Method for future pedestrian accident scenario prediction

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Abstract

This paper addresses future pedestrian accident scenarios involving next decade of small electric vehicles (SEVs) employed primarily in urban areas in 2025. The methodology used to predict the most relevant accident scenarios in 2025, in terms of speeds, impact locations, vehicle designs and inner-city boundaries, includes four main steps and as an example, the first three steps are shown for pedestrian impacts. First step is a Delphi study, supported by a public survey, to estimate future mobility concepts and city-layouts and helps to identify boundary conditions for future accident scenarios. Furthermore, the second step, the analysis of national and in-depth accident databases give an overall scenario definition and the boundaries for a relevant generic baseline accident type and scenario. Thirdly stochastic simulations based on the baseline scenario and evaluated with the Delphi, are used to predict future accident scenarios.

Keywords: accident prediction, future scenario, electric vehicles.

Résumé

Cette publication traite des futurs scénarios d’accidents piétons impliquant des véhicules légers de la prochaine décennie qui circuleront essentiellement en zone urbaine en 2025. La méthodologie mise en place pour la définition des scenarii d'accidents les plus probables en termes de vitesse, de zone d'impact et de conception des véhicules est organisée en quatre étapes, dont seuls les trois premières sont décrit. Une étude Delphi complétée par une enquête publique a permis d'établir les conditions aux frontières de ces situations d'accident. Une analyse des données d’accident et l’analyse des études détaillées d'accidents a permis de définir une gamme d'accidents génériques. La simulation stochastique des ces scenarii fait apparaître une réduction de la vitesse des véhicules.

Mots-clé: Prediction d’accidents, scénario futur, véhicule électrique

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1. Introduction

In 2020 possible electric vehicle (EV) sales are projected with 3 % up to 6 % by Pike et al (2011), which means approximately 0.36 to 0.72 million vehicles according to overall vehicle sales in Europe of 12 million in 2012 published by ACEA (2013). The expected rise in sales in the next years should then reach an amount of 20 million EV’s by 2020 proposed by Trigg & Telleen (2013), including plug-in hybrid-, battery- and fuel cell electric vehicles. A higher future market share of EV is expected. In the present work small electric vehicles (SEV’s) are selected with focus on pedestrian accidents.

For SEVs a driving range below 100km per day is seen in the majority of cases. Because of the weight factor of batteries compared to fuel tanks, influencing the vehicle mass and driving range, the focus of future developments should be set to small urban EVs. Some of these designs were recently presented at different Auto-Shows as concept vehicles (e.g. VW Nils) or are already available for customers (e.g. Renault Twizzy). Some of them are, due to their weight, defined as L7e category vehicles and have therefore nearly no safety regulations to pass for certification. Heavier vehicles, but still below or equal to 1000 kg are designed different as standard M1 category Sedan vehicles e.g. SmartED, with less bonnet length and a steeper front end. For these small low weight vehicles, i.e. actual pedestrian safety assessment protocols don’t fit real world accident scenarios seen on streets. Additionally, future technologies such as advanced driver assistance systems (ADAS) and new mobility concepts and city layouts will influence the overall pedestrian accident scenario in future i.e. 2025. For a reasonable safety level of future SEVs this work will carry out a method for future accident scenario prediction, shown also by Tomasz et al (2013) which can be seen as the input for development of a test proposal for SEVs (proposals will be developed in SafeEV). This study was part of the initial phase of the FP7 EU-Project SafeEV, namely “Safe Small Electric Vehicles through Advanced Simulation Methodologies” (Deliverable 1.1).

2. Methodology

The methodology is developed and structured in four different phases. Basic information on future trends in the first phase is obtained from a Delphi and a public survey. “A Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem” (Linstone & Turoff, 2002), for example to predict future scenarios and generate boundaries, used for the plausibility check of the second phase. Within these surveys the participants should predict urban traffic and accident scenarios based on their experience e.g. how urban areas will look like, how the collision speed will develop, what will be the market share of SEV’s, etc.

In the second phase it is necessary to identify appropriate target accident types. These pedestrian accidents were analysed according to their relevance based on accident frequency and injury severity. National statistics don’t show accident parameters such as collision speed, reaction time, etc. Therefore, in the third phase two approaches are possible. Firstly, the specification of boundary conditions e.g. speed limit, reaction time, driving direction of the pedestrian, etc. from literature. These parameters are needed as input parameters of a generic accident scenario. Secondly, real-world accident databases such as GIDAS (German In-Depth Accident Study, OTS (On-The-Spot), ZEDATU (Zentrale Datenbank zur Tiefeanalyse von Verkehrsunfällen) or other databases provide these informations. Both approaches can be used to define a so-called baseline scenario. The baseline should reflect the current accident situation. The definition of this baseline enables the evaluation of possible future accident scenarios. Due to the absence of reconstructed real-world accident cases a weighting method was applied to define the baseline scenario. The software used for the simulation is PC Crash. However, the data of the two approaches only provides information of the past or current accident situations. Future accident scenarios in the simulation are now predicted by integration of pre-crash safety systems (e.g. autonomous braking).

In the final phase future accident scenarios are predicted using the baseline and the Delphi survey results. A pedestrian kinematic analysis, within a multi body simulation software (> 6000 simulations), is performed to identify possible impact areas on future vehicles with different car front shapes and head impact speeds for first and second impact (adult and child dummies), evaluated with the results from the first three phases.
3. Delphi Study and Public Survey Definition and Results (First Phase)

In the methodology description it is defined to use the Delphi Method in order to include an accident scenario prediction which is focusing only on future developments and possible trends which are not seen by reviewing statistics only or forecast models. The results of this study are used to evaluate the boundary conditions for the numerical approach which is based on current accident statistics and limited to approximations for e.g. new technologies.

In general, a Delphi analysis requires the identification of experts with a good knowledge on the topic, which is of interest. In a first step, these experts are required to answer a set of questions. The answers are reviewed and combined, in a way that within the following “discussion rounds” in the best case a consensus is found. The chosen experts should not be in direct contact and must not know each other. (Rowe & Wright, 2001)

The Delphi study and results will be discussed as a starting point to predict a pedestrian scenario in the end. As there were many of important questions regarding pedestrian accidents the Delphi questionnaire for the Delphi method was split up into two parts, namely the technical questionnaire and the trend questionnaire. The main topics which are addressed in the two parts can be summarized to future vehicle designs, speed limitations, market shares of safety technologies or mobility types, modal split, city development, urban restrictions and demographic changes. The technical questionnaire was answered by five experts and the trend questionnaire by four experts.

Table 1: Experts for the Technical Survey

<table>
<thead>
<tr>
<th>Expert</th>
<th>Field of expertise</th>
<th>Years of experience</th>
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<tbody>
<tr>
<td>Expert 1</td>
<td>Senior consultant in Vehicle Safety</td>
<td>25</td>
</tr>
<tr>
<td>Expert 2</td>
<td>Professor in Vehicle Safety and Accident Research</td>
<td>30</td>
</tr>
<tr>
<td>Expert 3</td>
<td>Project Manager Accident Research</td>
<td>13</td>
</tr>
<tr>
<td>Expert 4</td>
<td>Senior Expert Passive Safety</td>
<td>12</td>
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<tr>
<td>Expert 5</td>
<td>Automotive Safety Consulting</td>
<td>35</td>
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</table>
Table 2: Experts for the Trend Survey

<table>
<thead>
<tr>
<th>Expert</th>
<th>Field of expertise</th>
<th>Years of experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert 1</td>
<td>Manager Innovation Business Environment</td>
<td>20</td>
</tr>
<tr>
<td>Expert 2</td>
<td>Chairman of the Institute of Urbanism</td>
<td>35</td>
</tr>
<tr>
<td>Expert 3</td>
<td>Researcher</td>
<td>10</td>
</tr>
<tr>
<td>Expert 4</td>
<td>Professor in Vehicle Safety</td>
<td>30</td>
</tr>
</tbody>
</table>

Additionally, a public survey based on the Delphi questionnaire was generated supporting the analysis of the expert opinions and to achieve a more precise future scenario with a broader “public view”. Public in this study can be defined as a selection of participants which were chosen from a technical point of view. The participants come from nine different European countries. Mainly they are from Research Institutes, OEM’s, small companies, or Engineering Consultants. 65 Participants were answering the survey. Only 20 % of all persons cannot be connected to the „expertise fields of interest”. The number of answers for single questions of the questionnaire varied because they are partly more specific, may be not in the field of expertise and a possibility in the survey was to skip single questions.

3.1. Future scenario prediction based on the Expert answers (Delphi Survey)

Considering all the information from the expert survey, estimation for a future inner-city traffic situation is given. There will be a share of approximately 14 % of all passenger cars which are electric propelled and defined as small city cars (L7e). Heavier SEVs in the lower weight range of M1 category vehicles were not directly addressed in the questionnaire. Due to an expected average car mass of 1100 kg for all vehicles in 2025 compared to 1390 kg in the EU 2011 (Mock, P. 2012), it can be derived that SEV’s with a share of at least more than 14 % and a mass below the average value are a reasonable conclusion. Most of these vehicles will have one to approximately three seats and will be equipped with assistance systems and partly with semi-autonomous systems (70 % and 15 % for all registered in 2025). A few urban vehicles will be designed as more than three-seater but this would reduce the initial purpose of use and can therefore further stay within standard regulations of the EC. What is more important is to come up with new regulations that focus only on SEVs (lightweight, active passive safety features, low range). The main operational area of these types can be seen in urban areas, where speed limits of 50 km/h and less are common. In critical situations this speed limits will further drop in comparison to that from nowadays, for example in school and business areas at important time periods (morning, lunch time) or weather conditions (dazzling, raining). This could be implemented as in-vehicle speed control systems, or as adaptable traffic signs. In the city centres and business districts with a lot of vulnerable road users traffic modalities will be more separated, expected with a higher share of public transport systems. Shared areas, estimated mainly in the neighbourhoods or outer districts could be seen in higher numbers which can decrease speed. Problems could rise with a higher number of elderly people but there are some suggestions to solve those problems by activation of the horn in critical situations and a higher amount of information which can be communicated with led-displays. For future accident scenarios involving SEV’s and pedestrians following conclusion from the expert opinion can be drawn. Due to higher market shares of assistance systems and semi-autonomous systems with a more separated traffic and an improved traffic management system the conflict areas can be reduced and the speed within these areas also. Due to higher public transportation possibilities also conflict partners will be reduced, but this depends on how fast “new lines” will be implemented in future cities and if an implementation is possible. Until 2025, there is limited possibility to construct new subways, even trams could be a problem if this is not already planned and decided. Such projects have a certain time period with years of discussion and planning. Buses instead seem to be a good solution, maybe electric.

This indicates a further reduction in traffic accidents including also accidents with pedestrians. If an accident will happen it will be in average with a lower velocity. It is estimated that the most frequent impact velocity will be between 10 km/h up to 30 km/h with the pedestrian coming from nearside on junctions. The percentage of SEV’s involved in accidents will rise as there will be a lot more of these vehicle types on the road (< < 1 % 2012 to > 14 % in 2025).
3.2. Future scenario prediction based on the Public answers (Public Survey)

In comparison to the expert survey most of the answers are heading in the same direction, what is not surprising as most of the persons are familiar with the topics as it can be seen in the introduction of this public survey. According to the answers of the public survey a higher number of small electric vehicles can be expected on the road in 2025. The design can differ from today’s designs, but it will be most likely the same as today, a bit more aerodynamic. The number of seat possibilities in the car will range from one-seaters to more than four-seaters. A bigger difference is seen in autonomous driving where the mean value for vehicles which are equipped with such a technology is by nearly 10 %. Also semi-autonomous systems (SAS) and assistance systems (AS) are estimated to have a higher share (+12 % AS and +17 % SAS). Taking all public survey answers into account, the future is heading in the same direction as the overall expert opinion with a few exceptions.

3.3. General Discussion on the Surveys

What cannot be addressed within the Delphi study are the persons who are not willing to follow instructions by law and bring themselves into hazardous situations. On the other side it is possible that active safety systems fail or have no physical chance for accident mitigation. Reasons for this could be differing between sensors and the environmental effect or to short reaction time. Also there was no question regarding negative effects of such future safety systems included in the survey, which could possibly increase the frequency of other accident types.

A limitation, due to the “small expert group”, can be seen in information of future systems or novel solutions for an enhanced mobility concept which were not mentioned (e.g. intellectual property). But as described, for this case, the public survey was set up. In the end reasonable “facts” could be missed which would be useful, but as this is a future estimation the only chance to find proof is to review the report in 2025.

4. Accident Type Assessment (Second and Third Phase)

Even if there is a huge reduction on fatal pedestrians since 2000 compared with 2009 there is still a huge share of roughly 18.3 % in 2009 in the European Union (EU-24) (Dacota, 2011). Pedestrian victims are thus a major concern due to their high injury severity in road accidents. Rosen & Sander (2009) reported in their study that the fatality risk at 50 km/h is twice as high as at 40 km/h and five times higher than at 30 km/h impact speed. This leads to the conclusion that reducing the impact speed is a major factor influencing the pedestrian injury severity. Therefore, it becomes necessary to identify the appropriate pedestrian accident types in more detail. Pedestrian accident investigation shows that “pedestrians crossing the road on a straight section” have a portion of roughly 59 % and “pedestrian crossing the road on a straight section with an obstruction” has a share of about 27.4 % (Aprosys, 2007). In the vFSS (Advanced Forward-Looking Safety Systems) a Working Group (Leimbach, 2011) has shown that typical pedestrian accidents are “pedestrians coming from the nearside” (45.0%) and “pedestrians coming from the far side” (29.3 %). Further accident types were identified for situations on “junctions with turning vehicles”. A study for the city of Toronto showed that pedestrians were hit when they crossed the road from near or from far side (41 % of all collisions). The Autonomous Emergency Braking (AEB) Test group identified pedestrian accident types similar to the previous studies. The definition is based on findings of Lenard et al. (2011) who used a cluster analysis to identify groups of collisions with similar characteristics. The AEB pedestrian scenarios were summarized to pedestrians coming from the nearside without an obstruction (39%). The second most pedestrian accident type was identified as pedestrians coming from the nearside with an obstruction (14 %). Further figures were obtained from Austrian national statistics. The most frequent accident type is when the pedestrian comes from the near side with a share of 33.6 % followed by a situation when the pedestrian comes from the far side having a share of 27.3 %. Other pedestrian accident types are situations in which the vehicle is turning off.

The analysis showed that six pedestrian accident types are highly relevant for safety countermeasures in longitudinal traffic. These accidents can be divided into collisions when the pedestrian comes from the nearside and from the far side (Outside of a junction, Before a junction, After a junction).
Table 3: Identified pedestrian accident types

<table>
<thead>
<tr>
<th>Accidents with Pedestrian</th>
<th>Outside of a junction</th>
<th>Before a junction</th>
<th>After a junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>near side</td>
<td>421</td>
<td>401</td>
<td>451</td>
</tr>
<tr>
<td>far side</td>
<td></td>
<td>431</td>
<td>471</td>
</tr>
</tbody>
</table>

4.1. Stochastic Accident Prediction Approach

One of the possible accident type assessments could be identified as a simulation method. Such a virtual simulation method called “pre-crash-simulation” has proven to be useful for the impact assessment of driver assistance systems. In this method real accidents or generic accident scenarios based on real accident data are rerun within a virtual forward simulation. Each setup is simulated at least twice: Firstly with car equipment defined to be standard, the so called “baseline”. In this sense standard equipment can include such which is legally obligated and such which is thought to be basic equipment – but available as stand-alone – for the system to be analyzed. To give an example, ESC and ABS belong to the first group. An existing collision warning system may be basic for an autonomous braking system. The other runs of the simulation additionally include the system and vary different parameters, e.g. reaction times, if necessary. This is called the “system”. A comparison between the results of the baseline simulation and the system simulation should indicate the change of accident parameters such as collision speed, etc.

4.1.1. Stochastic simulation

Due to a lack of real-world accident data to use the real world accident approach a stochastic simulation approach based on a generic accident scenario was used. The six different accident types from accident analysis were combined with accidents where pedestrians are coming from nearside or from far side. The generic accident scenario is based on these two main pedestrian types. De Lange (2007) analysed the initial and collision speed in pedestrian accidents. He concluded that the initial speed of the vehicle at average is at 50 km/h (±20 km/h) with an impact speed of 35 km/h (+20 km/h; -10 km/h). The pedestrian is crossing with a speed of 5.4 km/h (+10.8 km/h; -3.6 km/h) on average. For the present study it is thought that SEV’s will have a small driving range and probably only used in urban traffic. The Delphi results show a tendency to lower speed in urban areas. Therefore only urban areas are included in the simulations with a speed limit of up to 50 km/h.

The stochastic method used in this study is explained in the following paragraph. It is assumed that a passenger car (PC) is driving on the priority lane and the pedestrian wants to cross the road. The intention of the pedestrian, further referred to as PP (Pedestrian Participant), is to approach the junction “without paying enough attention to the traffic”, i.e. looked-but-failed-to-see-errors. It is postulated that the PC has time to react in some way to the action of the PP. This reaction could be steering, braking or steering and braking. For the simulation only the braking possibility is assumed, since automatic collision avoidance by steering systems are still in the development phase and might not have a substantial market share in 2025. The conflict situation starts when the PP steps into the traffic lane of the PC. Obviously the PC needs some time to recognize the situation. Therefore the point of reaction of the PC is defined as the moment when the PP steps into the driving lane of the PC. At this specific moment the PC needs to react. As simulation software PC Crash is used.

For the simulation the cars are positioned at any distance to the PP at which a collision would still occur. At this specific position it is assumed that the driver has to react. The distance of the PC to the potential collision position with the PP is meant to be the point of reaction of the PC. At this specific position the PC and PP undergo different parameter variations (see Table 4). As an example, the PC has a distance of 12 m at the point of reaction (PP is stepping into the PC travel line). The PC is travelling with 50 km/h, the reaction time is at 0.8 s, lag time 0.1 s and the acceleration at 5 m/s². The PP is crossing the road very slowly (elderly person) with 3 km/h constant speed (acceleration: 0 m/s²). Within a further simulation the reaction time is changed to 1.0 s, etc. All single parameters are combined with each other and sum up to some thousand simulations. Having in
mind that the PC starts at a certain distance away from the PP a collision could occur or not, depending on the parameters which can be influenced by the driver (reaction time, acceleration). Depending on the distance and rather quick reaction time and/or high braking force the PC will stop in time and the PP could cross the road safe. If the PC has a longer reaction time and/or low braking force a collision would occur. These collision results are analysed. The position 0 is defined as the position at which the pedestrian might hit the PC at the rear end on the left or right side. Based on this position the vehicle is consequently moved backwards indicating the reaction position.

Table 4: Simulation parameters to predict future accident scenarios

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Step</th>
<th>Parameter</th>
<th>Range</th>
<th>Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity [km/h]</td>
<td>30-50</td>
<td>10</td>
<td>Velocity [km/h]</td>
<td>3-11</td>
<td>2</td>
</tr>
<tr>
<td>Acceleration [m/s²]</td>
<td>0-8</td>
<td>1</td>
<td>Weight [kg]</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>500</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reaction time [s]</td>
<td>0-1.6</td>
<td>0.2</td>
<td>Lag time [s]</td>
<td>0.1</td>
<td>0</td>
</tr>
<tr>
<td>Position [m]</td>
<td>0-36</td>
<td>1</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Obviously the combination of individual factors will lead to a collision and non-collision situations, e.g. the passenger runs across the street; the passenger car’s starting position is too far away and drives very slowly so that a collision might not occur. For further analysis only parameter combinations resulting in collisions are considered.

This stochastic approach uses a uniform distribution because all of the variation parameter combinations of Table 4 have the same possibility being considered in the simulation. This combination of the parameters leads to a scenario matrix which is called road traffic scenario cloud with some thousands of possible scenarios. An additional method is needed to identify the proper parameter combinations for the baseline simulation results. That means influencing parameters of Table 4 are weighted according to weighting functions. Each parameter has an own function and is associated to a weighting factor. In Figure 2 an example of a weighting function is given. The red line indicates all possibilities of the reaction times used in the simulations. That means that all parameter combinations of Table 4 with a reaction time of e.g. 0.4 s have a probability of 9.1 % being present in the road traffic scenario cloud. A reaction time of 0.9 s will likewise have the same probability of 9.1 % being present in the road traffic scenario cloud. However, real world accident reaction times don’t show a uniform distribution. Figure 2 illustrates a real reaction distribution obtained from Derichs’ study (1998). For the weighting method all of the reliable reaction times are weighted according to their probability at a specific reaction time e.g. the weighting factor of 0.4 s is 0.023.

Further factors for weighting considerations are acceleration of the vehicle, velocity of the passenger car and the pedestrian and the position of the passenger car prior to the collision. The weighting factors are combined to an
overall weighting factor and used to build the baseline scenario. The weighting factors were obtained from in-depth analysis of GIDAS.

For analysis of future accident scenarios it is assumed that the PC is equipped with a generic accident avoidance system. This system does not have a real-life algorithm, i.e. braking at the point of reaction. The system reacts at the moment when the pedestrian enters the travelled lane of the PC. The deceleration influenced by the generic system is predefined with a value of 8 m/s² and the system react within a timeframe of 0.2 s.

4.1.2. Results

In total 32 805 simulations are performed and out of these 16 260 simulations could be identified with a collision for the baseline. For the other simulations no collision occurred, e.g. the pedestrian crossed the street before the passenger car arrived at the scene. If the PC is equipped with a system which detects the pedestrian crossing the street and decelerate the car autonomously the number of situations without collision increases (see Figure 3, left the baseline and right the use of a future accident reduction system). The purple line indicates a running pedestrian with a speed of 9-11 km/h. At a Time To Collision (TTC) of more than 2.6 s a collision does not occur (pedestrian walking speed 3-5 km/h). It is obvious that at a speed of 11 km/h (3.1 m/s) the pedestrian crosses the road lane already before the passenger car arrives. Obviously the number of impacts increases with lower pedestrian speed. The mean values are represented by the dashed line. The area on the left side of the graph indicates impacts (red area). The area on the right side of the graph doesn’t have an impact (green area). If the passenger car is equipped with an accident avoidance system indicating any system which could detect a pedestrian defined as a generic system, the numbers of accidents are reduced. The system used in these simulations identify the pedestrian within a time frame of 0.2 s (pedestrian comes from the nearside) and start emergency braking with a deceleration of 8 m/s². Even if such a system is on board accidents will occur e.g. the pedestrian steps into the lane immediately before the PC. The figure shows that the graphs are moved to the left with an increased number of non-collision situations. If the point of reaction will be the same as for the baseline scenario the number of collisions is decreased.

![Cumulative share of pedestrian to passenger car accidents at different pedestrian speed (pedestrian comes from the nearside)](image)

![Cumulative share of pedestrian to passenger car collisions in future scenarios and different pedestrian speed (pedestrian comes from the nearside)](image)

Looking to the baseline defined with the assumptions above most of the collisions take place between 20 km/h and 50 km/h. Most frequent collision speed is in the range of 30 to 40 km/h. If the car is equipped with an accident avoidance system (without having the algorithm included, just a generic system) it turns out that accidents with pedestrians will be avoided but still impacts will occur. However, for these cases the analysis showed that the most frequent collision speed will be reduced to a range between 20 to 40 km/h. Similar conclusions were found in the Delphi expert survey and the public survey. Anyway, there will be still a certain number of collisions above this speed range.
5. Conclusion – Prediction of Future Accidents involving SEV’s

The method used in this study has shown the possibility to predict possible future accident scenarios. From a database analysis relevant future pedestrian accidents were identified. In most cases the vehicle is going straight with a possible legal speed up to 50 km/h in urban areas. The main focus is on urban areas due to the high share of pedestrian accidents (90%) and the expected target area for small electric vehicles (because of range, seat possibilities, comfort). In 2025 14 % of all vehicles are expected to be small electric vehicles and these SEV’s will be probably better equipped as most of the registered vehicles in 2025 because of the year of production/market introduction. From the stochastic analysis it became clear that the impact speed will be reduced by approximately 20 % (from an average of approximately 30 km/h to approximately 25 km/h in 2025) with a market penetration of mitigation systems, i.e. autonomous emergency brake, of 100 %, which was assumed for the simulations as real life data from 2025 is not available. In comparison with the Delphi study this velocity will be a bit higher as a market penetration of 100 % is not estimated. Another limitation causing a higher impact speed is e.g. the sensor effectiveness and the pedestrian reaction. Situations will emerge where novel safety systems are not able to avoid accidents, independently of the pedestrian reaction.

The Delphi survey analysis showed that approximately 14 % of all passenger cars will be electric propelled and defined as small city cars. The average estimated car mass of 1,100 kg proofs a higher share of small vehicles. These vehicles will have one to approximately three seats. They will be equipped with assistance systems and partly with semi-autonomous systems. The overall speed limit is expected to be variable and can switch in critical situations to lower levels in comparison to that from nowadays. In the city centres and business districts with a lot of vulnerable road users there will be more separation between traffic modalities expected with a higher share of public transport systems. Problems could arise due to a higher number of elderly people. More and better public transportation will reduce the number of possible conflict partners.

The most frequent future accident scenarios involving SEV’s can be defined as accidents with pedestrians coming from Near Side & Far Side (outside of a junction, before a junction, after a junction). The most Frequent Impact Speeds derived from the surveys are between 10 km/h to 30 km/h and the three most expectable vehicle designs (bonnet, inclined, flat) are identified. The results from the stochastic analysis shows relevant speeds between 20 km/h and 40 km/h but with the limitation of an initial vehicle speed range between 30 km/h to 50 km/h. Due to the urban use case lower initial vehicle speeds can influence this more than higher speeds. A first idea for future updated pedestrian testing proposal can be introduced with two impact speeds, one corresponding at a low travelling speed with a high real accident frequency (between 10 km/h and 30 km/h) and considering moderate head injury risk. On the second level a higher travelling speed should be defined (between 30 km/h and 50 km/h), considering more severe head injury risk but with less quantity and higher injury criteria thresholds. An overall rating in combination with ADAS testing procedures for pedestrians can enhance future SEV designs and minimize injuries, injury severity or at best mitigate accidents.
6. Outlook – Pedestrian Kinematics

The fourth and final phase of the methodology would be the kinematic analysis of pedestrian accident scenarios involving SEVs. The approach will take into account data from accident databases, field operational tests and pedestrian kinematic studies. This will be reflected on certain SEV concepts to be expected in the coming years. The objective of this part of the methodology is to analyse the pedestrian kinematics and head impact conditions. The method is to simulate a large quantity of impact situations using multi-body systems considering different future Electrical Vehicle (EV) geometries, a number of pedestrian sizes and positions and a number of car impact velocities. The main outputs of this phase are the head impact conditions expressed in terms of: Head impact location, Head velocity vector, Impact location on the head, Second impact and Throw distance. These results can be compared against regulatory crash tests. Due to significantly changed boundary conditions new test scenarios as well as modified injury criteria needs to be evaluated for an improved safety performance of SEVs.

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References


