AN OVERVIEW OF CAR-TO-TWO-WHEELER ACCIDENTS IN CHINA: GUIDANCE FOR AEB ASSESSMENT

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ABSTRACT

Users of two- and three-wheelers account for 35% of total traffic fatalities in China, a statistic which calls for attention. C-NCAP has predicted that AEB for pedestrian protection will be assessed from 2018 onwards, and it appears likely that AEB for two-wheelers will also be assessed in the near future. The objective of this study was to describe car-to-two-wheeler accidents in China in detail to guide the selection of relevant scenarios and test parameters for two-wheeler AEB assessment. Data from the China In-Depth Accident Study for the years 2011 to 2016 was analyzed for this study. Statistics were available for 830 accidents involving one two-wheeler (referring to two-wheeled vehicle) and one M1 vehicle (passenger car, SUV, or minivan) and 1,017 recorded two-wheeler users, including both drivers and passengers of the two-wheelers.

Of the 830 two-wheelers, electric powered-two-wheelers constituted 42%; motorcycles, 32%; moped, 16%; and normal or electric bicycles, 11%. Of the total 1,017 two-wheeler users involved, only 12% of them wore a helmet and nearly half (46%) were severely or fatally injured.

The study included 830 car-to-two-wheeler accidents, of which 67% occurred during daytime. City areas accounted for 67% of accidents and 80% occurred on roads with a speed limit below 60 km/h. The majority of accidents occurred at road junctions (62%).

A case-by-case analysis of the relative movements of the bicycle and car before the collision showed that in 47% of accidents the car and the two-wheeler were moving perpendicularly to each other; in 21%, longitudinally from opposite directions; and in 31%, longitudinally from the same direction. In the majority of cases, the car was going straight forward before the crash (52%), while in 28% it was turning left, and in 20% it was turning right. For the two-wheelers, 83% were going straight forward, while 15% were turning left, and only 2% were turning right. Information about vehicle speed was not available, but road speed limits can give an indication of vehicle speed. The data was not necessarily representative of China as national statistics are not available.

The results of this study show that an electric-powered two-wheeler is the most common type of two-wheeler, which is easy to understand that the electric power-two-wheelers are very popular in China. The most common accident scenario for the car-to-two-wheeler accidents is a straightforward moving vehicle colliding with a straight forward moving two-wheeler in perpendicular direction. This can be explained by the fact that most accidents happened at crossings.

Our recommendations, therefore, based on Chinese real-world car-to-two-wheeler accidents, are that priority for AEB assessment should be given to a straightforward-moving car impacting a straightforward-moving electric powered two-wheeler from a perpendicular direction with a speed of up to 60 km/h during daytime. Turning cars, collisions with motorcycles, and nighttime driving are the scenarios that should be considered next.

INTRODUCTION

In 2008, there were an estimated 313 million powered two-wheelers (PTWs) in operation worldwide, a vast majority of which (77%) were in Asia. The worldwide annual production of PTWs is about 50 million units, comparable in number to the 65 million passenger cars [1].

In China, increasing ownership of PTWs has been observed in recent years, due to rising fuel costs, traffic congestion, and the parking difficulties related to passenger cars [2]. However, PTWs represent an important challenge for road safety. PTW users are at far more risk than car occupants per kilometer ridden in terms of fatalities and severe injuries entailing long-term disability [3]. Moreover, they have not benefited from safety improvements at the same pace as car occupants over recent decades [1].

Globally, PTWs account for nearly a quarter of all road traffic fatalities. The South-East Asian Region and Western Pacific Region stand out: as much as 34% of all traffic fatalities are PTW users in these regions [3]. In China, the total number of traffic fatalities decreased from 107,077 to 65,225 between 2004 and 2010. However, fatalities of PTW users increased from 589 to 4,029 [4] [5]. Non-powered two-wheelers, i.e. cyclists, are also at risk. Worldwide about 48,000 cyclist fatalities occur each year [3]. In China, of the total 58,539 fatalities in road traffic accidents in 2013, 8% were cyclists [3].

The automotive industry is making significant efforts to develop and implement active and passive safety systems in cars to avoid or mitigate collisions with vulnerable road users. In 1997, Euro NCAP introduced its first pedestrian impact test for the head, upper leg and lower leg [6]. In recent years, pedestrian protection airbags and pedestrian hood lifters have been introduced [7] [8]. Pedestrian safety has, by most developers, been given priority in the first instance but systems also applicable to cyclists are following. One of the most promising active safety systems is Autonomous Emergency Braking (AEB); research indicates that AEB has considerable potential to save lives and mitigate severe injuries in frontal car-to-pedestrian collisions [9]. Such a system is able to bring the car to a safe halt before a pedestrian is struck or can at least reduce the speed of the collision [10].

Euro NCAP included AEB for pedestrians as part of their test and assessment procedure in 2016. Euro NCAP additionally intends to include Cyclist-AEB systems in the safety assessment from 2018 onwards [11]. C-NCAP 2018 has included an AEB test assessment for pedestrians in its draft version, and it is highly likely that AEB systems for 2-wheeler protection will also be included in assessments in the near future.

To date, PTW accident characteristics have been reported primarily for developed countries [11] or in regard to passive safety in China [1] [12]. There is a need to study the car-to-two-wheeler accident characteristics of real world accidents in China in order to provide guidance for AEB assessment.

The objective of this study, therefore, is to meet this need though providing a detailed analysis of car-to-two-wheeler accidents in China to identify the relevant scenarios and test parameters for car to two-wheeler AEB assessment.

METHOD

CIDAS, short for China In-Depth Accident Study, is one of the most detailed accident databases available in China today. It started as a project initiated by the China Automobile Technology and Research Center (CATARC) in 2011, with the aim of collecting 500 to 600 cases per year. Currently, there are 6 cities involved in the project, from the north to the south of China: Changchun, Beijing, Weihai, Ningbo, Chengdu and Foshan. The intention is to cover all the characteristic road types and economic situations represented in China. The CIDAS investigation team, working in shifts for 24 hours per day, goes to the accident scene with the traffic police if someone is injured, if at least one four-wheeled vehicle is involved, and if the accident scene is still intact when the investigation team arrive. The CIDAS database has 31 data tables, containing over 2,800 data items in total.

In this study, the CIDAS database was queried for accidents involving two-wheelers from July 2011 until February 2016. There were 1,470 vehicle-to-two-wheeler accidents in total, with all injury severities and all types of impacts involved. When the vehicle type was restricted to M1 vehicles (vehicles used for the carriage of passengers and comprising not more than eight seats in addition to the driver's seat), 1,087 cases were yielded. As the objective of the study was to guide the assessment of potential vehicle-equipped AEB systems, two-wheelers crashed with the rear end of vehicles were

excluded from the database. In addition, some accidents were excluded due to incompleteness of the case photos. In total, 833 car-to-two-wheeler accidents were found to match the scope of the study. There were 3 cases where the drivers of the two-wheeler were under 12 years old. These 3 cases were not included in the study, but child passengers were included. So in the end, the final sample comprised 830 cases. In total, 1,017 two-wheeler users were involved in the 830 car-to-two-wheeler accidents.

Accident scenario classification was carried out based on the relative location of the car and the two-wheeler, the driving motion of the car, and the driving motion of the two-wheeler. This information was gathered in a case-by-case manner based four types of data: the coding of a variable called UTYP (Unfalltyp) in the CIDAS database, accident description, driver interviews and CAD sketches. UTYP is a three digit code giving a brief explanation of the accident, especially for the description of the situation or the conflict that led to the accident [13] [14].

RESULTS

Type of two-wheeled vehicle
Based on different types of driving power and body structure of two-wheelers, four types of two-wheelers were identified: bicycle/e-bike, electric-Powered Two Wheeler (e-PTW), moped and motorcycle, as shown in Table 1, which provides pictures of typical body structures.

Table 1.
Summary of two-wheelers characteristics

| Category	Description	Picture
Bicycle/e-bike	Mainly human powered	
e-PTW	Mainly electric powered	
Moped	Fuel powered, small wheel	
Motorcycle	Fuel powered, big wheel	

Of the total 830 car-to-two-wheeler accidents, the most common type of two-wheelers involved was e-PTW (42%), followed by motorcycle (32%), moped (16%) and bicycle or e-bike (11%).

Environment Information
Most accidents happened in the daytime (67%) rather than nighttime (33%). 68% occurred in city areas while 32% occurred outside city areas. In terms of weather, 72% of accidents occurred on clear days while in 19% it was cloudy and in 8% rainy.

Speed limit
As no reconstruction results are available in CIDAS, the speed limit of the road on which the car was travelling was used to estimate the travelling speed of the vehicle. As Figure 1 shows, around 34% of roads had a speed limit of under 40 km/h. The majority of accidents happened on roads with speed limits of 60 km/h or under. No car-to-two-wheeler accidents happened on roads with speed limits higher than 90 km/h.
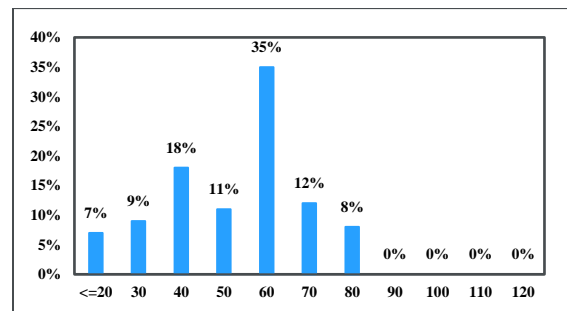
Figure 1. Speed limit.

Road type
The most common types of roadway on whichcar-to-two-wheeler accidents occur are road junctions, including intersections, T-junctions, and Y-junctions. Many accidents happened at the exit or entrance of a gas station, suburb, or shopping area, as shown in Figure 2.
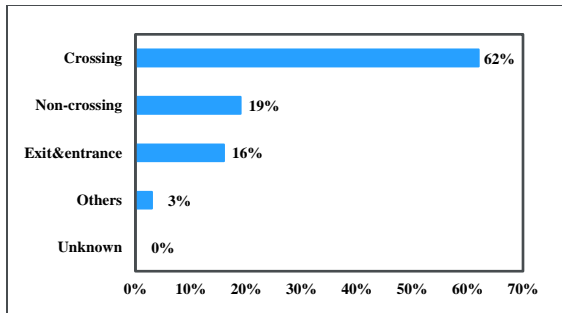
Figure 2. Road type.

Bicycle lane & traffic light control
Nearly half of the roads on which two-wheelers were travelling did not have a bicycle lane. Further, of the total 830 car-to-two-wheeler accidents, 67% happened on stretches of road or junctions without traffic light control and only 23% in areas with traffic light control.

View obstruction
From the view of the car driver, most two-wheelers (84%) were visible before the crash. However, there were still many two-wheelers (12%) obscured by walls, parked vehicles, and bushes. Figure 3 illustrates some examples.

a) Wall   b) Parked vehicle
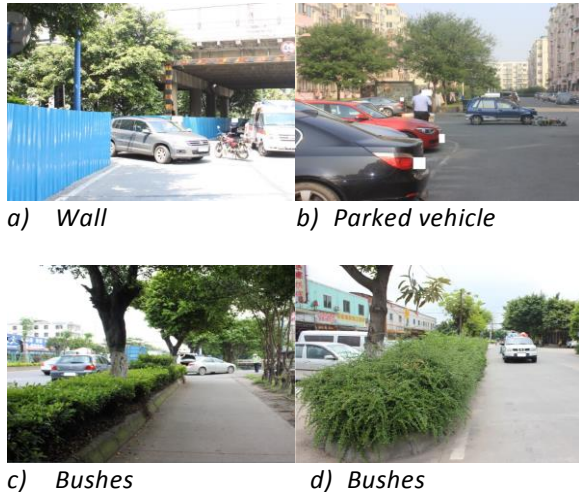
c) Bushes   d) Bushes
Figure 3. Type of view obstructions.

Relative movement of the car and the two-wheeler
We grouped the car and the two-wheeler according to their relative movements before the crash. The most common relative movement was that of the car and the two-wheeler travelling from directions perpendicular to each other (47%), followed by their travelling longitudinally in the same direction (31%), and then longitudinally in opposite directions (21%).
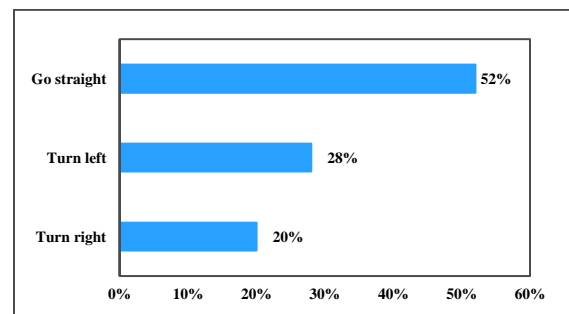
Pre-crash driving behavior
The pre-crash driving behaviors of the car and the two-wheeler were analysed and specified as either going straight, turning left or turning right. As shown in Figure 4, most car drivers were travelling straight forward before the crash, followed by turning left. Very few were turning right before the crash. Similarly, most of the two-wheeler drivers were going straight forward before the crash, followed by making turns. However, compared to car drivers, more two-wheeler drivers were turning right, as Figure 5 shows.
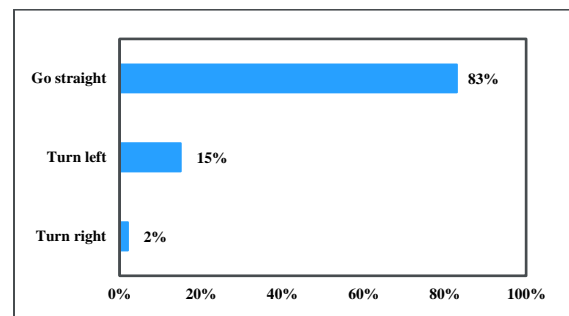
Figure 4. Pre-crash driving behavior of the car.

Figure 5. Pre-crash driving behavior of the two-wheeler.

Accident classification in CIDAS
Combining the relative movement information with the pre-crash driving behavior results in a specification of accident situations on different road types as presented in Table 2. Accidents with unknown or other information about the relative movement and pre-crash driving behavior of the car and the two-wheeler were excluded. The most common accident situation was that both the car and the two-wheeler were going straight ahead in
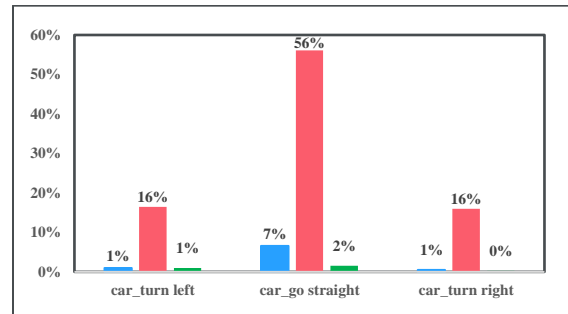
directions perpendicular to each other (n=221), followed by cases where the car was turning right and the two-wheeler was travelling straight from longitudinal same direction (n=83). Cases where the car was turning left and the two-wheeler was travelling straight from longitudinal opposite direction were also common (n=81) in the data sample.

Table 2.
Summary of accident situations (N=822)

| Perpendicular	Car_turn left	Car_go straight	Car_turn right
Two-wheeler_ turn left	4	26	2
Two-wheeler_ go straight	65	221	63
Two-wheeler_ turn right	4	6	1
Longitudinal same direction			
Two-wheeler_ turn left	4	47	1
Two-wheeler_ go straight	67	48	83
Two-wheeler_ turn right	0	4	2
Longitudinal opposite direction			
Two-wheeler_ turn left	3	33	1
Two-wheeler_ go straight	81	39	14
Two-wheeler_ turn right	2	0	1

Perpendicular Cases where the car and the two-wheeler were driving perpendicularly to each other before the crash are shown in Figure 6. In the figure, each collection contains three bars, the left bar corresponding to the two-wheeler turning left, the middle bar corresponding to the two-wheeler going straight forward and the right bar corresponding to the two-wheeler turning right. The sum of all bars is 100%. The most common accident situation was that both the car and the two-wheeler were going straight. An equal share (16%) involved the car turning to the left or right while the two-wheeler was going straight. There were

also some cases with the car going straight, and the two-wheeler making left turns.
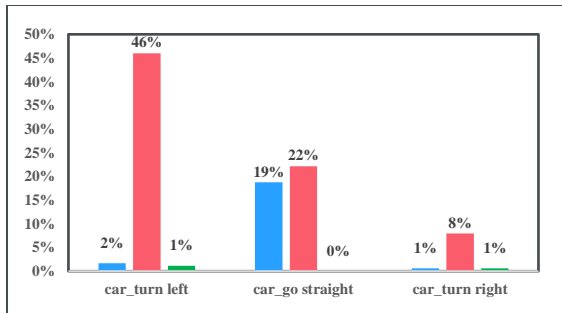

Figure 6. Proportion of accidents where the car and the two-wheeler were perpendicular to each other before the crash.

Longitudinal same direction For the cases when the car and the two-wheeler were driving longitudinally in the same direction, no big difference was identified between the car turning left or right when the two-wheeler was going straight. Similarly, when the car was going straight, there was no substantial difference between left and right turns of the two-wheeler, as shown in Figure 7
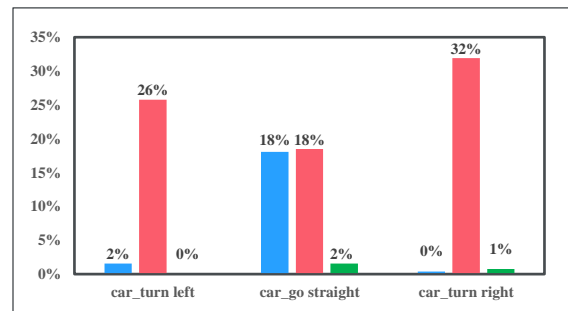
Figure 7. Proportion of accidents where the car and the two-wheeler were travelling longitudinally in the same direction before the crash.

Longitudinal opposite direction As shown in Figure 8, when the car was travelling longitudinally to the two-wheeler from the opposite direction, nearly half of cases involved the car turning left and the two-wheeler going straight, while around 40% of cases involved either the car and the two-wheeler going straight, or the car going straight and the two-wheeler turning left.

Figure 8. Proportion of accidents where the car and the two-wheeler were travelling from longitudinal opposite direction before the crash.

Person Information

Injury severity More males (69%) compared to females (31%) were injured. Of the total two-wheeler users, 46% sustained slight injuries, 38% were severely injured, 8% sustained fatal injuries and 8% were uninjured. The mean age of the two-wheeler user was 40 years old, with youngest at 10 years old, and oldest at 85 years old. Only a few (12%) were found to be wearing a helmet, most (84%) were not. Helmet usage was unknown for the remainder (4%).

Injury body regions Of the total 1 017 two-wheeler users, 935 sustained injuries. 586 users had multiple injuries. As illustrated in Figure 9, 48% sustained injuries to the head and 49% to the lower extremities.
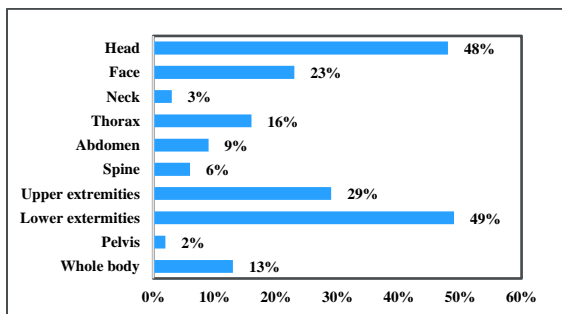
Figure 9. Injury body distribution.

DISCUSSION

Results
Our findings are similar in many respects to those of a study based on the German in-depth accident database GIDAS [15], which also found that most car-to-two-wheeler accidents happen where two or more roads intersect and in city areas. Results from GIDAS also suggest that some accidents happen at exits or entrances, as found in CIDAS. More accidents occurred at night in CIDAS compared to GIDAS; this might be due to different lifestyles in China and Germany.

Our findings differ, however, from those of a study offering an in-depth analysis of bicyclist accidents in Changsha, China [16], which found that the majority of bicycle accidents happened on straight roads. In contrast, we found that two-wheeler accidents were more frequent at junctions, a difference which might be due to the geographic characteristics or different two-wheeler types of the investigation area in Changsha.

A previous study based on real-life traffic data in Shanghai, China, showed a similar distribution of the relative movement between the car and the two-wheeled vehicle [17]. One difference was, however, that more cases were found where the pre-crash movements of the car and the two-wheeler were perpendicular to each other. A possible reason is that the cases were mostly drawn from one district of Shanghai, where crossing roads are more common. Another reason might be due to the low sample size of less than 100, which would affect the distribution of results. Accident databases with different types of investigation areas and a sufficient sample size are necessary to give a good representation of real world traffic situations.

Methodology
Situational parameters important for car-based AEB systems for two-wheeler protection were studied: the relative movement between the car and the two-wheeler, and the pre-crash driving behavior of each participant. In this study, a case-by-case analysis was carried out. Relative movement was identified from accident sketches and accident descriptions together with a predefined variable in CIDAS called UTYP. In CIDAS, accident sketches were drawn based on the on-scene measurements; an example is given in Figure 10. In this case, both the car and the two-wheeler were travelling from east to west before the car turned left into the entrance of a school. The front of the two-wheeler crashed with the left front part of the car and the driver of the two-wheeler was injured in the accident. Based on this information, the relative movement between

the car and the two-wheeler was identified as longitudinal, same direction.
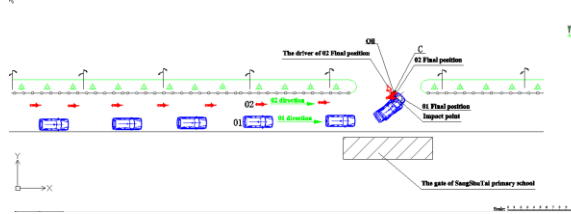
Figure 10. Example of accident sketches in CIDAS.

Instead a variable called UTYP can be used identify the accident situations, see Appendix 1. For example, as shown in Figure 11, UTYP 341 represents the accident situation wherein the car (A in the figure) and the two-wheeler (B in the figure) are perpendicular to each other before the crash.

341 - crossing - bicycle with right of way from bicycle lane left and straight
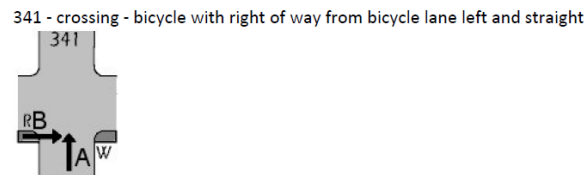
Figure 11. Example of UTYP 341.

Comparing these two methods, we found that 86% of cases would be grouped in the same category with regard to the parameter *relative movement between the car and the two-wheeler before the crash*. The mismatch of the remaining cases may be due to an incorrect coding of UTYP in CIDAS: after correcting some of the UTYP coding, the mismatch rate decreased to 8%.

Another method found in the literature used for the classification of the accident scenario is the application of reconstruction results which include information about the velocities, wheel angles, locations of the involved vehicles and driver actions such as steering and braking or accelerating over a given timeframe: the last five seconds before collision [15]. Since no such reconstruction results were available in CIDAS, a comparison of the accuracy of these different methods was not made in this study.

Limitations

Although CIDAS is the broadest and most detailed accident database in China, a clear picture of the car-to-two-wheeler accident situation for the whole of China is still difficult to obtain due to CIDAS's lack of representativeness.

Future work

Injury severity from car-to-two-wheeler accidents needs to be further researched. In addition, two-wheeler AEB test scenario definitions using clustering methods should be investigated.

CONCLUSIONS

A number of recommendations result from the findings of this study. Accident scenarios involving electric-powered two-wheelers should be considered in C-NCAP assessments since this vehicle is involved in a high proportion of two-wheeler accidents.

Based on Chinese real-world car-to-two-wheeler accidents, priority in AEB assessments should be given to a straightforward-moving car impacting a straightforward-moving electric powered two-wheeler travelling in perpendicular directions in daytime with speeds of up to 60 km/h.

Turning cars, collisions with motorcycles, and nighttime are the scenarios that should be considered next.
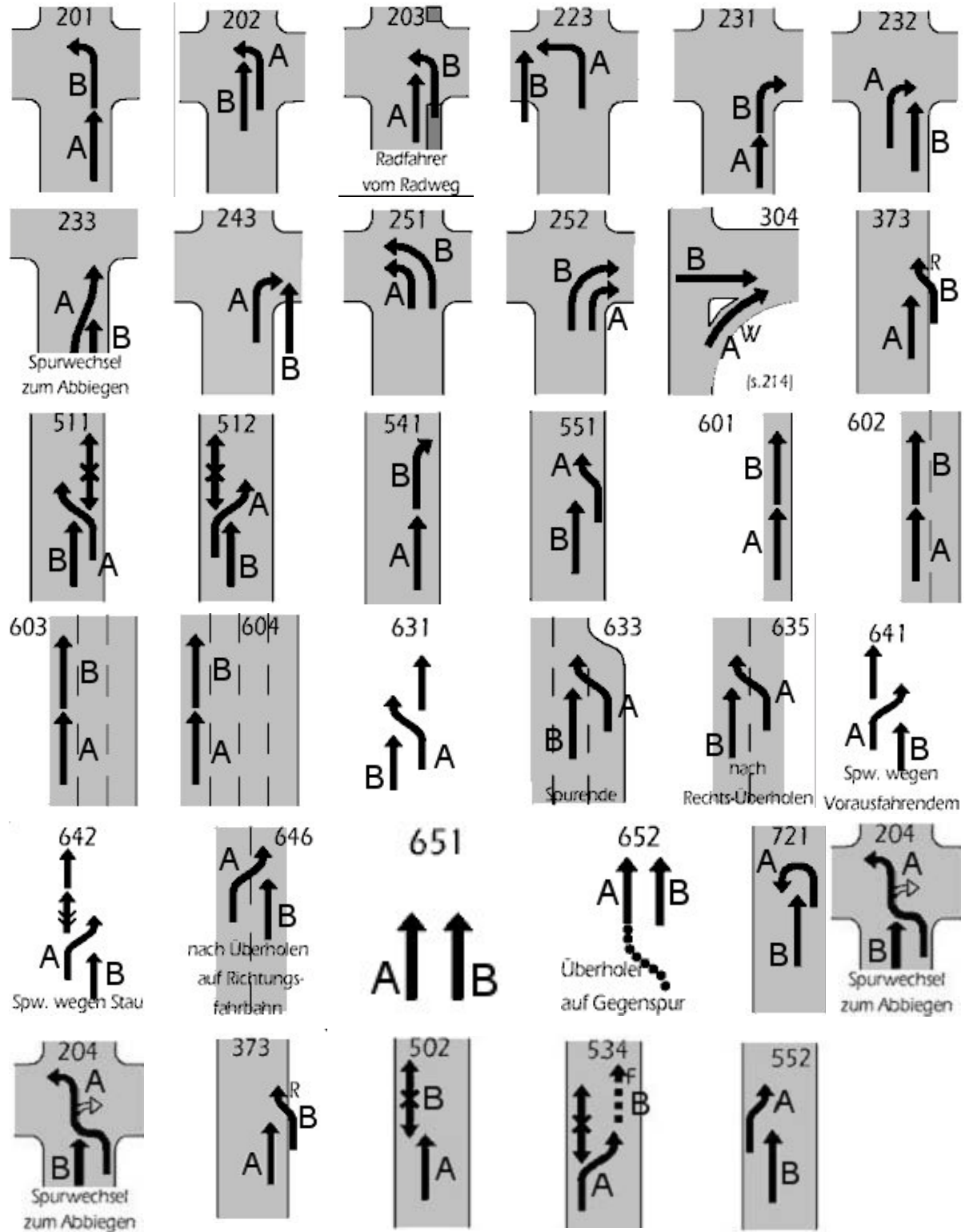
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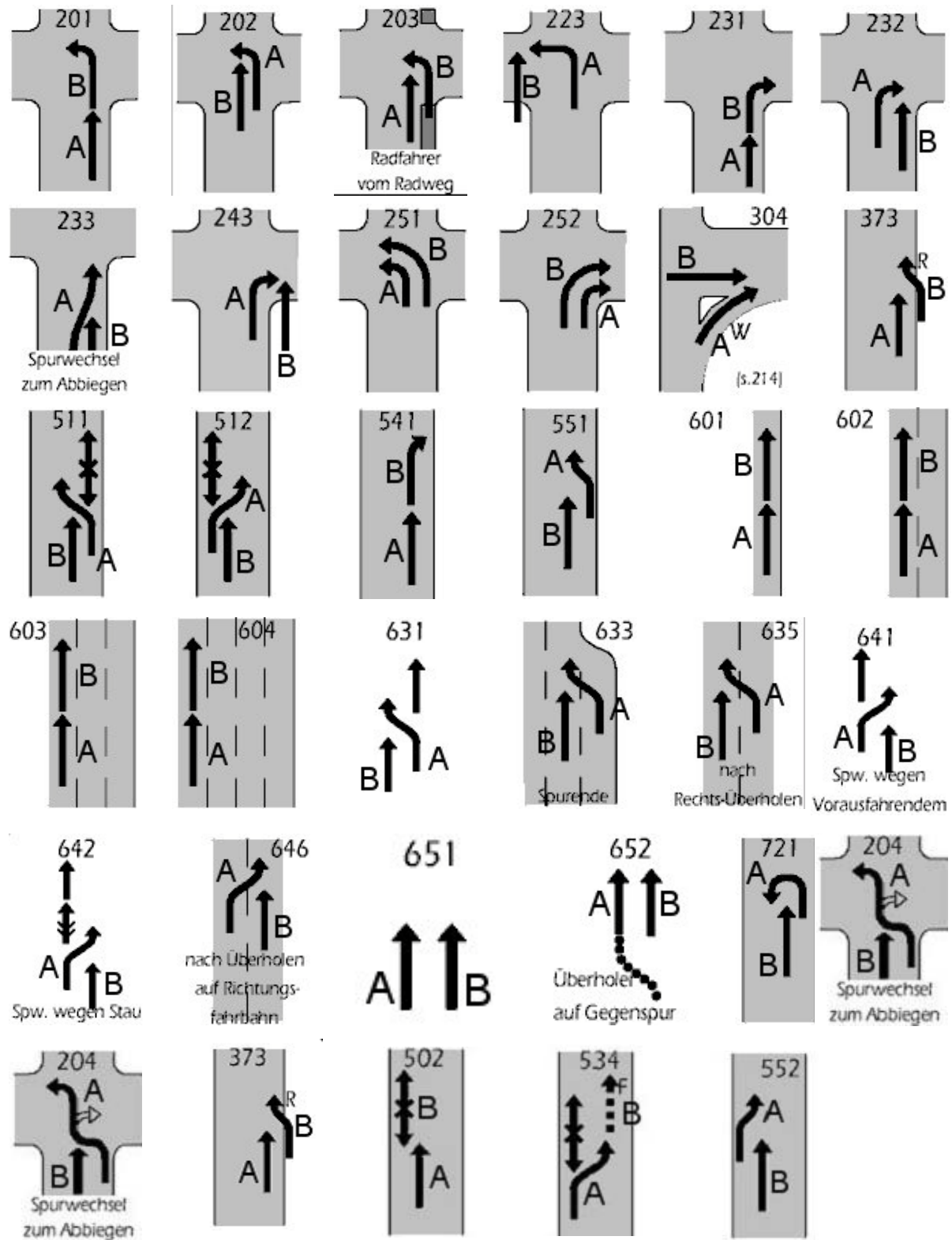real-life data". JSAE 2013, Japan. Paper No.:
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Appendix 1. Scenario Classification using UTYP
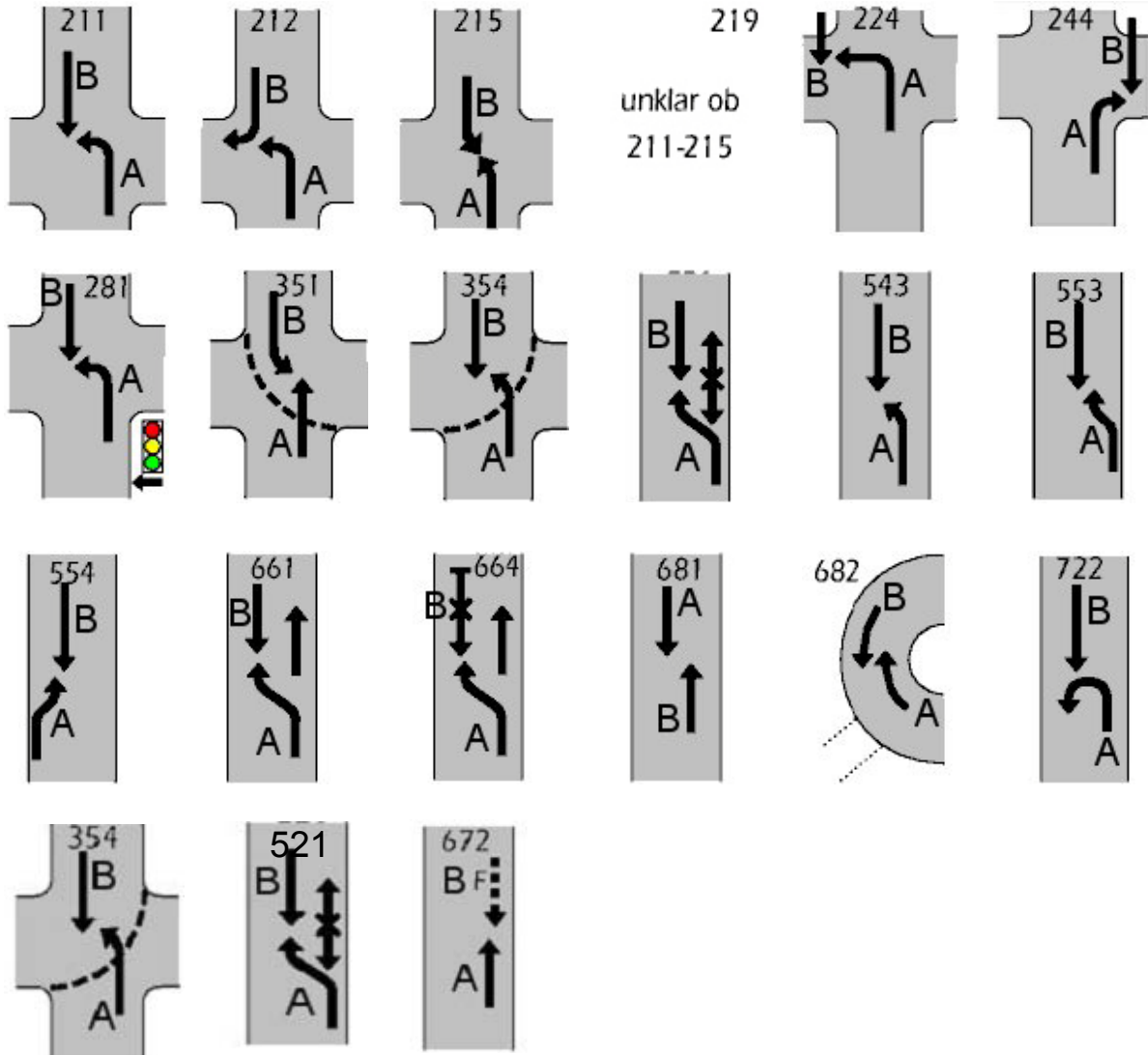Longitudinal same direction

Appendix 1. Scenario Classification using UTYP
Longitudinal same direction

Appendix 1. Scenario Classification using UTYP
Longitudinal opposite direction

Appendix 1. Scenario Classification using UTYP
Perpendicular