GDV
Unfallforschung
der Versicherer

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Accident occurrence: A comparison of electric and combustion engine cars

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1. Introduction

The present research results follow on from a series of studies by GDV into the ease of repair and damage claims made in respect of battery-electric cars (electric cars) and extend this actuarial viewpoint from the perspective of the German Insurers Accident Research [1]. The results show that there are indeed differences in accident occurrence: The studied dataset for battery-electric cars (electric cars) differs on a number of relevant points from the data for comparable cars with combustion engines (combustion engine cars), even though these differences are not obvious at first sight. Instead, a more thoroughgoing analysis indicates a trend for certain patterns to emerge within the studied dataset.

2. Study method and explanatory power

The following results are based on UDV research report no. 103 [2]. The research report combines three components: an overview of the literature and technology, an in-depth analysis of real-life accident data from the insurers' accident database (UDB), and a complementary online user survey. For the purposes of an overall assessment, it is important to note that the greatest differences are not to be found in an "overview" of the entire set of accidents, but instead in certain selected detailed patterns within it.

Component	Data basis	Significance in the project
Review of the literature and technology	State of the art of research and technology	Categorises the findings and indicates the risks that were already known, for example low acoustic perceptibility, higher weight and the possible consequences of one-pedal drive.
UDB accident analysis	Approximately 500 specially selected accidents; approximately 250 electric and 250 combustion engine cars; 16 electric car models giving rise to the most claims in the statistical data for the years 2019–2022, with at least 2,500 incidents per year; comparison models as identical/similar as possible in terms of manufacturer/series, power, weight and year of market launch; UDB database representative of third-party motor insurance claims involving personal injury and damage costs of at least 15,000 euros	Delivers the project's most robust findings: real accident patterns, injury severity, safety of other road users, collisions with pedestrians and misuse of pedals.
Online survey	238 respondents; 171 data records on electric cars and 186 on combustion engine cars	Extends the accident data by adding subjective driving behaviour, perceptions and patterns of use; particularly useful for categorising driving style, perceptibility and usage profiles.

Important for interpreting the accident data: The UDB database does not contain all the accidents that occur in Germany, but instead an extract representing the largest third-party insurance claims involving personal injury. It therefore offers only a limited capability to draw conclusions about accidents overall, trivial claims or general accident frequency. At the same time, however, this database is particularly valuable for analysing the consequences of injuries and noteworthy trends and patterns.

AVAS Acoustic Vehicle Alerting System; acoustic warning system for hybrid and e-vehicles of classes M and N at speeds of up to 20 km/h [3].

AIS / MAIS Abbreviated Injury Scale; scale indicating the severity of injuries; AIS 3+ stands for severe to life-threatening injuries. MAIS designates the most serious single injury to a person who has suffered multiple injuries.

3. Overview of key take-aways

The five most important findings are as follows

- → The aggregated data from the dataset initially seems to show a similarity between electric and combustion engine cars. The main differences only become evident in certain accident patterns and usage scenarios.
- → Electric cars tend to provide their occupants with better protection – in particular in the smaller vehicle segments. However, this advantage is closely linked to the higher weight and the, on average, more recent vehicle fleet.
- → The UDB dataset indicates a considerably higher occurrence of pedal misuse in electric cars. This finding is statistically significant despite the small absolute number of cases.
- → The drivers of electric cars tend to be more circumspect in their driving. The project did not reveal any higher accident rate for electric cars.

3.1 Passenger safety

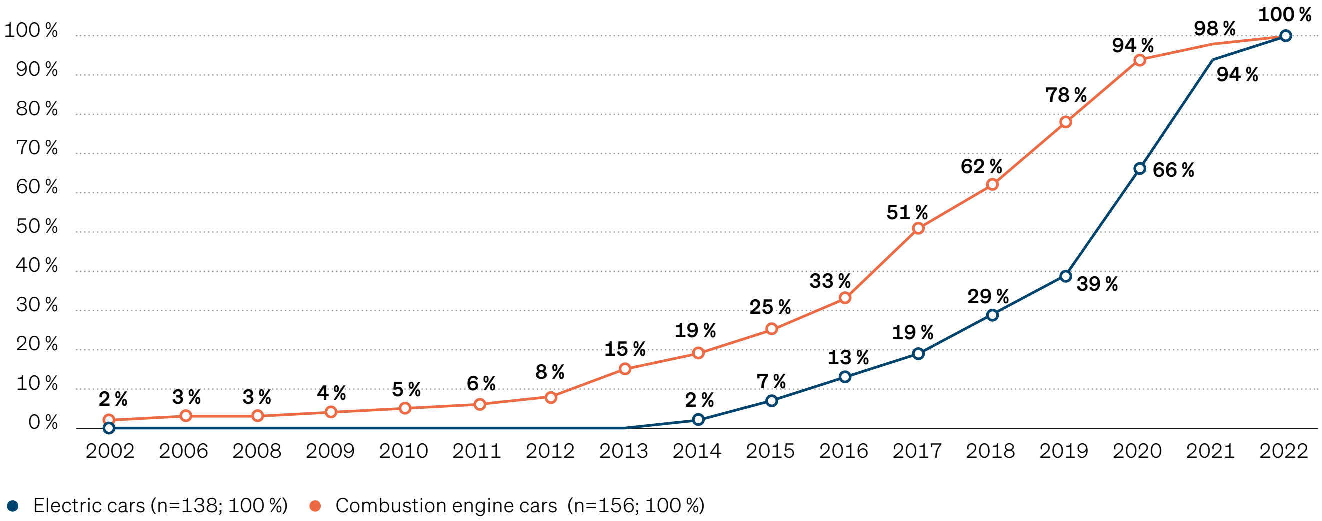
One important conclusion drawn from the project is that electric cars tend to keep their occupants safer than comparable combustion engine vehicles. This statement is not intended as an inviolable fact “covering every situation”, but as a reliable trend subject to clear limits.

Viewed across all car/car collisions, neither the degree of damage itself nor the general severity of injuries immediately suggest any significant differences. The relevant findings are revealed only by a segment-by-segment consideration of the individual vehicle classes: Electric vehicles do better, above all, in the mini- and small car segments. In the mini-class, there were no AIS-2+ injuries for electric cars compared to 12 % for their combustion engine-equipped counterparts. In the small car class, the proportions were 6 % and 10 %, respectively. This advantage all but disappears in the larger vehicle segments.

This pattern can be explained first and foremost by the higher weight. On average, electric cars are heavier. This means that small electric cars, in particular, benefit from an advantage in terms of weight and solidity. In addition, the fleet of electric cars studied during this research was newer (Fig. 1). This is a snapshot and the situation will change in the future due to the higher proportion of electric cars in the vehicle fleet.

In the analysed dataset, the electric cars were, on average, newer than the combustion engine cars

Figure 2 · Comparison of the year of initial registration for the two examined drive types; cumulative year of initial registration (n=294)



The results show that the current combination of higher weight, more rigid structure and more recent fleet improves passenger safety in many scenarios. However, the number of cases in the subgroups was generally insufficient to make it possible to draw the statistical inferences necessary to validate the findings.

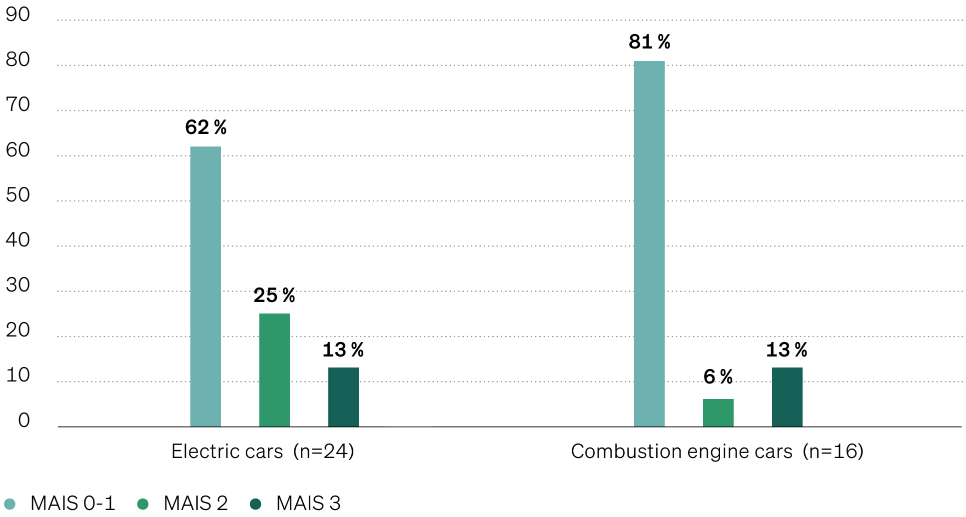
3.2 Safety of other road users

While electric cars keep their own occupants safer, this same physical advantage may be prejudicial to the other party involved in an accident. Precisely this imbalance is observed throughout the detailed analyses of crash compatibility.

In the case of head-on collisions between electric and combustion engine cars, the drivers of the combustion engine vehicles suffered severe injuries significantly more frequently: More than a third of those affected exhibited AIS-2+ injuries, whereas the corresponding proportion in combustion engine/combustion engine collisions was less than 20 % (Fig. 2). In the case of side impacts, AIS-2 injuries occurred in 12 % of cases in which a combustion engine car was hit by an electric car; no corresponding case was observed for combustion engine/combustion engine collisions in this analysis. With regard to rear-end collisions, the probability of AIS-2 injuries was approximately twice as high, even though the average collision speed of electric cars was lower.

In head-on collisions, the drivers of combustion engine cars are more frequently severely injured when colliding with an electric car

Figure 2 · Comparative breakdown of severity of injuries to drivers of combustion engine cars in electric/combustion engine and combustion engine/combustion engine collisions



These findings clearly indicate conflicting aims: more protection for oneself, but less for other road users. It is important to point out here that statistical validation was not possible in all the partial analyses. However, this does not change the fact that the pattern is physically plausible (electric cars are heavier) and that multiple analyses all point in this direction.

3.3 Pedestrians

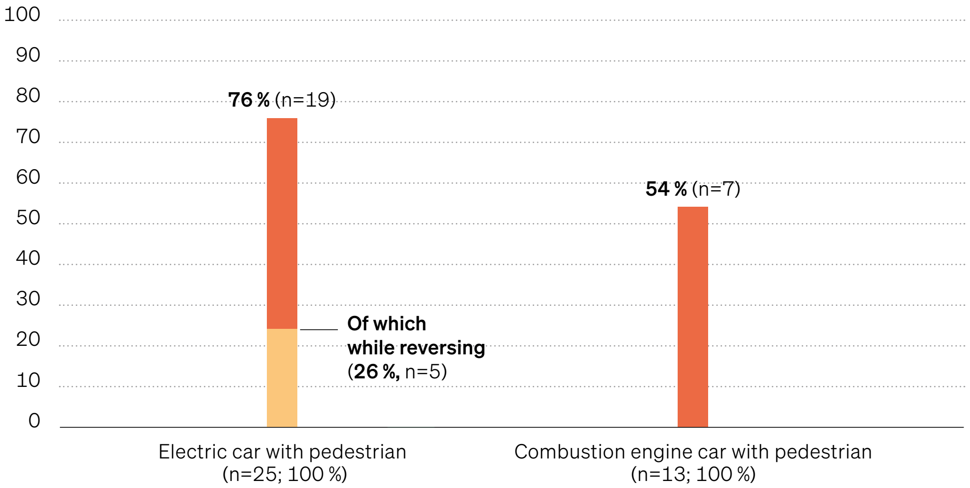
The clearest difference relates to interaction with unprotected road users, and pedestrians in particular. The results suggest that, in certain perceptually critical situations, electric cars constitute an increased accident risk for pedestrians.

A total of 38 car/pedestrian collisions were analysed, 25 of which involved electric cars and 13 combustion engine cars (Fig. 3). Of the cases involving electric cars, 19 patterns (76 %) were categorised as potentially having AVAS relevance; the corresponding figure for combustion engine cars was 7 out of 13 cases (54 %). It is particularly noteworthy that five of the 19 relevant electric car accidents occurred while the vehicle was reversing, whereas not a single case of this type was identified in the comparison pool of combustion engine cars. There were also three turning-off accidents at very low speeds and with simultaneously poor visibility, as well as three collisions on sidewalks or in the vicinity of entrances – these also exclusively involved electric cars.

The distribution of these perceptually critical situations was statistically significant ($\chi^2(1)=9.0$; $p<.005$). This is one of the key results of the project: The problem clearly comes from specific situations in which vehicles are difficult to see or are only heard too late.

Electric cars are more frequently involved in collisions with pedestrians in perceptually critical situations than combustion engine cars

Figure 3 · Proportion of perceptually critical scenarios observed for collisions between electric or combustion engine cars and pedestrians (accidents n=38)



The finding regarding AVAS is particularly striking: An acoustic alerting system was undoubtedly present in at least half of the studied electric car accidents in the turning-off and reversing scenarios. However, this system was unable to prevent the accident. This may be due to the technical design of current AVAS solutions.

3.4 Pedal misuse

A second robust key finding relates to the misuse of pedals. This topic was not part of the core scope at the start of the project. However, it came to the fore so prominently during the analysis of the individual cases that it led to a series of results in its own right.

The UDB dataset contained nine accidents involving electric cars which were caused by the driver mixing up the pedals or by uncontrolled acceleration. By way of comparison, only one similar case was identified for combustion engine cars. The difference between the groups was statistically significant (^{2}(1)=6.44; p=.011). The way this scenario has evolved over time is noteworthy: Whereas an earlier UDB analysis dating from 2020 found the probability of this type of accident to be approximately 0.5 %, the current analysis reports a value of 2.2 %. Approximately 90 % of the cases of pedal misuse observed in the current analysis occurred in electric cars.

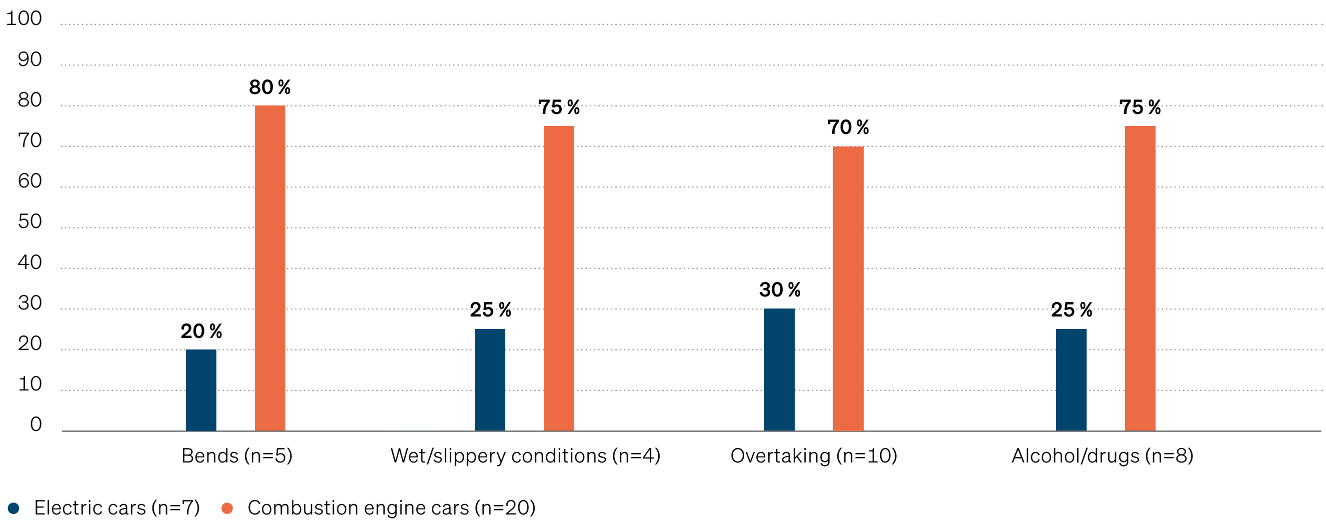
A qualitative analysis of the cases indicates three potential mechanisms: firstly, a confusion between the accelerator and brake pedals; secondly, delayed reactions in situations that demand a rapid change of pedal; and thirdly, the reinforcement of the mistaken reaction by the high, immediately available torque. The one-pedal drive may also be a plausible risk factor. Based on the current data, it is not possible to say in each individual case whether or not this mode was activated. Assessing these results, one can say that although the absolute number of cases is small, the signal they send needs to be taken very seriously.

3.5 Driving behaviour and usage

Although the results of the analysis of driving behaviour are less robust than the findings on pedestrian accidents and pedal misuse, they are nevertheless highly informative of the general situation. The typical driving accidents in risk situations recorded in the UDB database primarily point to the involvement of combustion engine cars: They predominate in accidents in bends with a ratio of 4 to 1, in driving accidents in wet or slippery conditions at a ratio of 3 to 1, in risky overtaking manoeuvres at 7 to 3 and in accidents involving alcohol or drugs at 6 to 2. (Fig. 4) This can be interpreted as indicating a clear tendency towards riskier patterns of road use in the case of combustion engine cars. However, the number of cases is too small to permit any reliable statistical inferences.

Drivers of combustion engine cars tend to adopt riskier driving behaviours

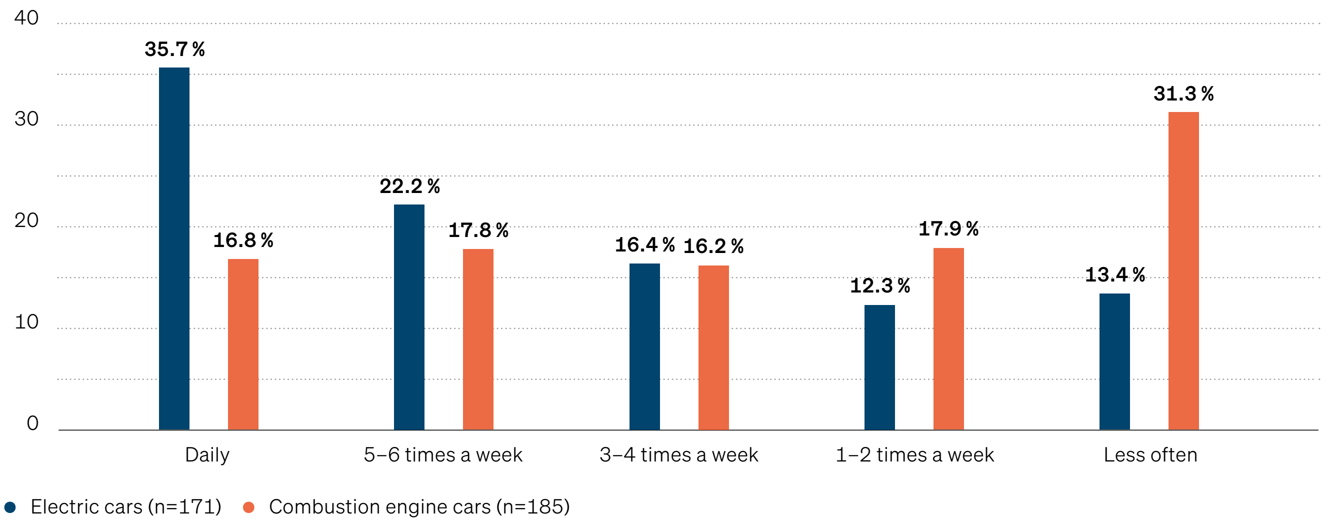
Figure 4 · Analysis of selected characteristics as indicators of driving behaviours for electric vs. combustion engine cars (accidents n=27))



The user survey supports the impression of different driving styles. As Figure 5 shows, the electric cars in the sample are more likely to be used on a daily basis (35.7 % compared to 16.8 %), are driven rather more often on urban and interurban roads, and are used disproportionately often for shopping and leisure trips. The drivers of electric cars are significantly more frequent in saying that they adapt their driving style and drive more circumspectly in order to save energy. They also pay more attention to charging options and route planning than the drivers of combustion engine cars.

Electric cars are more frequently used on a daily basis

Figure 5 · Comparative analysis of the use of electric and combustion engine cars



At the same time, the respondents to the survey are very clearly aware of two specific characteristics of their vehicles: the higher starting torque and the poorer acoustic perceptibility. However, neither of these factors automatically leads to compensatory behavior. In concrete situations such as reversing or turning-off, the data reported in the survey shows no significant or major changes in behaviour compared to the drivers of combustion engine cars. This gap between risk awareness and behavioural adaptation is in itself an important result.

It is also important to note one thing that the project did not find: The self-reported proportion of accidents in the last twelve months was similar for the two drive types at approximately 3 to 4 %. Critical situations were reported approximately three times more often than accidents. On the basis of this data, it not possible to conclude that the accident level is higher for electric cars.

4. Reliability of the four key project take-aways

The results can be condensed into four key take-aways whose reliability can be assessed with reference to four sources of information: Literature, descriptive accident data, inferential statistical analysis of the accident data, and user survey. The table below provides a concise overview of this approach.

Take-away	Literature	UDB, descriptive	UDB, statistical	Survey	Overall judgement
When similar vehicle classes are compared, electric cars protect their occupants better than comparable combustion engine cars. This is primarily due to their higher weight.	+	+	○	–	Adequate support; primarily evidenced in smaller vehicle classes but without broad-based statistical validation.
Electric cars represent a higher risk for pedestrians.	++	++	++	+	Robust support; the clearest finding of the project.
The drivers of electric cars drive more circumspectly.	++	+	○	+	Reliable support overall; however, cannot be concluded solely from the UDB partial analyses.
The risk of pedal misuse is considerably higher in electric cars.	++	++	++	○	Reliable support; small sample of cases but clear, significant difference.

Key: ++ = reliable evidence; + = identifiable tendency;
○ = no or little evidence; – = issue was not within the study scope.

The accident analyses do not reveal any differences between electric and combustion engine cars with regard to accidents due to fire and therefore also confirm the findings reported in the literature [1].

5. Limitations to explanatory power

The results contain a number of robust findings and it is therefore important to categorise these correctly. Some of the results are robust, whereas others should be viewed more as credible indicators than as definitive proofs.

5.1 Methodological limitations

First of all, the analysis of the data from the UDB database focused on a targeted sample of accidents involving electric cars which resulted in major liability claims and involved personal injury and substantial damage costs. The results therefore tell us a lot about the consequences of injuries and the typical risk patterns involved in serious accidents, but less about general accident occurrence, including minor bodywork damage.

Secondly, many of the subgroups are small. This applies, in particular, to the segment-by-segment car/car analyses and individual patterns of road user involvement and driving behaviours. As a result, differences that may stand out at the descriptive level are not always statistically significant.

Thirdly, the online survey is not based on a random sample. It contains a substantial gender imbalance and is also characterised by various differences between the compared vehicles, for example vehicle age, transmission type and scope of the driver assistance systems. The current survey was also unable to specifically investigate the topic of the one-pedal drive.

Fourthly, the results constitute a snapshot. of the present state of the market. The current safety advantage of electric cars in terms of passenger protection is also related to the comparatively recent and heavy vehicle fleet. The situation may change as the BEV fleet becomes older and more varied.

5.2 Potentially incorrect interpretations of the results

It is necessary to state that results are in no way an argument against e-mobility. Instead, they plead for the further development of safety considerations at the levels of vehicles, infrastructure and regulations.

Equally, the results provide no evidence that, overall, electric vehicles cause more accidents. Neither the aggregated assessment of the UDB database nor the survey indicate a higher overall accident rate. The differences can be found in certain patterns – not in any general “danger” posed by electric drives.

The question of fire, which has often been aired in public, is also not central to the project results. Instead, the overview of the literature indicates that, on the basis of the evaluated studies, the risk of electric car fires causing accidents is not high.

6. Conclusions and practical recommendations

First of all, electric cars should be made easier to perceive in those situations in which the current systems are clearly inadequate: when approaching very slowly, when reversing, when turning off from locations that offer poor visibility, and in situations in which pedestrians cannot immediately identify a stationary or nearly stationary vehicle as a possible source of danger. This indirectly points to the need to further develop AVAS concepts and the associated regulations. In the future, AVAS should therefore also be able to emit a sound that can be clearly heard by pedestrians.

Secondly, the mode of operation of modern electric cars is attracting more attention. If pedal misuse is indeed due to the operating concept, the high torque and deeply ingrained patterns of expectations and behaviour, then conventional vehicle safety in the strict sense is no longer sufficient. What is required are human-focused human-machine interfaces, preventive driver assistance functions, appropriate test protocols and – possibly – clearer guidelines for the design of recuperation-based driving modes. Thus the state of the vehicle (e.g. readiness to move off) should be unambiguously clear to the driver at all times.

Thirdly, the safety of passengers and that of other road users should not be considered separately. The results show that the higher weight of electric cars increases the safety of their own passengers, while simultaneously potentially prejudicing that of other parties involved in accidents. For industry professionals, this means that crash assessments, vehicle design and infrastructure verification (e.g. at crash barriers) must concentrate more closely on questions of compatibility.

Fourthly, the continuous monitoring of accident occurrence is recommended in view of the rapidly changing circumstances. The larger and older the electric car fleet becomes, the more likely it is that the effects observed today will weaken, strengthen or reappear in another form. The project results should therefore be seen less as an end in themselves and rather as a solid starting point for the next study phase.

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