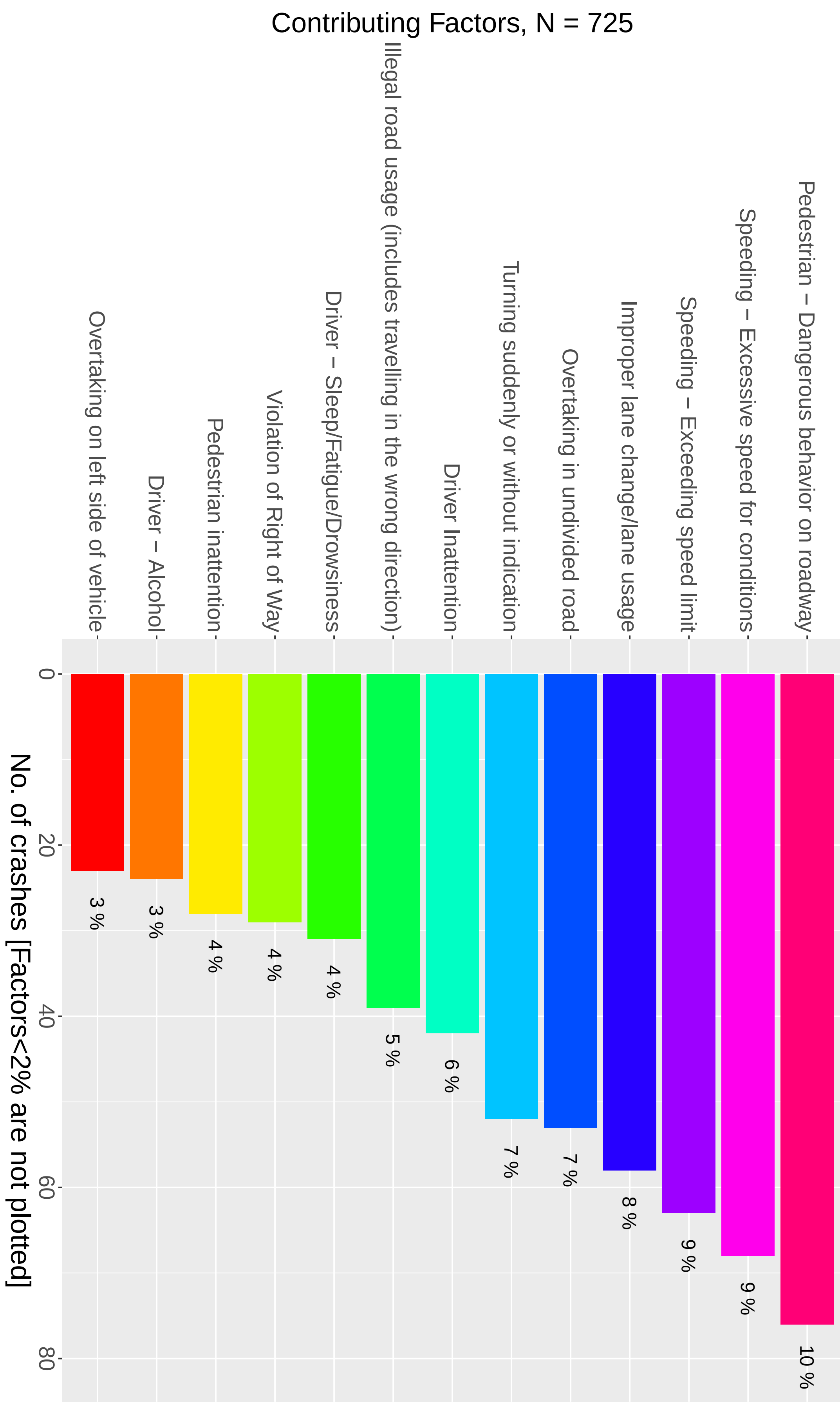

Figure 4.6: Driver dependent contributing factors from sampled RASSI data with N=500 crashes

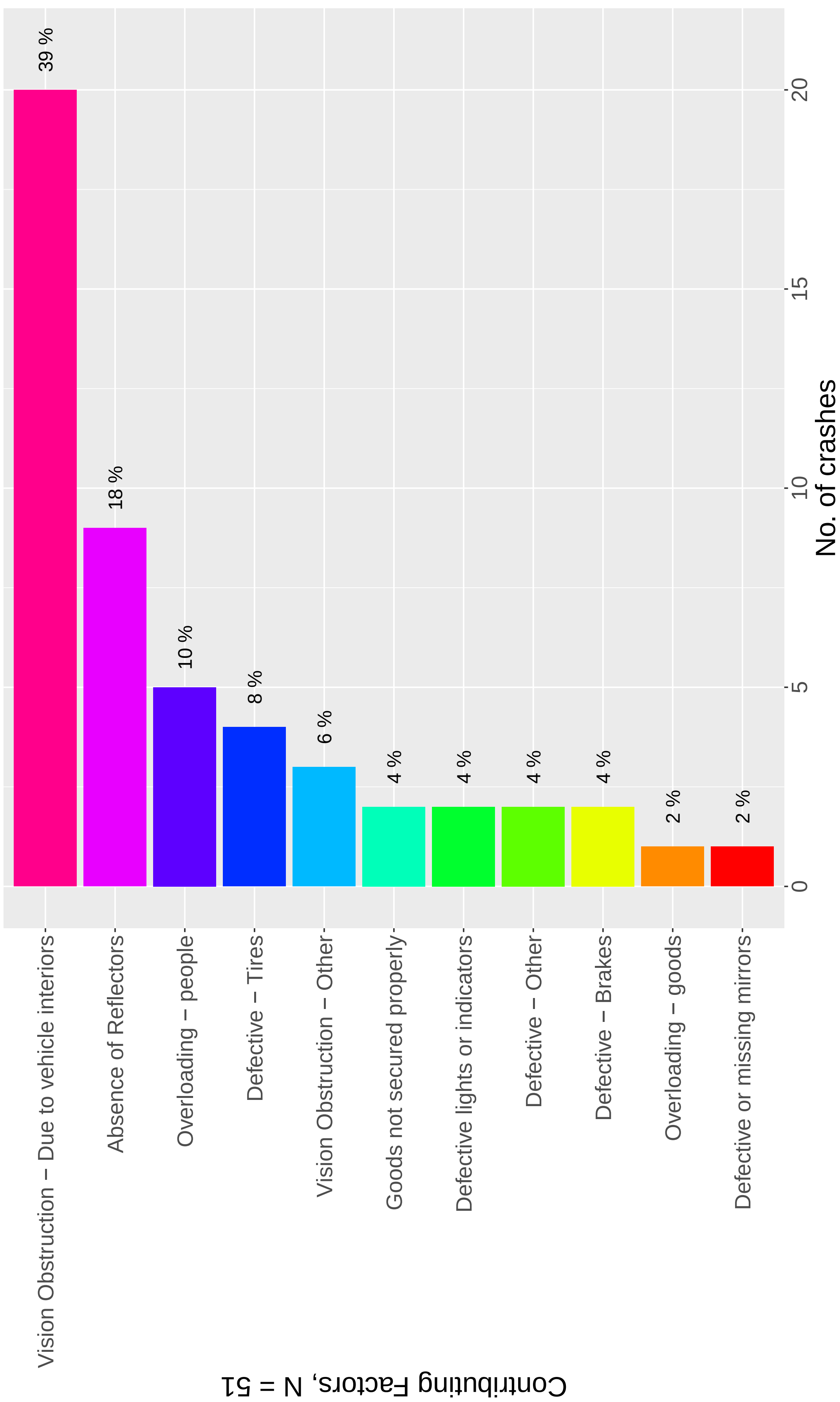

Figure 4.7: Vehicle dependent contributing factors from sampled RASSI data with N=500 crashes

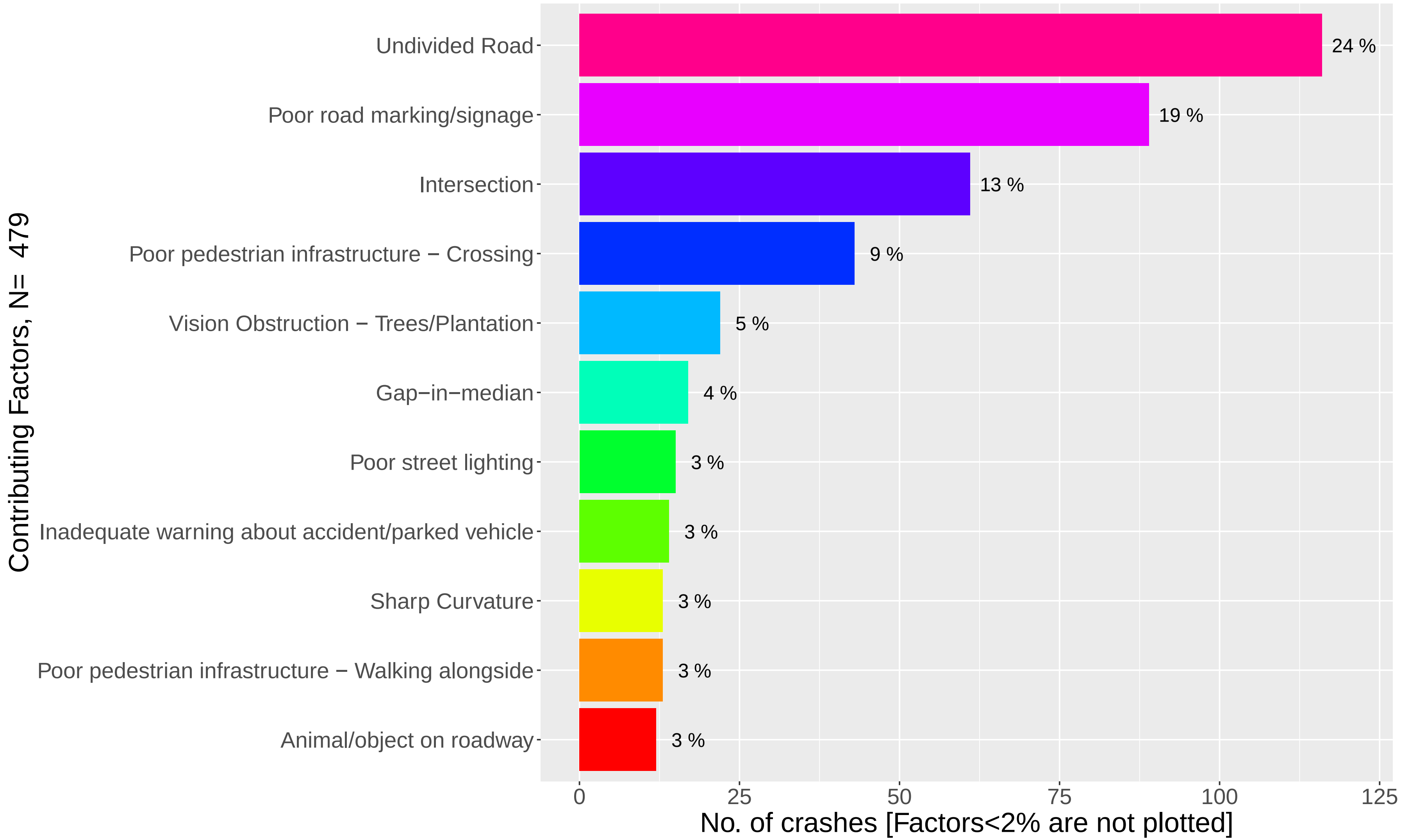

Figure 4.8: Infrastructure dependent contributing factors from sampled RASSI data with N=500 crashes

4.2 AutoDREAMing

The tool developed for the application of DREAM, AutoDREAMing, can also be considered as one of the results of this master thesis. The tool has enabled quicker DREAM analysis and an easier way to store the results of the analysis so that it could be easily used for the aggregation of DREAM charts. The steps for installing and using this tool can be found in the Appendix A.1. The setup files for this tool are found in the following repository: `https://github.com/Lakshya31/AutoDREAMing`

4.3 Aggregated Driving Reliability and Error Analysis Method Charts

Aggregation of DREAM charts is a step in identifying common crash contributing factors and crash causation mechanism. The aggregation is done based on the criteria listed in the Section 3.3.1.

Overall aggregated DREAM chart for all sampled crashes is shown in the Figure 4.9. The major phenotype or the critical event that lead to the crash is 'Timing:No Action', i.e. the road users, either drivers or the VRU, did not perform any manoeuvre that would have prevented the crash. 'Misjudgement of situation'(N=435) is the most common crash contributing factor, i.e even though there are cues for the road users to anticipate the critical event, they did not. Further, other contributing factors with frequency of occurrence following and connecting the highest factor indicates the crash causation mechanism as bounded in red color in the figure. The Figure 4.10 is the aggregated DREAM chart for all sampled crashes from the driver's perspective. The major phenotype is 'Timing:No Action' and the most common crash contributing factor is 'Expectance of certain behaviour' (N=199). The driver's are expecting VRU's to behave in a particular way. The Figure 4.11 is the overall aggregated DREAM chart for all sampled crashes from VRU's perspective. 'Timing:No Action' is the major phenotype and 'Misjudgement of situation'(N=223) is the most common crash contributing factor.

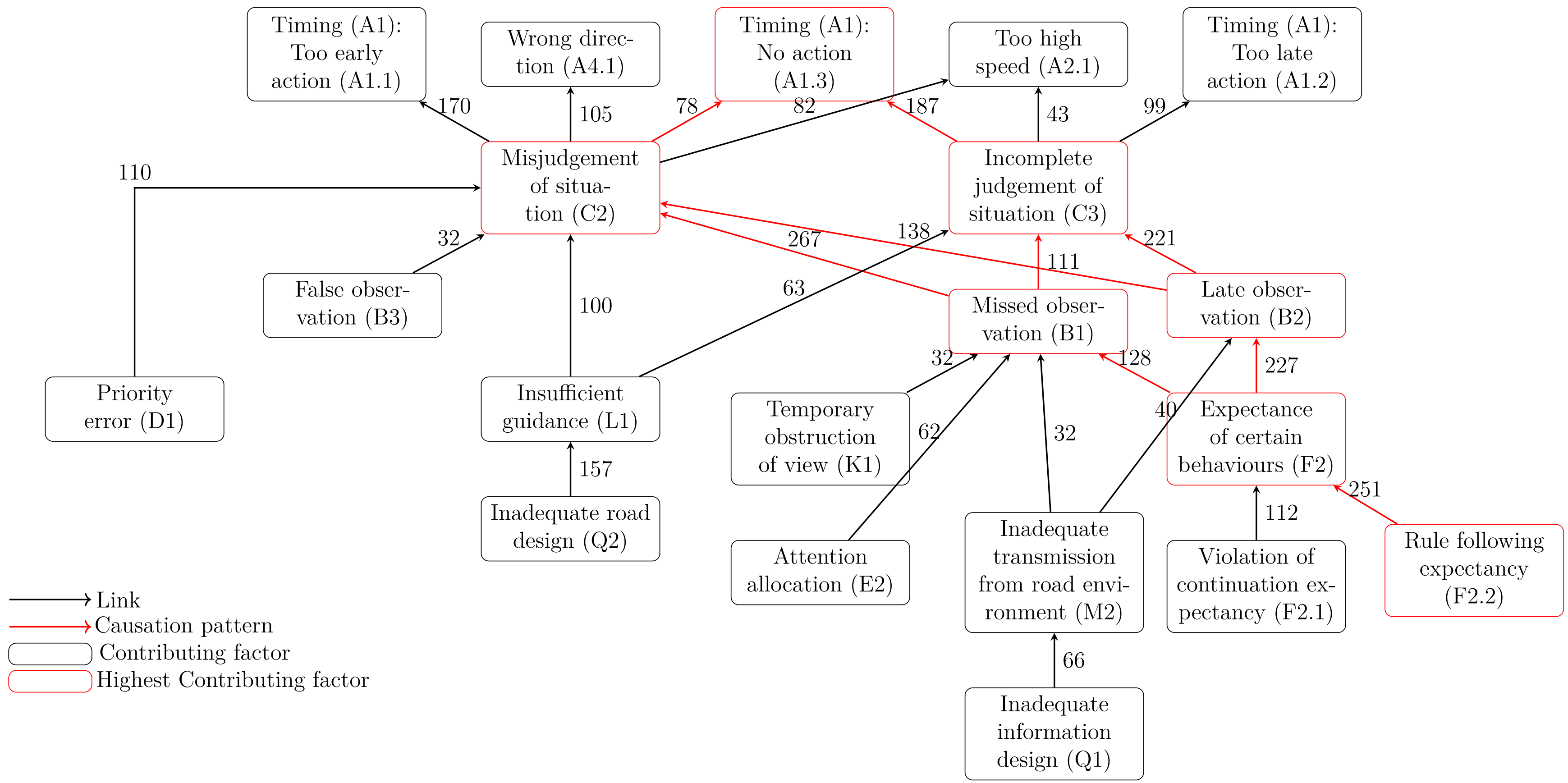

Figure 4.9: Aggregated DREAM chart for all sampled cases

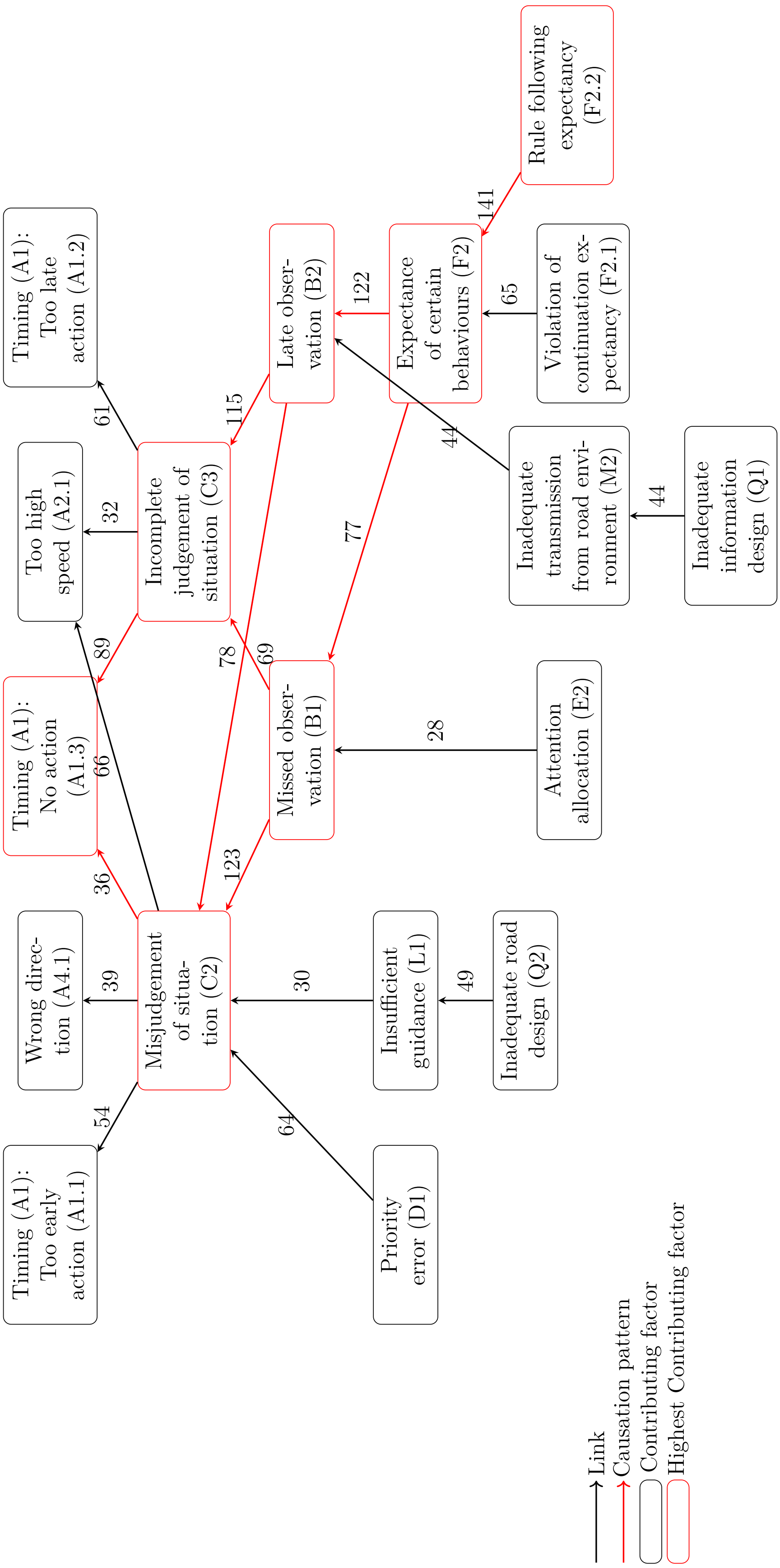

Figure 4.10: Aggregated DREAM chart for all sampled cases from driver's perspective

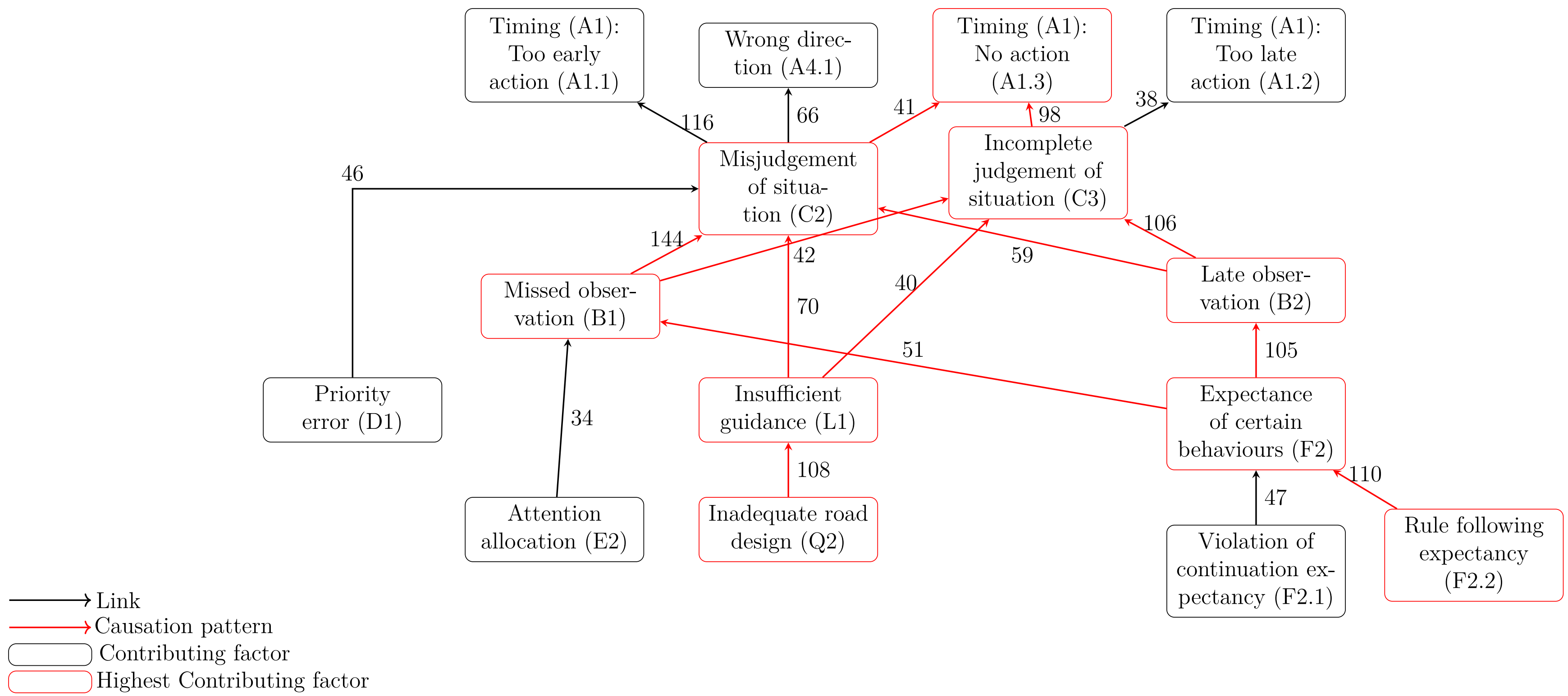

Figure 4.11: Aggregated DREAM chart for all sampled cases from VRU's perspective

The Figure 4.12 is the aggregated DREAM chart for all single vehicle crashes from driver's perspective. Here, 'Too high speed' is the most common phenotype and 'Misjudgement of situation'(N=35) is the most common crash contributing factor. Aggregated DREAM chart for single vehicle crashes from the M2W rider's perspective is shown in the Figure 4.13. The most common phenotype is 'Timing:No Action'. 'Late observation' (N=17) is the common crash contributing factor in M2W involved single vehicle crashes.

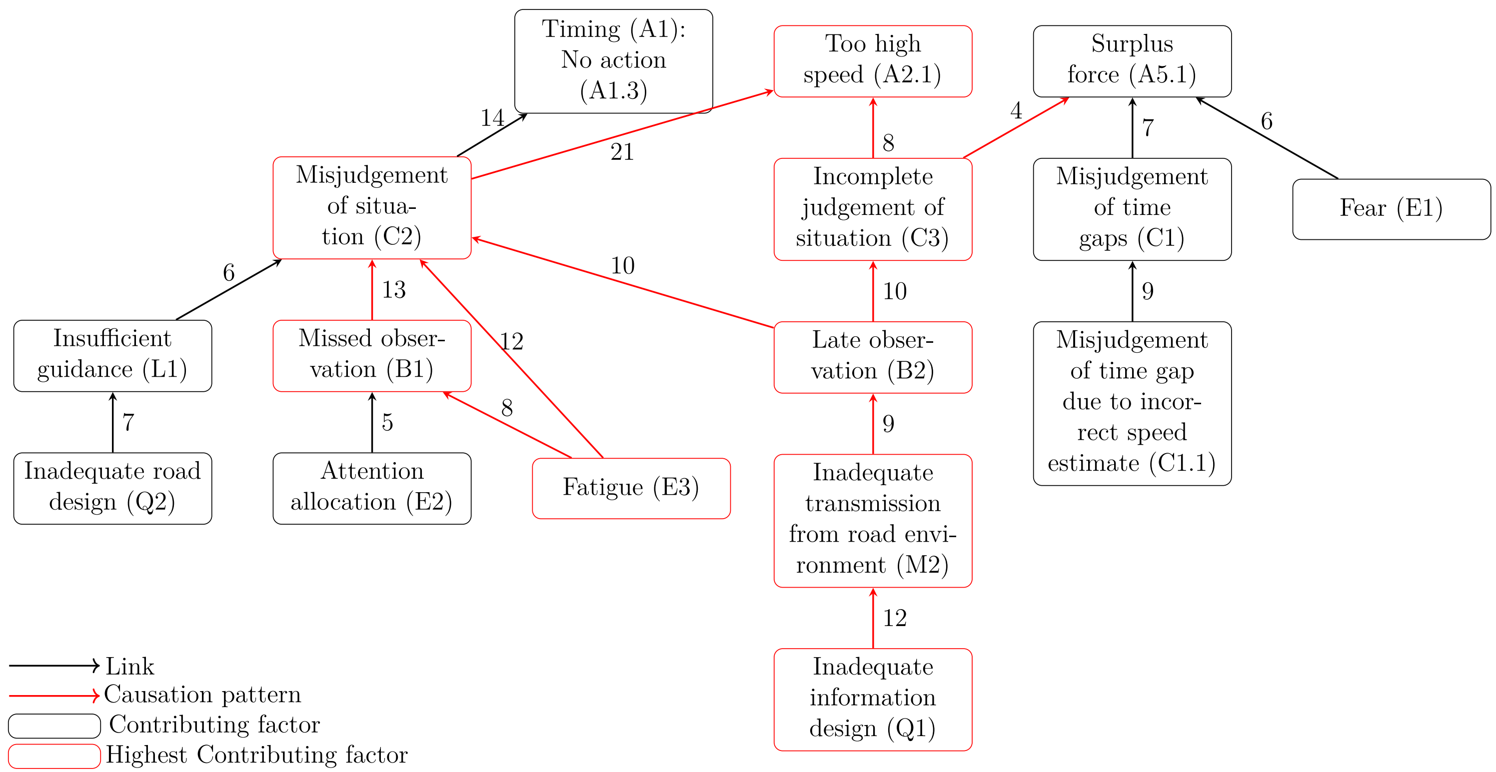

Figure 4.12: Aggregated DREAM chart for Single vehicle crashes from driver's perspective

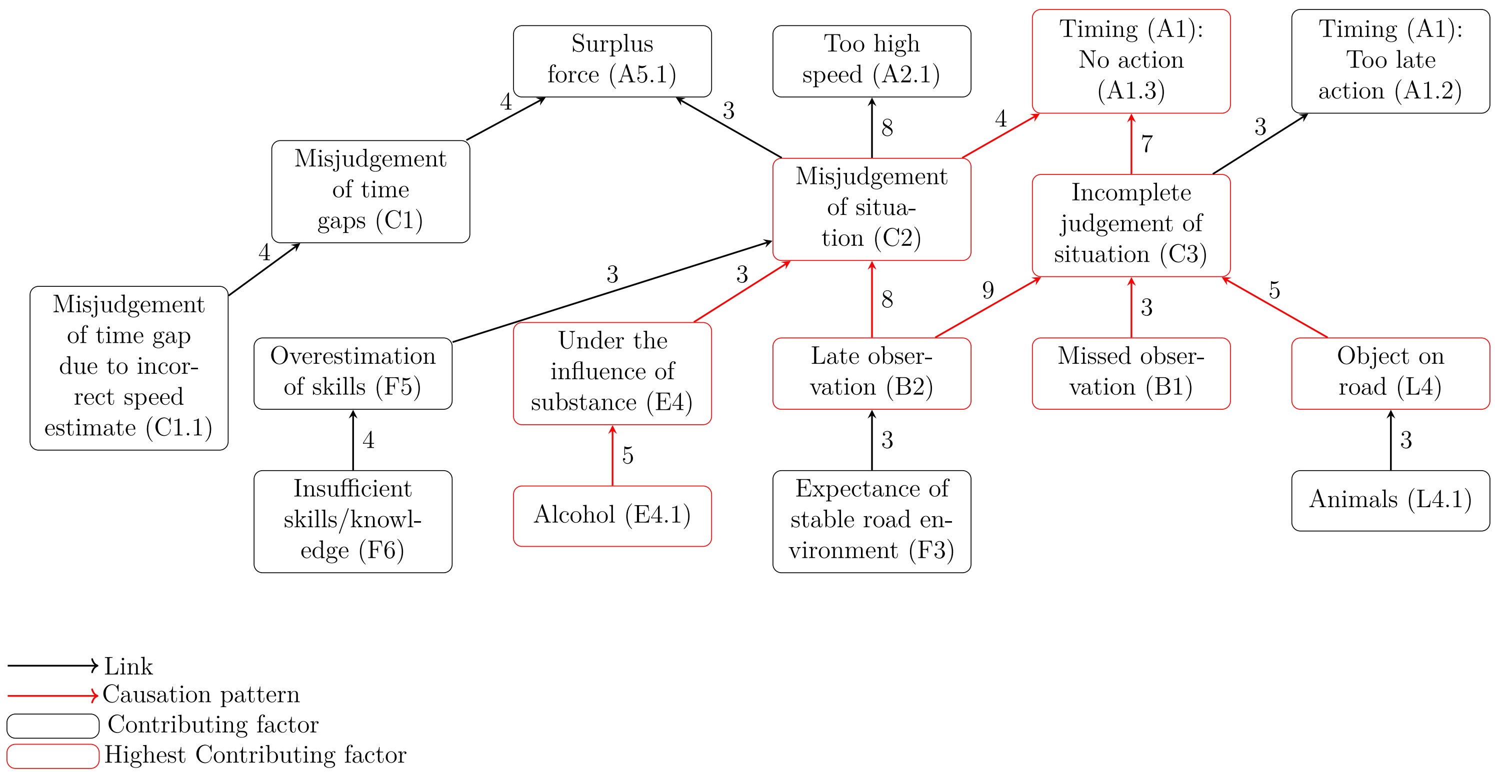

Figure 4.13: Aggregated DREAM chart for Single vehicle crashes from M2W rider's perspective

The Figure 4.14 is the aggregated DREAM chart for crashes between passenger cars and VRU from driver's perspective. The major phenotype is 'Too high speed'. 'Late observations' (N=60) is the most common crash contributing factor. The Figure 4.15 is the aggregated DREAM chart for crashes between passenger cars and VRU from VRU's perspective. The major phenotypes are 'Timing: Too early action' and 'Timing: No action'. The most common crash contributing factor is 'Misjudgement of situation' (N=58).

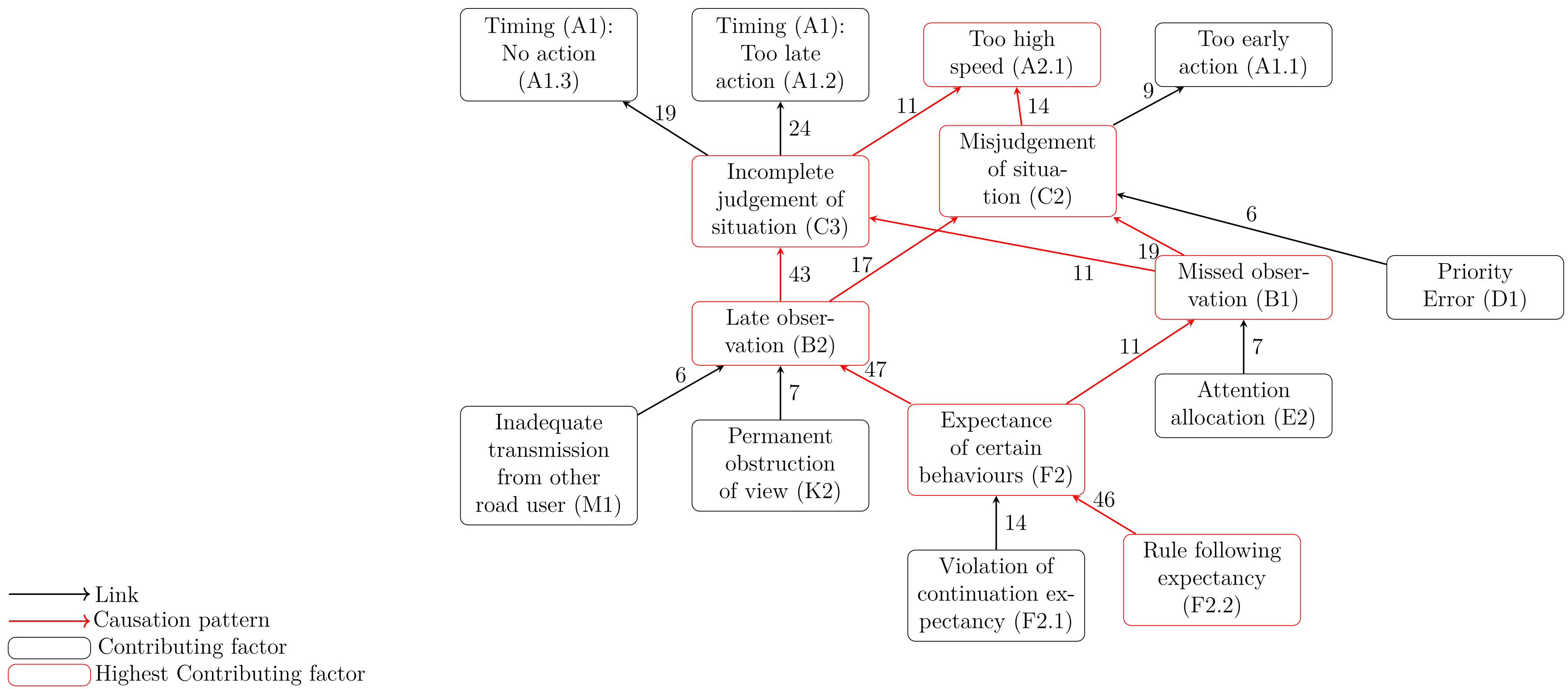

Figure 4.14: Aggregated DREAM chart for crashes involving passenger cars and VRU from driver's perspective

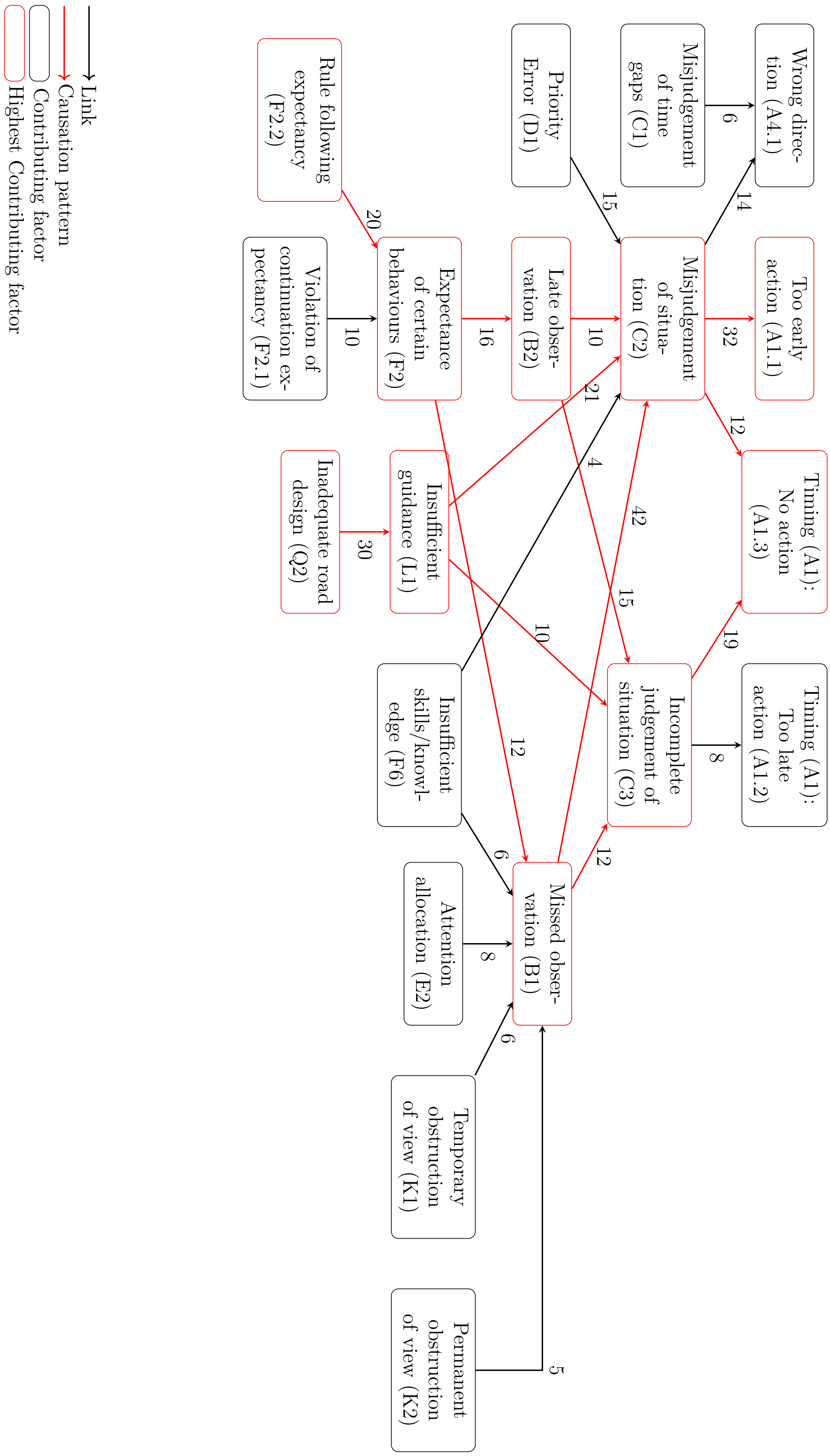

Figure 4.15: Aggregated DREAM chart for crashes involving passenger cars and VRU from VRU's perspective

The Figure 4.16 is the aggregated DREAM chart for the crashes between commercial vehicles and VRU from the perspective of drivers of the commercial vehicle. ‘Timing: No action’ is the major phenotype and ‘Expectance of certain behaviour’ (N=53) is the most common crash contributing factor. The Figure 4.17 is the aggregated DREAM chart for the crashes between commercial vehicles and VRU from the perspective of VRU. The major phenotypes are ‘Timing: Too early action’ and ‘Timing: No action’. The most common crash contributing factor is ‘Misjudgement of situation’ (N=59).

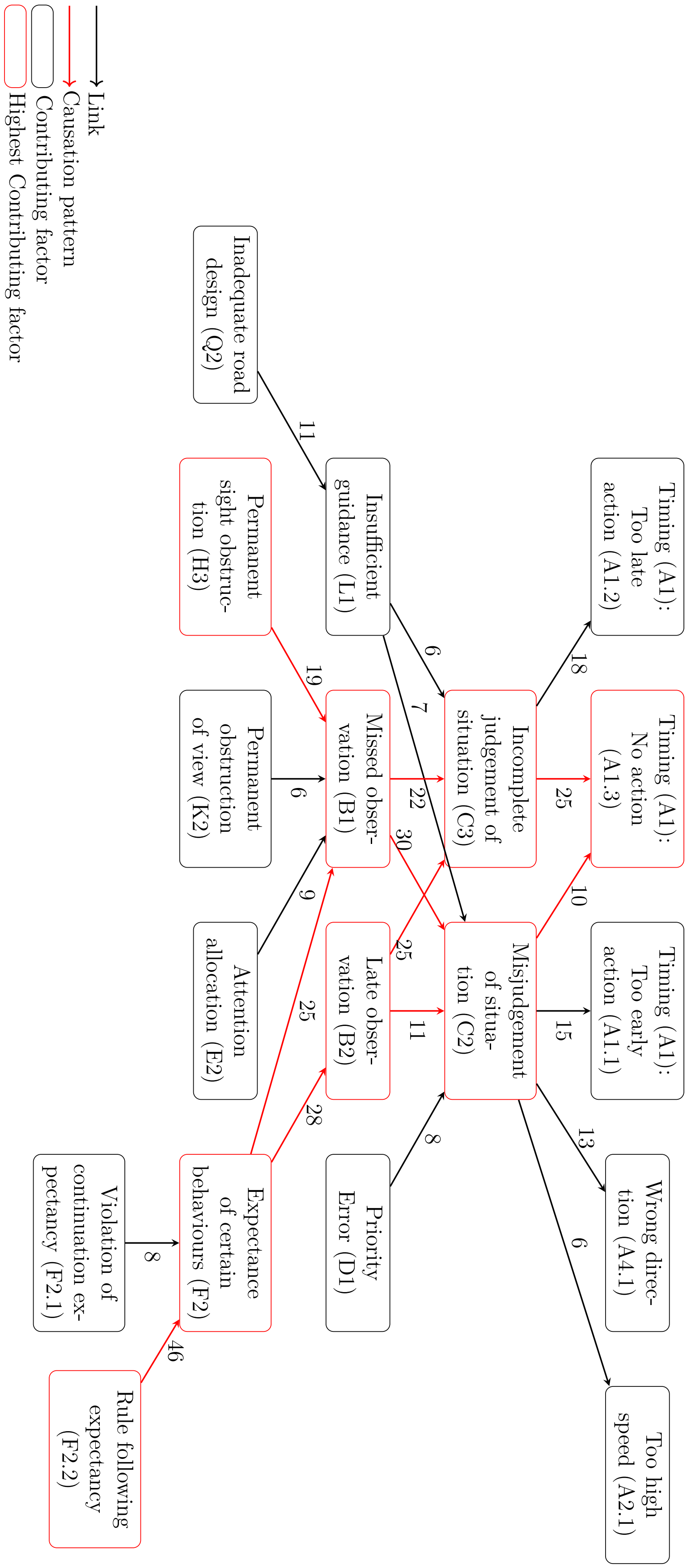

Figure 4.16: Aggregated DREAM chart for crashes involving commercial vehicles and VRU from driver's perspective

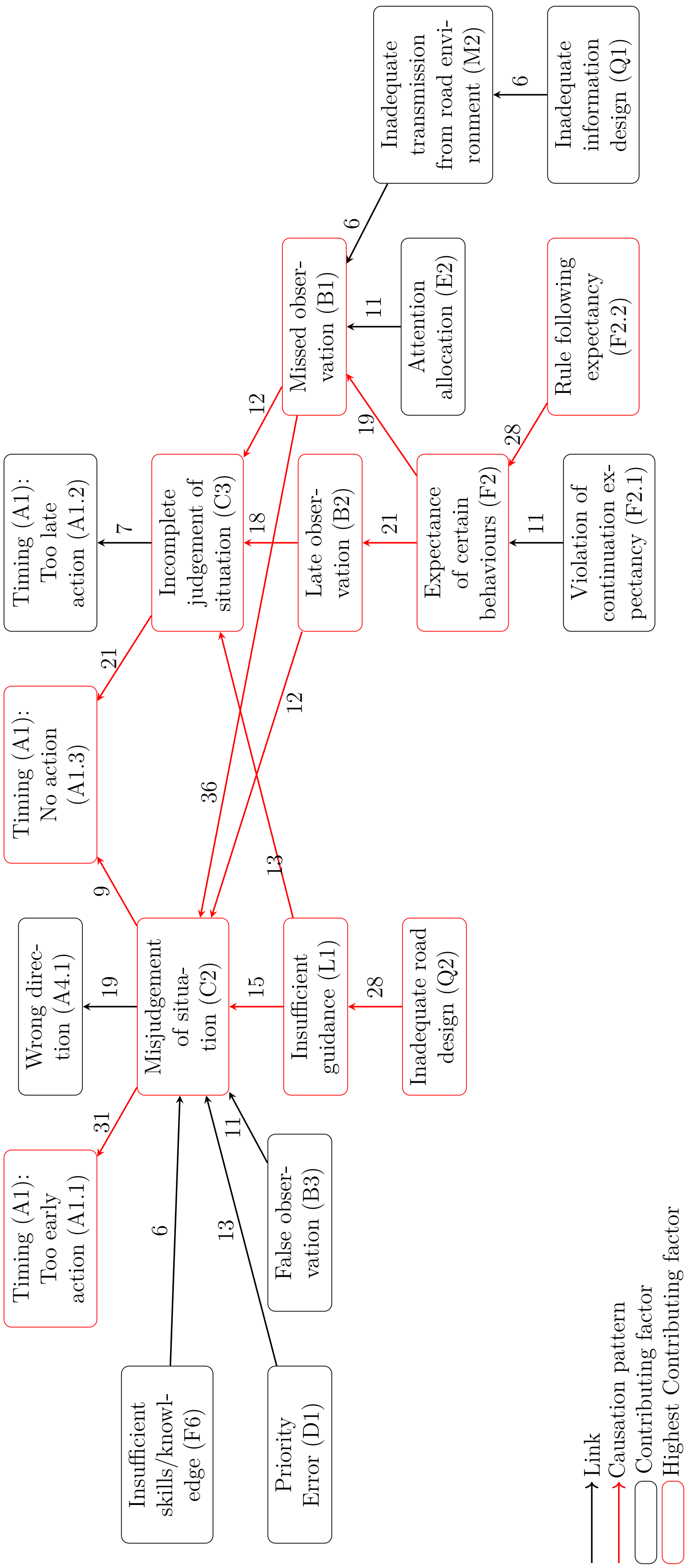

Figure 4.17: Aggregated DREAM chart for crashes involving commercial vehicles and VRU from VRU's perspective

The Figure 4.18 is the aggregated DREAM chart for the crashes between M2W and VRU from the perspective of M2W rider. The most occurring phenotype is 'Timing: No action'. 'Late observation' (N=88) is the most common crash contributing factor. The Figure 4.19 is the aggregated DREAM chart for the crashes between M2W and VRU from the perspective of URU. The most common phenotype is 'Timing: Too early action'. 'Misjudgement of situation' (N=51) is the most common crash contributing factor.

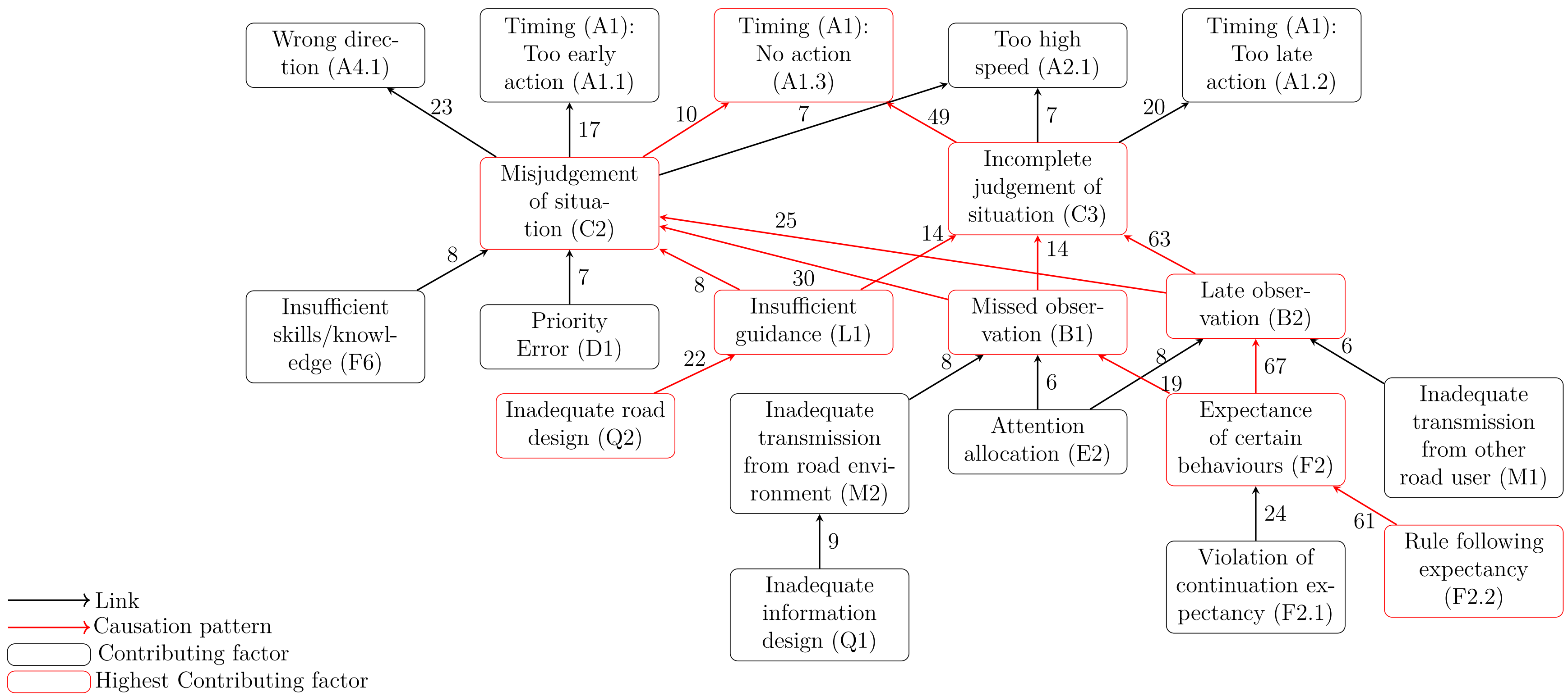

Figure 4.18: Aggregated DREAM chart for crashes involving M2W and VRU from the rider's perspective

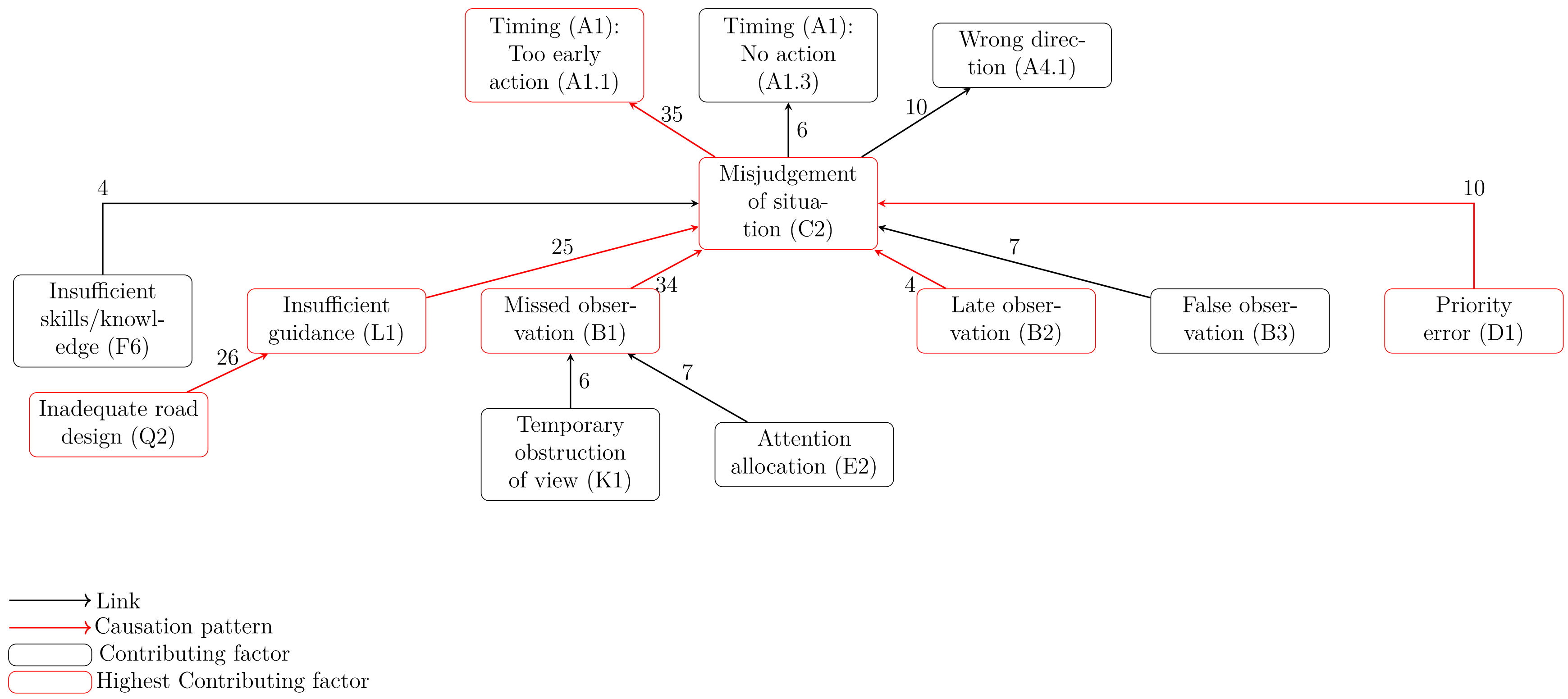

Figure 4.19: Aggregated DREAM chart for crashes involving M2W and VRU from URU's perspective

The Figure 4.20 is the aggregated DREAM chart for the crashes between commercial vehicles and passenger cars, or between passenger cars. The most common phenotype here is 'Timing: No action' and the most common crash contributing factor is 'Missed observation' (N=96).

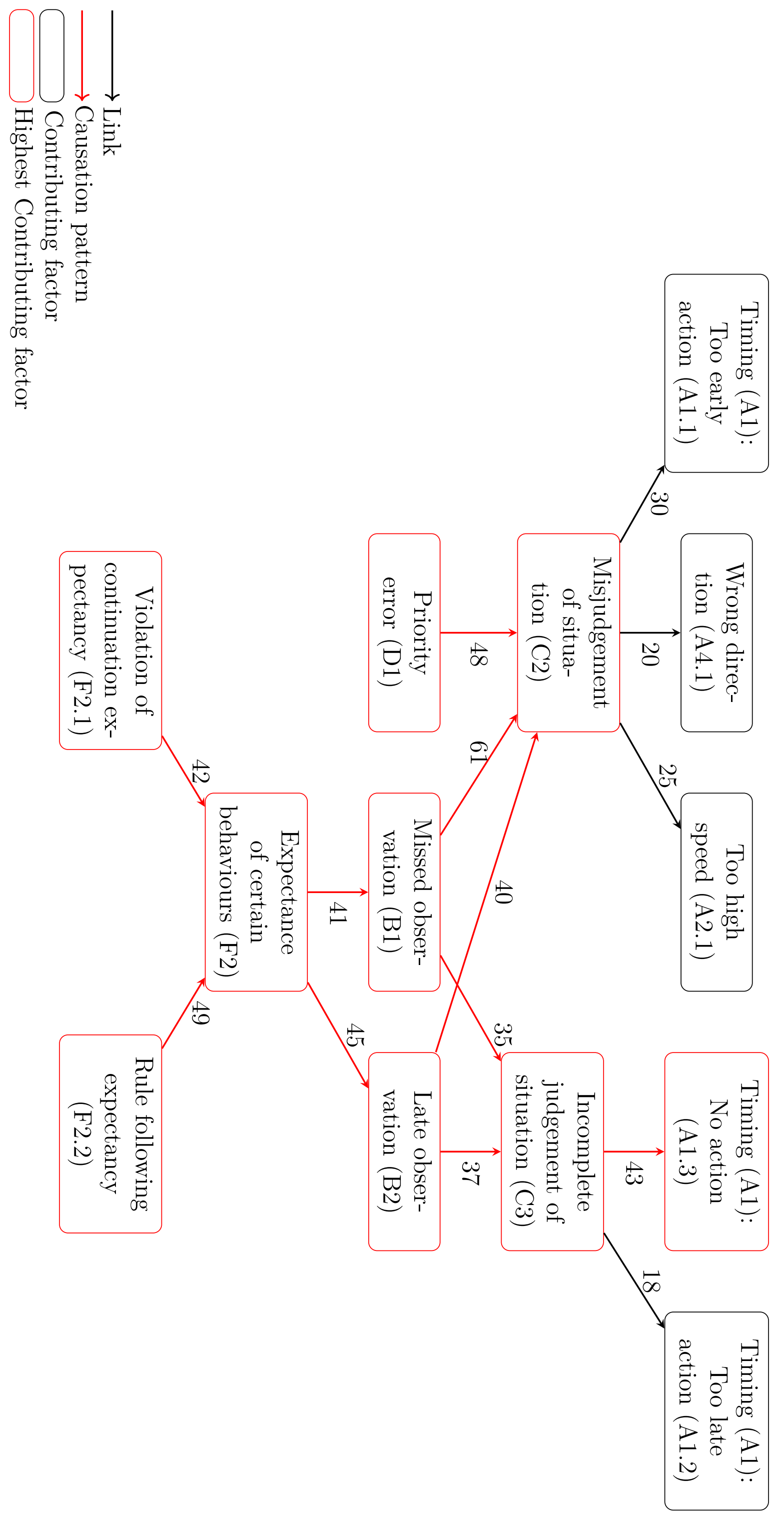

Figure 4.20: Aggregated DREAM chart for crashes involving cars and commercial vehicles

The Figure 4.21 is the aggregated DREAM chart for the crashes that occurred in the urban area. 'Timing: No action' is the major phenotype. The most common crash contributing factor is 'Misjudgement of situation' (N=293). The Figure 4.22 is the aggregated DREAM chart for the crashes that occurred in the rural area. The major occurring phenotype here is 'Timing: No action' and the most common crash contributing factor is 'Missed observation' (N=146).

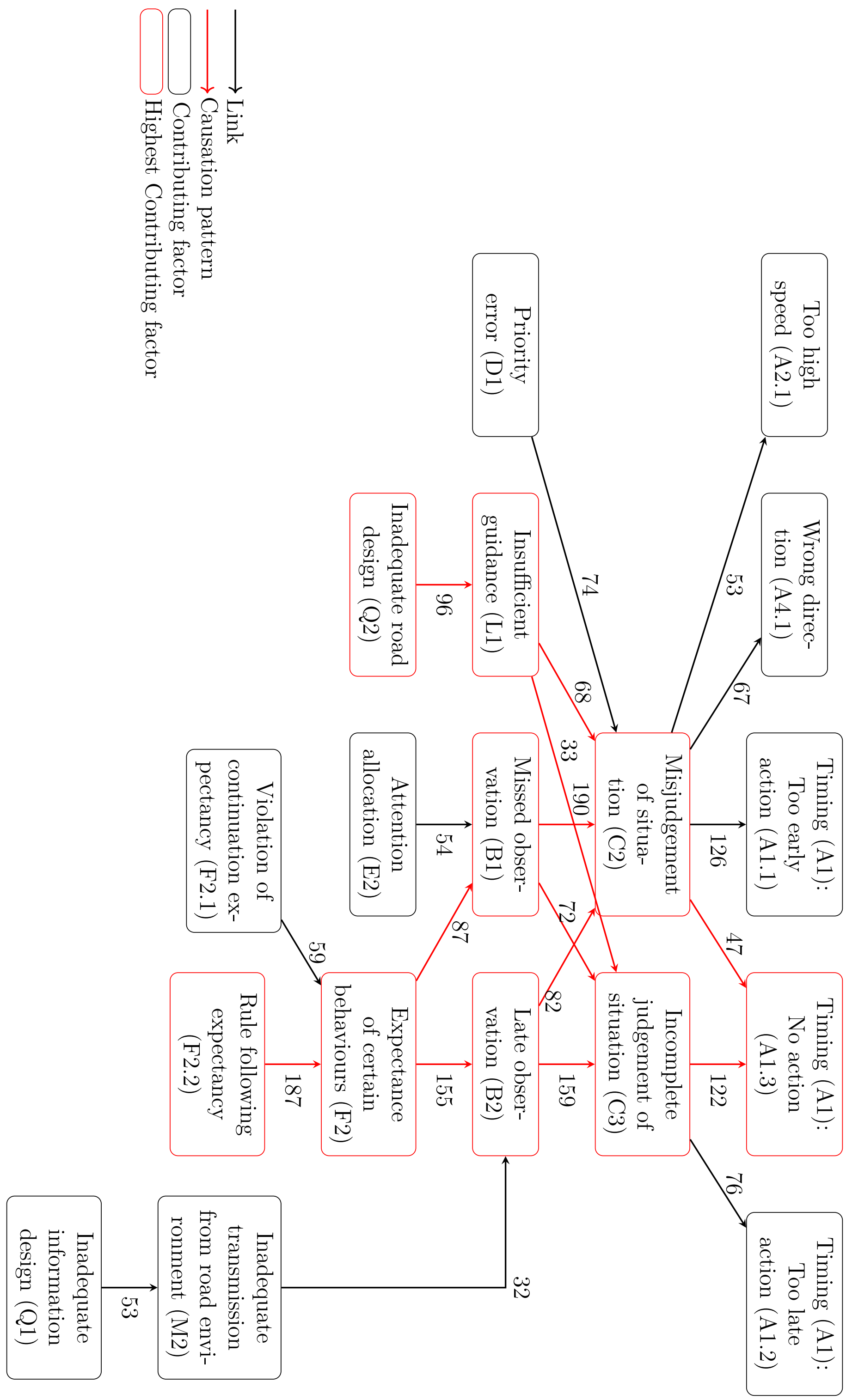

Figure 4.21: Aggregated DREAM chart for crashes that occurred in urban areas

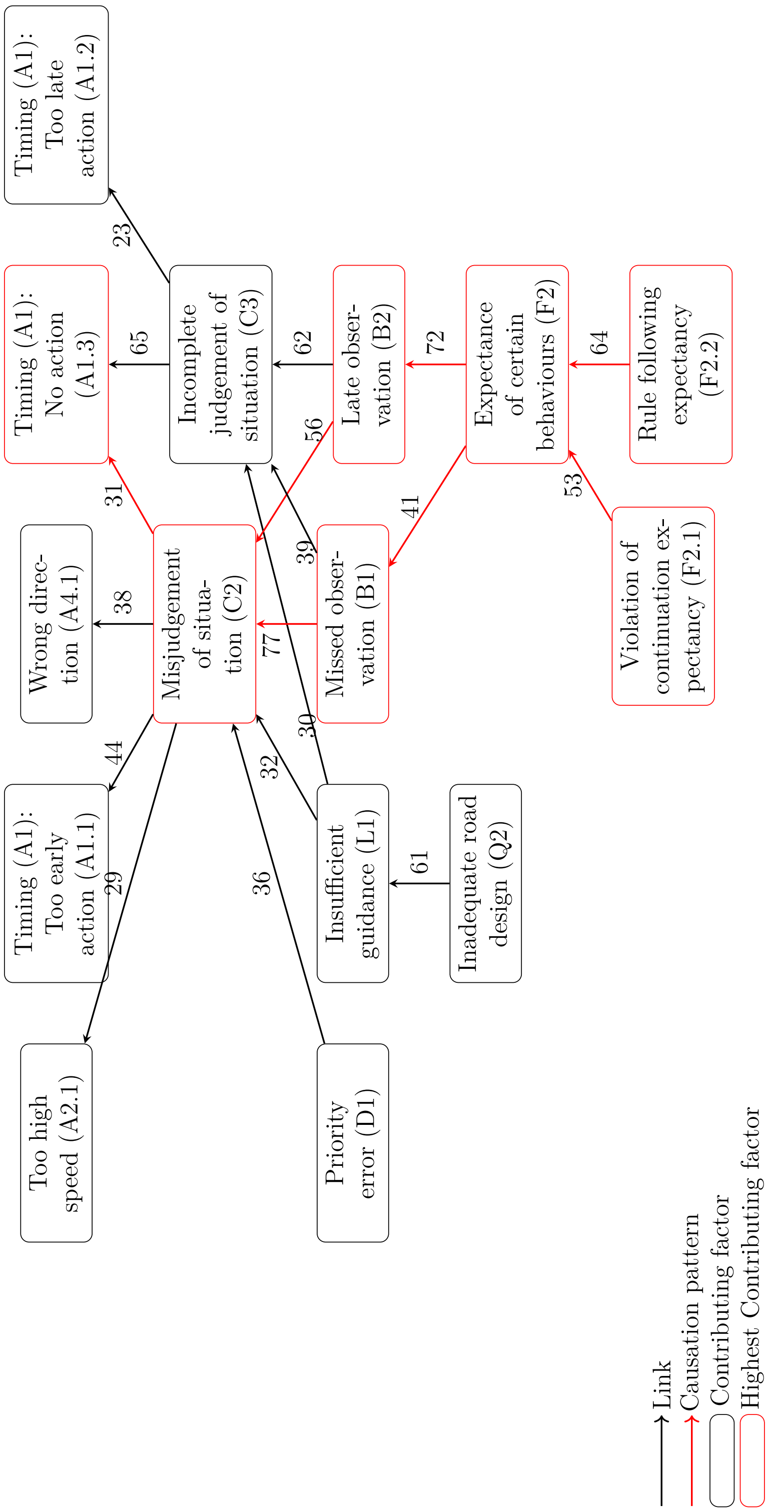

Figure 4.22: Aggregated DREAM chart for crashes that occurred in rural areas

The Figure 4.23 is the aggregated DREAM chart for the crashes that occurred in divided roads. ‘Timing: No action’ is the major phenotype. The most common crash contributing factor is ‘Incomplete judgement of situation’ (N=43). The Figure 4.24 is the aggregated DREAM chart for the crashes that occurred in the undivided roads. ‘Timing: Too early action’ is the major phenotype. The most common crash contributing factor is ‘Misjudgement of situation’ (N=50).

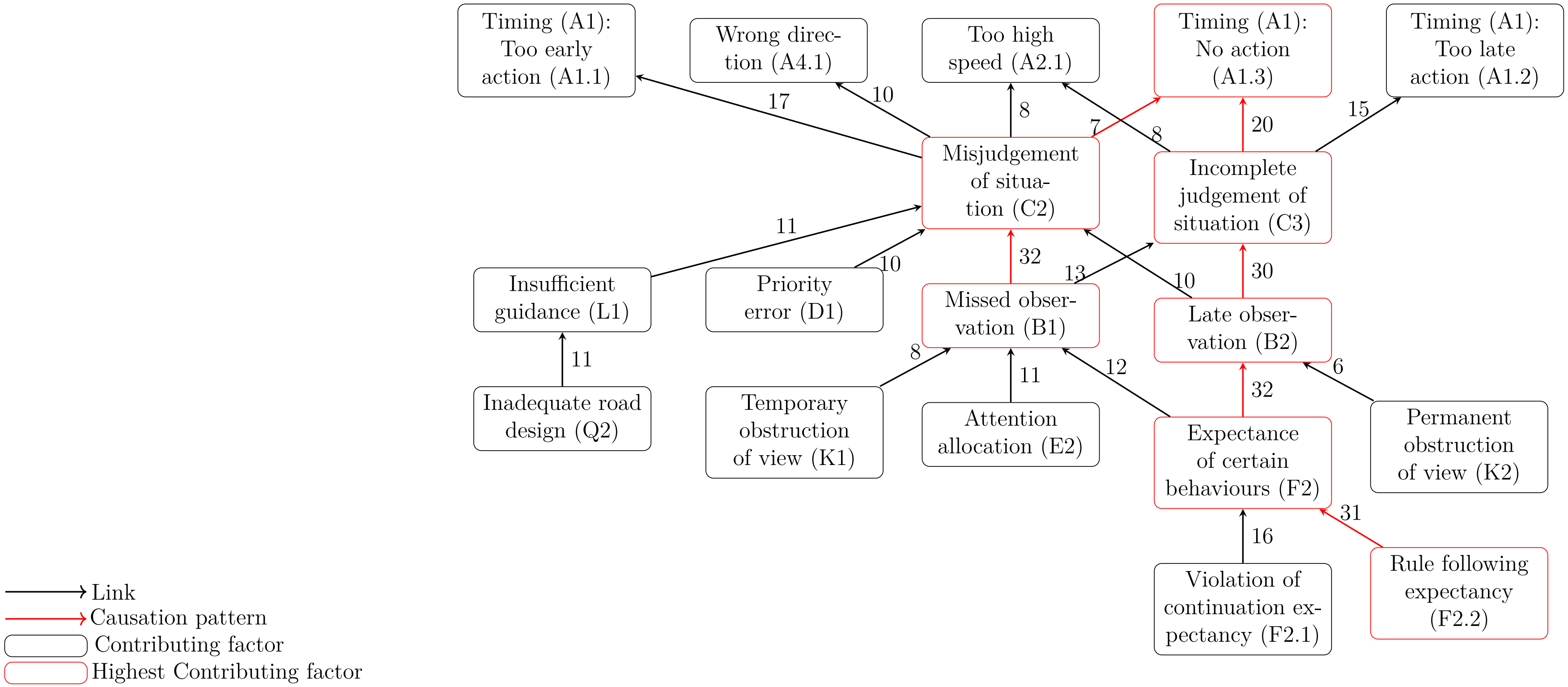

Figure 4.23: Aggregated DREAM chart for crashes that occurred in divided roads

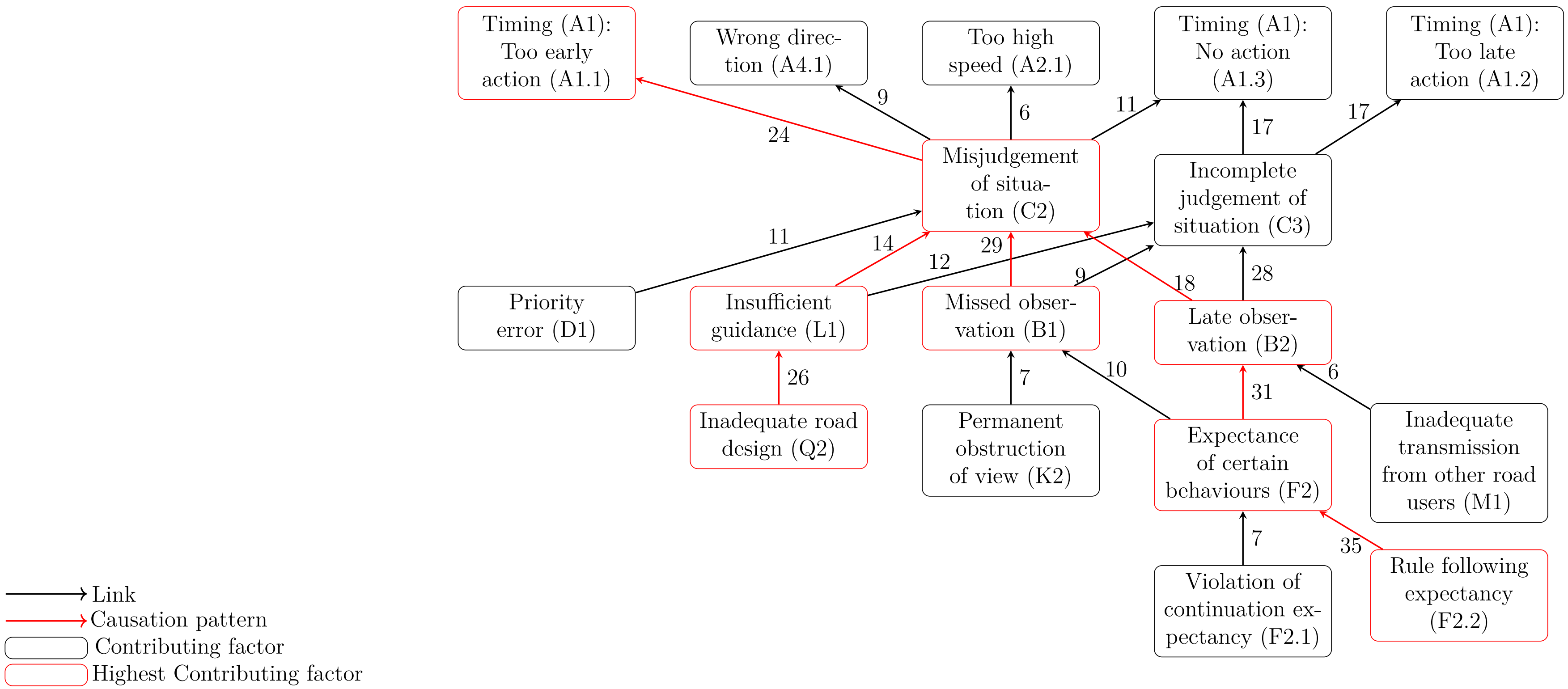

Figure 4.24: Aggregated DREAM chart for crashes that occurred in undivided roads

The Table 4.1 summarises the results of aggregated DREAM charts in various conditions. The crash types column is the main aggregating criteria and the perspective column denotes in what perspective the aggregation is carried out.

Table 4.1: Most common contributing factors observed after DREAM aggregation in different conditions

Crash types	**Perspective**	**Most common contributing factor**
All	Overall	Misjudgement of situation
All	Driver VRU	Expectance of certain behaviour Misjudgement of situation
Single vehicle crash	Driver Rider	Misjudgement of situation Late observation
Passenger car - VRU	Driver VRU	Late observation Misjudgement of situation
Commercial vehicle - VRU	Commercial vehicle VRU	Expectance of certain behaviour Misjudgement of situation
m2w - VRU	m2w URU	Late observation Misjudgement of situation
Commercial vehicle - passenger car or between passenger cars	Overall	Missed observation
Urban area	Overall	Misjudgement of situation
Rural area	Overall	Missed observation
Divided road	Overall	Misjudgement of situation
Undivided road	Overall	Misjudgement of situation

4.4 Potential countermeasures to address crashes: Advanced Driver Assistance Systems and infrastructural changes

The results from the DREAM aggregation did not result in a single crash contributing factor which stands out in the majority of crashes that could directly be addressed with the current ADAS in the market. However, the patterns in crash causation mechanisms in different cases indicate different issues that are discussed in the Section 5.4. Based on this observation, a few suggestions to improve the infrastructure as well as utilise available and proven ADAS that might potentially address the crash contributing factors to reduce the crashes are listed as follows:

- Systems for identifying other road users ahead of the vehicle and provide warning would prevent or mitigate the crashes due to missed observation of other road users
- AEB or EBA could help to effectively help prevent or mitigate the crashes due to late observations by the driver
- The systems like DSM could possibly address single vehicle crashes due to driver distraction or fatigue
- Breath Alcohol Ignition Interlock devices could be used to restrict the driver who has consumed alcohol prior to driving
- Infrastructural improvements like divided roads with positive median barrier

and good information design also could help reduce crashes

4.5 Potential Benefits of Countermeasures

When all the roads are divided with a positive barrier in the median, 447 crashes (14%) are prevented out of all 3167 crashes. When the vehicles are deployed with FCW systems, the number of crashes prevented is 462 (14%). Further, when the vehicles are also deployed with FCW for detecting pedestrians, another 397 crashes (13%) are prevented. Inclusion of system to have an interlock like the Breath Alcohol Ignition Interlock device in order not to let the drivers who have consumed alcohol to drive the vehicle, another 136 crashes (4%) could be avoided. Furthermore, with the DSM in place to monitor drowsy and distracted drivers, 569 more crashes (18%) could be avoided. If all the above systems together with the infrastructural changes are in place, 1722 crashes (54%) could be prevented.

However, it is to be noted that the results are based on the sampling of 100 crashes from each of the five major crash types occurring in India as per RASSI data. The sampling is not performed in proportion to the actual number of crashes occurring in India rather it is according to the RASSI database.

5
Discussion

5.1 Road Accident Sampling System India and Driving Reliability and Error Analysis Method

The crash contributing factors in the RASSI database are collective information of crashes based on the site inspections, police reports and crash participants interviews. On the other hand DREAM is a structured way of analyzing crashes by identifying relation between each crash contributing factor and, later try to break this relation using some strategy and thus preventing the occurrence of the crashes.

In RASSI data, it is seen that undivided roads and poor road markings or signage are infrastructure related contributing factors that are highly responsible for crashes. But it is not easy to understand how these factors would develop and lead to crashes. With the help of DREAM, we could easily understand how these factors are responsible for crashes in a single image. When it comes to comparing the crash contributing factors, both the distribution of RASSI data and DREAM aggregation almost have the comparable results. However, in DREAM, the relation between different crash contributing factors and how these factors finally lead to crashes could be understood just by a glance at the DREAM charts [24]. Further, it is to be noted that this study is carried out based on the random sample in five categories and the weights that make the data representative of India is not used. One main reason is the complexity in adding weights for the DREAM chart. In addition, the RASSI data is over-represented with crashes involving passenger cars [7]. So, the results in this project are not representative of entire India and it is limited to the RASSI database.

5.2 Validation of Driving Reliability and Error Analysis Method on Road Accident Sampling System India data

There was quite a dilemma whether or not to use DREAM on RASSI data because DREAM was mainly developed considering European crash databases. The large difference in infrastructure, population and vehicle density between India and European countries might have deemed the application of DREAM invalid. However, a quick trial run of the DREAM on about 20 cases cleared the ambiguity.

The results of both individual and aggregated DREAM charts are quite comparable to the works done previously for different in-depth databases like SafetyNet [12], Intact [25], NDS Japan [31] and STRADA [32]. It is a rule to stop the assigning of genotypes when there are no further information regarding a contributing factor. In few cases in the RASSI data, information to be concluded after interviews are missing due to various reasons. In such cases, the DREAM chart will not have any specific crash contributing factor and it will stop at a higher level of analysis. So, even though there might be some practical difficulty in collecting the data, from research perspective, it would be good to have some additional information in the RASSI database like:

- Why an observation is missed while overtaking and leading to a head-on collision in Undivided roads?
- What factor specifically leads to driver distractions?

5.3 AutoDREAMing

There is no doubt that AutoDREAMing, the tool developed by Lakshya Sharma and Keshava Pranath, has enhanced the speed and quality of the process of analysis. However, it still has to be developed so that the aggregation based on a certain criteria could be easily handled. Currently, the results were filtered manually based on the criteria and used for aggregation. Also, currently there is no live back-end database for the tool. Hence editing the uploaded data is not possible. Instead it has to be erased and a new entry has to be created. Further, the reason why a particular phenotype or genotype is selected (i.e the description of why a contributing factor is selected) could not be added due to the limitations in handling and storing the vast data in the software. Instead, an advanced version of AutoDREAMing, like a standard database with the possibility of editing the DREAM parameters, storing the reasons or comments and an option to filter and select crashes of interest would be beneficial.

5.4 Aggregated Driving Reliability and Error Analysis Method Charts

As shown in the Figure 4.9, linking the most common crash contributing factors, it can be seen that majority of the road users either misjudge or incompletely judge the situation, and either miss or observe other road user very late, and cause the crash. The study based on the EU project SafetyNet showed that about 70% of road users misjudged or incompletely judged the situation and led to the conflict [12]. This is due to the subject road user expecting a certain behaviour from other road user, i.e. expecting other road user to follow a certain rule. With this expectation in mind, the subject road users do not perform any crash avoidance manoeuvre as they are not aware that other road user did not follow the rule. The study of driver behaviour in car to pedestrian crashes from NDS Japan [31], and causation patterns and data collection for accidents in Norway [33] have identified that expectance of certain behaviour from other road user as one of the major crash contributing factor. An exact crash causation mechanism is seen for the overall aggregation from the drivers' point of view as shown in Figure 4.10. A similar pattern as the overall aggregation is seen for overall aggregation from VRU's perspective in Figure 4.11. In addition, insufficient guidance and inadequate road design are also leading for false interpretation of the situation.

In the single vehicle crashes from driver's perspective which is shown in Figure 4.12, connecting the common crash contributing factors, it is seen that the situations are either misjudged or incompletely judged by over-speeding drivers leading to miss or observe the changes in the road very late and lead to single vehicle crashes. It is also pointed that inadequate road and information design are leading for the late observation and fatigue which are mainly responsible for missed observation or misjudged situation. When it comes to the single crashes from riders of the M2W (Figure-4.13), there is no avoidance manoeuvre performed by the riders to avoid the crash. The situation is either misjudged or incompletely judged due to missed or late observations, presence of objects or animals on road, and also due to intoxication by the consumption of alcohol. An attempt to understand the crash causation mechanism in single vehicle crashes in Gothenburg, Sweden had also observed over-speeding and missed observation as major causes for crashes [34]. Furthermore, it was noted in this study that stressed driver was also one of the main reasons for crashes.

As shown in the Figure 4.14, from the drivers' perspective in crashes between passenger car and VRU, the situations are either misjudged or incompletely judged by over-speeding drivers leading to miss or observe the changes in the road very late and lead to crashes. This is due to the subject road user expecting a certain behaviour from other road user similar to that seen in overall aggregation. When seen from the VRU's perspective, the crash causation mechanism is very similar to that of driver's but the critical events are either performing actions early or not at all. A research to identify causation mechanisms in car to VRU crashes from the perspective of VRU had discussed the similar results [12]. Further, insufficient guidance and inadequate road design are also leading for the interpretation of the situation wrongly.

The crashes between commercial vehicles and VRU from driver's perspective in Figure 4.16 shows exact same pattern as overall aggregation but an addition of a crash contributing factor for missed observation, the permanent obstruction of view is highlighted. It would have been a surprise if this factor is not highlighted due to the simple reason of commercial vehicles possessing a larger area of blind spots. The Volvo Trucks annual report on safety has also pointed that blind spot is one of the main reasons for the drivers to not see other road users, especially the VRU [35]. However, the causation pattern from the VRU's perspective is exactly similar to that of VRU's perspective in passenger car and VRU crashes.

In the crashes between M2W and VRU, the situations are either misjudged or incompletely judged by the drivers due to missed or very late observation of other road user and led to crashes. Also, insufficient guidance and inadequate road design are responsible for the interpretation of situation wrongly. Further, the observation is affected by expecting other road users to follow a certain rule. A review on factors responsible for M2W mentioned inadequate road design and judgemental issues as some of the major reasons for crashes [36]. In case of the URU's perspective (Figure 4.19), the cyclist or pedestrian performs an action very early by misjudging of the situation either due to missed or late observation, priority errors or insufficient guidance and inadequate road design. The VRU perspective in implications for active safety systems has mentioned visual obstructions and inadequate planning as most common crash contributing factors [12].

In the Figure 4.20, the aggregation of DREAM charts for crashes involving passenger cars and commercial vehicles, shows that the situations are either misjudged or incompletely judged by the drivers due to missed or very late observation of other road user and leads to crashes because of expectations of certain behaviour from other road user. Further, situations are also misjudged by not maintaining the required priorities.

In the Figure 4.21, for the crashes that occurred in urban area, the crash causation mechanism is similar to that of overall aggregation with an addition that insufficient guidance and Inadequate road design are also responsible for interpreting situations differently. A similar observation is found in the 4.24. Here, a rule following expectance from other road user is also the common crash contributing factor. Further, in Figure 4.22, in the aggregated DREAM chart for the crashes that occurred in rural area, the road users either misjudge or incompletely judge the situation and either missed or observed other road user very late due to expecting other road user to behave in a particular way and ended up in crash by not performing any crash avoidance manoeuvre which is also observed in the crashes that occurred in divided roads (Figure 4.23. The studies on common patterns in aggregated causation charts, causation patterns from Norway and various other studies from Sweden had pointed at quite similar observations [12, 26, 32, 33].

5.5 Identified Countermeasures: Advanced Driver Assistance Systems and Infrastructural changes

Since it was not very evident to find one single crash contributing factor, addressing which would potentially reduce the number of crashes in India, a set of solutions based on the DREAM analysis carried out in different scenarios are suggested in this project. To identify and reduce the crashes even more, additional studies are required in aggregating the DREAM charts in some particular situations like crashes in intersections, round-about, etc. Researchers in the studies to identify crash causation mechanisms in particular situations have found varied results [12, 26]. So it is important to study the particular situations as well.

It is seen that in majority of the DREAM charts, expecting of certain behaviour from other road user lead to crashes. In many cases, subject driver did not expect other vehicle to come into their lane while overtaking an un-involved vehicle and ends in head-on collision. Also, from the overall distribution of contributing factors from RASSI, undivided roads are leading contributors for crashes. This link has lead to proposing of dividing all roads with a positive median barrier. A whopping 97% reduction in cross-median crashes is observed in rural four lane freeways in the USA [37].

Missed observation and late observation of other road users are one of the frequent observed crash contributing factors in the aggregated charts. To assist the driver or to apply the break autonomously in such situations, EBA or AEB is used in the countries with better infrastructure and regulations [38]. However, using systems like AEB is very expensive and is very far from reality in India. Instead a comparatively cheaper system would be the warning system. Hence, FCW is suggested to use so that front-rear crashes and crashes with pedestrians could be potentially avoided by warning the driver to act in critical situations.

Some of the crashes, mainly single vehicle crashes, are due to the drowsy and distracted driver. A very efficient method to address this is to use DSM which monitors the driver and alerts the driver in case of drowsiness or if the sight is away from the road. However, this system has a challenge addressing the cases where drivers are looking at the road but not seeing. Also, alcohol consumption prior to driving has lead to a few crashes. So systems like Breathing Alcohol Ignition Interlocking Device is suggested to avoid such crashes. Various organizations and automotive companies are emphasizing the need and use of these systems [38, 39, 40]. One thing to to be noted here is, some of the suggested countermeasures are now being used mainly in developed world. So, implementing these expensive devices in less expensive M2W and other vehicles is quite challenging in countries like India. Also, the reliability and the behaviour of the sensors used in these systems are to be verified.

5.6 Effectiveness of Countermeasures: Advanced Driver Assistance Systems and Infrastructural changes

The rules as mentioned in Section 3.6 have resulted in an ideal number of crashes that would have been prevented if the proposed system were in place. The improvement in infrastructure and introduction of three ADAS have resulted in reduction of crashes by about 54% in the data analyzed. But the point to note is that the data is not representative and also the countermeasures suggested are warning systems. So the actual number of crashes prevented would be less than the estimated effectiveness. Selection of the sample of crashes in this study in proportion to the actual number of crashes occurring in India would have resulted in a more representational estimates. Nevertheless, at a first outset, implementing these countermeasures should be very advantageous to reduce the crashes in India. However, the time and cost for making it happen is not considered here as this project mainly focuses on identifying the problem. In a study on active and passive safety technologies for passenger cars, use of both the technologies have estimated a large reduction of fatalities due to crashes in India [7].

5.7 Future work

To further understand the crashes, the aggregation has to be done at particular scenarios like in a X-intersection or a signal, etc. This would help to understand if there is a similarity or difference in the crashes occurring at different locations, and would help develop or identify ADAS that would reduce even more crashes. Further, setting up a system for Naturalistic Driving Data (NDD) studies based on the current results would help to compare and validate this project. Furthermore, applying DREAM on this collected NDD would provide answers to the questions discussed in Section 5.2. Also, it should be taken care to utilise the weighted data so that the results would represent entire India. The tool used for storing dream parameter-AutoDREAMing could be improved further to make it like a live database. The aggregation tool, DREAM-AT could be updated to include weights, and also an easier way of filtering crashes would be useful.

6 Conclusion

DREAM when performed on RASSI database provides results that are comparable with previous works in Europe and helps to identify most common crash contributing factors at a higher level. Some of the common crash contributing factors observed in different aggregation criteria are inadequate road design, missed or late observations of other road users and driver distraction. However, no single ADAS that could majorly address the crashes are observed in this study. But a few changes in the infrastructure like dividing all the roads with a positive median barrier, deploying ADAS like FCW, DSM, Breath alcohol ignition interlock device, etc. would address the observed common crash contributing factors and thus prevent or mitigate crashes in the future. Based on the sampling method followed in this project, about 54% of the crashes in the RASSI database are potentially avoided by implementing the countermeasures.

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A

Appendix 1

A.1 AutoDREAMing

AutoDREAMing is a software that runs locally on the computer. The person analyzing cases and intending to apply the principle of DREAM has to download the two files, Frontend and Backend, to a specific location and set those two as directories in two separate command windows (terminals). Then executing the command 'npm run local' in both the terminals would enable a local server in the Backend, and Frontend would be ready to launch the tool. The analyzer has to go to `http://localhost:3000/` in a web browser, preferably Google chrome. More information on how to install the setup files can be found in: `https://github.com/Lakshya31/AutoDREAMing`. People interested in improvising the tool are always welcome and the source files could be found in the same location.

An example to create a DREAM chart shown in Figure 2.1, the analyzer has to follow the following steps:

- Select Phenotype as `Timing (A1): No Action (A1.3)` and press `Next` in the first card
- Select `Misjudgement of situation (C2)` in the next card and press `Next`
- Select `Missed Observation (B1)`, `Inattention (E2)` and `Expectance of certain behaviours (F2)` in the next card and press `Next`
- Select `Permanent obstruction of view (K2)` corresponding to `Missed Observation (B1)` and press `Next`
- Now press `Done` to enter the case identification number. Here, to differentiate between different road users, case identification number is appended with an underscore followed by numbers.
  Example: If a case identification number is `abcde12345` then here it is stored as `abcde12345_1` and `abcde12345_2` for first and second road users respectively
- Select `Element Year`[1]and `Nodes`[1] file where the new DREAM parameters are to be saved. Based on the requirement of the project, new files could be used every time or a single file could be used to save the data cumulatively
- The DREAM results would be appended to the selected files and automatically two new files would be downloaded to the default Download location.

[1]a .CSV file found in the repository with the required format

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