Prospective Estimation of the Effectiveness of Driver Assistance Systems in Property Damage Accidents

Klaus Gschwendtner  
Dr. Miklós Kiss  
AUDI AG  
Germany

Philip Feig  
Prof. Dr.-Ing. Markus Lienkamp  
Institute of Automotive Technology, Technische Universität München  
Germany

Paper Number 15-0037

ABSTRACT

Projects for the analysis of traffic accidents are focused mostly on personal damage. But analyses show that property damage occurs 42 times more often than personal damage [4]. Officially registered accidents on German roads result in mere damage to property (2.1 mio accidents [1]). A significantly higher number of property damage accidents are not reported to the police. Some of which are reported to the insurers [2]. A significant number of minor damage does not appear in the statistics. According to [3] the number of minor damage cases amounts to 4.8 mio cases per annum. 35% of full comprehensive cover accidents occur at low speeds and pose a high potential for future advanced driver assistance systems (ADAS) [4]. Details of accidents involving minor damage cannot be found in official statistics. In “In-Depth” property damage analysis, the conflict leading to damage is of high relevance. Uncertainties need to be settled by means of an expansion of the existing accident conflict situations [4]. Currently, equipment rates of ADAS are low requiring a purchase incentive for customers. Based on [5] this paper describes how damages of vehicles can be classified and brought into relationship with ADAS functions and the vehicle itself. Various configurations and different materials of outer attaching parts (OAP), e.g. aluminum, CFRP or plastics induce variable costs of repair. For a prospective evaluation method of the monetary effect of ADAS it is necessary to know all influence parameters and to quantify them. The evaluation of vehicle concepts in combination with an ADAS is possible.

Keywords: In-Depth Property Damage Analysis, Field Effectiveness, Prospective Evaluation, Property Damage Risk Function, Accident Research.

INTRODUCTION

Accident research units mainly analyze accidents involving personal injury. Derived findings run in the development of infrastructural arrangements or the vehicle safety. This has been mainly reflected in the decreasing number of traffic fatalities during the last decades. An investigation shows [4] that just every fourth of insurance cases of the property damage accident is reported officially. According to [3] the number of minor damage cases which do not appear in statistics amounts to 4.8 mio cases per year. Hence property damage occurs 42 times more often than personal damage. Official statistics only represent a fraction of real-world accidents involving property damage.

Up to now there is no detailed analysis of the accident characteristics and causes of accidents in large scale projects in the property damage field. Just pilot-studies like [4] deal with it. The objective is to make the „blank spot“ on the accident scenario map disappear. Detailed information and knowledge about the emergence of accidents and the underlying conflict scenario are very helpful for developing and designing advanced driver assistance systems.

35% of full comprehensive cover accidents occur at low speeds and pose a very high potential for current and future advanced driver assistance systems (ADAS) [4]. Currently, equipment rates of ADAS are low requiring a purchase incentive for customers.

Safety systems are currently mainly intended for reduction of injury severity in accidents at high initial and collision speeds, as for instance Adaptive Cruise Control with emergency brake function [6]. However, fitting rates for such systems are small. Therefore, a purchasing incentive for the customer shall be established in order to trigger a higher effect on traffic safety. However, this requires knowledge of the effectiveness of the system prior to market introduction. Purchasing incentives for the customer can be saved repair costs or lower insurance premiums. Hence systems would partly or fully pay off in the course of their service life.
A retrospective effectiveness analysis of active systems is elaborate and time-consuming concerning the data collection and because of the low fitting rates only viable over a long period of time (approx. 3 years). Therefore a statement on the effectiveness of a system is only possible at a late stage after launch of sales. Prospective analysis methods of ADAS in the field of property damage accidents are rarely available. This paper presents based on the methodology for the prospective determination of field effectiveness of ADAS focusing on the potential of reducing property damage accidents given in [5] a detailed evaluation of damages. Various equipment configurations and different materials of OAPs have a big impact on the repair costs. Furthermore the influence of the vehicle class has to be considered. An increasing number of automated systems is expected in the course of the next years and especially in the low speed range these systems could have a major influence on the number of occurring property damage accidents. Appropriate dimensions for the evaluation and comparability of the changing repair costs are needed.

METHODS AND DATA SOURCES

For evaluating the benefit of ADAS in property damage accidents a systematic procedure like described in [5]. This method consist of the main parts of data collection, reconstruction and new simulation of accidents and a Damage Risk Function (SRF) for evaluating modified accident parameters. The modified accident parameters are evaluated with the SRF. This function is build up modular for covering nearly every individual accident. Vehicles are divided into damage segments: Front, fender, doors, side panel and rear. Every area is related with components plugged in each.

Damage points and Matching coefficients

The resulting damage of a collision is reflected as a standard value in relation to the volume model of the respective manufacturer. A standardized description of the damage allows a comparison over a long period of time. If the resulting damage is currency related there would be no possibility to do a comparison many years later because component costs and wages would have changed. A further reason for standardized representation is improved comparability of vehicle models. Besides validity over a long period of time the evaluation of damages should also be transferable to various models. In an identical damage scenario the resulting damage should be on the one hand be comparable and on the other hand individual influence factors regarding the extent of damage have to be considered.

These requirements can be achieved by means of the modular design of the SRF and using damage points (SP) as an independent damage value (Eq. (1)). The volume model of the respective manufacturer serves as a basis. Total cost of a repair consisting of component costs (ET), wages (LW) and paint-work costs (LACK) are under consideration. For every single part the total costs of replacing are considered and subsequently divided by the basic factor $\alpha$.

Besides the complete replacement of components repair procedures like smart repair, paint work and removal of dents can be considered. The depth and surface area of the deformation are the main factors for the determination of the repair method.

$$SP_i = \frac{ET_i + LW_i + LACK_i}{\alpha} \quad (1)$$

Mainly the OAPs are considered here since it can be assumed that in the low speed range without personal damage no significant structural elements are damaged. This was derived in other studies of [5]. The generated damage points are identical for each vehicle model in order to ensure comparability of components. Different materials of components, equipment speciation of vehicles and various vehicle classes have to be evaluated the same way. Therefore matching coefficients are necessary (Table 1). These coefficients are separated into different influence parameters as can be seen in the first column. The coefficients show the ratio of different prices of repair costs for different parts and vehicles. An estimator tool was used to determine repair costs.
Table 1.
Specifications of matching coefficients

<table>
<thead>
<tr>
<th>Influence-parameter</th>
<th>Symbol</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle class</td>
<td>$\beta_{\text{class}}$</td>
<td>small car, compact car, medium-sized vehicle, upper middle-sized vehicle, luxury class vehicle</td>
</tr>
<tr>
<td>Light</td>
<td>$\beta_{\text{light}}$</td>
<td>Xenon-, LED- or laser-headlights</td>
</tr>
<tr>
<td>Material</td>
<td>$\beta_{\text{material}}$</td>
<td>aluminium, CFRP or plastic</td>
</tr>
<tr>
<td>Dynamic Design packet</td>
<td>$\beta_{\text{dynamic}}$</td>
<td>S-Line, M-packet, AMG- packets</td>
</tr>
<tr>
<td>Alloy rim size</td>
<td>$\beta_{\text{rims}}$</td>
<td>15&quot;, 16&quot;, 17&quot;, 18&quot;, 19&quot;, 20&quot;, 21&quot;</td>
</tr>
<tr>
<td>Type of varnish</td>
<td>$\beta_{\text{varnish}}$</td>
<td>solid paint or special painting</td>
</tr>
<tr>
<td>Layout ADAS</td>
<td>$\beta_{\text{ADAS}}$</td>
<td>ACC with one or two sensors</td>
</tr>
</tbody>
</table>

For example if there is a damage on the right front edge all damage points of the components are taken into account. If the vehicle class is higher than the volume model, the material of the engine hood and the front fender have changed and also the technology of the headlights is a different one. The coefficients for class, light and material have to be multiplied to the individual damage points and are called damage units.
Figure 1 gives an overview over the range of the matching coefficients. This method can be applied for all manufacturers and would therefore provide a comparison option for damage scenarios.

\[
SE_i = SP_i \prod_{n}^{m} \beta_{n} \tag{2}
\]

\(m, n \in \{\text{class, light, material, rims, dynamic, varnish, ADAS}\}\)
In the most cases of an accident many components at once are damaged. Equation (3) contains all affected parts

\[ SE_{\text{sum of external components}} = \sum_{i}(SP_i \prod_{n}^{m} \beta_n) \quad (3) \]

In addition, there are basic costs which are identical for every repair job as for instance varnish preparation if paint work is required. The damage points and the damage units for the varnish-preparation are equal because there is no difference between various vehicle-models. They can be added to the total sum of damage units (Eq. (4)).

\[ SE_{\text{all}} = SE_{\text{sum of external components}} + SE_{\text{varnish prep}} \quad (4) \]

The back calculation to the damage extent in the used currency can be ensured all time. Therefore the sum of damage units including the varnish preparation is multiplied with the basic factor \( \alpha \) (Eq. (5)). In the course of time only the basic factor has to be adjusted for considering changing prices.

\[ SH = SE_{\text{all}} \alpha \quad (5) \]

On the basis of this methodology it is possible to evaluate future vehicle concept without knowing the exact component costs. Only the vehicle class and the used materials have to be known for calculating the expected repair costs. The repair costs are in the first instance interesting for insurers.

The methodology of damage points and damage units facilitates a separate consideration: The ADAS can reduce damage points, the reduced damage points have vehicle individual impact on the resulting damage units. Both dimensions are referred to the basic factor.

**Property Damage Risk Score**

According to [7] risk is the combination of damage extent and the probability of occurrence. Using an overall statistical relevant damage frequency distribution like DEKRA, GIDAS or AZT can provide it, a basic risk can be calculated. If available even for different classes of vehicles. These information can be used in combination with vehicle specific information about materials of components and equipment. A property damage risk score (SSR score) can be calculated due to summing up all products of damage units and frequency in all damage segments around the vehicle (Eq. (6)).

\[ SSR = \sum_{i}(SP_i \cdot \prod_{n}^{m} \beta_n \cdot p_{\text{damage,i}}) \quad (6) \]

In application of the SSR Score a distinction between the upper and the lower SSR score. The difference between is the considered extent of damaged components. The lower SSR score considers bumpers, fenders, doors and side panel. The upper SSR score considers in addition lights on front and rear, ADAS sensors as well as front and boot lid. Therefore an interval between minor loss and bodily injury can be defined. A multiplication of these intervals with the annually expected damage frequencies a monetary potential of ADAS can be defined.

Based on this intervals a risk label is derived. It is divided in eight categories from A to H. In the categories from F to H a progressive rise is visible whereas the categories A to E show a linear rise. This is necessary because the rise...
in repair costs for complex technologies like laser light or extreme lightweight constructions cannot be represented in a linear scale. Table 2 shows the intervals and the according risk labels.

<table>
<thead>
<tr>
<th>risk label</th>
<th>lower boundary property damage risk score (SSRL)</th>
<th>upper boundary property damage risk score (SSRU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&gt; 0</td>
<td>40</td>
</tr>
<tr>
<td>B</td>
<td>&gt; 40</td>
<td>80</td>
</tr>
<tr>
<td>C</td>
<td>&gt; 80</td>
<td>120</td>
</tr>
<tr>
<td>D</td>
<td>&gt; 120</td>
<td>160</td>
</tr>
<tr>
<td>E</td>
<td>&gt; 160</td>
<td>200</td>
</tr>
<tr>
<td>F</td>
<td>&gt; 200</td>
<td>280</td>
</tr>
<tr>
<td>G</td>
<td>&gt; 280</td>
<td>400</td>
</tr>
<tr>
<td>H</td>
<td>&gt; 400</td>
<td></td>
</tr>
</tbody>
</table>

A risk classification of vehicles has to be conducted because resulting repair costs in property damage accidents depend significantly of the equipment of the vehicles and the materials of the OAPs. Based on the findings in the risk classification an investment strategy could be derived how a vehicle should be protected by systems to achieve a good risk label. In order to achieve a positive effect on damage requirement there are two options: either reduction of frequency or reduction of damage extent. In both options ADAS functions can be a big advantage with a direct derive of a cost-benefit ratio.

RESULTS

The most interesting thing of the evaluation method is the possibility to evaluate future vehicle concepts. A distribution of damage frequencies can be taken from a precursor or comparable model of a competitor. The used material for OPSs is one of the main influence on the SSR score. Like Table 3 shows the influence of materials based on a middle class vehicle with OAPs of steel and a plastic bumper (ranking C). The adjustment to aluminum parts shows a little higher risk score but is in general a damage neutral possibility to use lightweight OAPs.

A complete change to CFRP parts results in a D label. This corresponds the risk score of a high class vehicle with aluminum structure and OAPs. An exact weighing up of the advantages of CFRP parts has to be done meticulous. There is a high potential for lightweight but also economical disadvantages. Plastic OAPs lower down the SSR score and yield an B label. Additionally plastic parts can be brought to the workshop undercoat-varnished resulting in a shorter immobilization time of the vehicle and therefore lower cancelation expenses for customer and insurer.

Table 4 gives a overview of the influence regarding the light technology. This is the most considerate factor. The reference model is equipped with a halogen headlight. Using xenon headlights increases the SSR score for 10%, LED for 38% and using laser-lights would be an increase of 129%. Damaging headlights causes high repair costs and additionally headlights have a very exposed position in case of a crash.

<table>
<thead>
<tr>
<th>middle class vehicle</th>
<th>steel</th>
<th>aluminum</th>
<th>CFRP</th>
<th>plastics</th>
</tr>
</thead>
<tbody>
<tr>
<td>lower SSR score</td>
<td>49</td>
<td>50</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>upper SSR score</td>
<td>83</td>
<td>86</td>
<td>156</td>
<td>67</td>
</tr>
<tr>
<td>risk label</td>
<td>C</td>
<td>C</td>
<td>D</td>
<td>B</td>
</tr>
</tbody>
</table>
Table 4.
Influence of headlight technology

<table>
<thead>
<tr>
<th>middle class vehicle</th>
<th>halogen</th>
<th>xenon</th>
<th>LED</th>
<th>laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>upper SSR score</td>
<td>83</td>
<td>91</td>
<td>115</td>
<td>191</td>
</tr>
<tr>
<td>relative change</td>
<td>-</td>
<td>+10 %</td>
<td>+38 %</td>
<td>+129 %</td>
</tr>
<tr>
<td>risk label</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>E</td>
</tr>
</tbody>
</table>

The fitting position of ADAS sensors has also a high influence on the resulting risk score. For example the use of two radar sensors causes an increase of 34% compared to the reference vehicle without any sensors.

A minor influence can be found regarding alloy rims. Up to 19” there is just a little increase. Using 20” rims and higher there is an bigger influence because of the higher renewal costs.

Nearly every component brings a rise of the SSR score. Just plastic OAPs have a positive effect. ADAS functions therefore have to compensate this effect due to an active intervention for mitigating or avoiding a collision. This will be analyzed in further work.

DISCUSSION AND LIMITATION

For validation of the systematic of damage points and matching coefficients real damage cases were taken into account and compared with the results out of the damage unit calculation. All considered cases of losses were taken out of the accident type extension analyzed in [4] and [5]. In every case damaged parts, manufacturer and model of vehicle, at hand ADAS and repair costs are known. Constitutive to this information the damage extent in damage units is calculated depending on vehicle class, materials and equipment options. The resulting damage is compared to the estimated damage of authorized experts.

Figure 2 shows the comparison of the resulting damage extents in motor-own-damage cases. The square shapes represent the findings of experts, the triangular shapes the ones of the described systematic. The dotted lines represent an equivalent SSR-score. In this figure the frequency and the specific scenarios are from no importance the interesting point is the deviation of the square and triangular shape.

The averaged deviation between the two different approaches is 2.9 percent. 64.1 percent of the analyzed cases were calculated directly under the assumption only to change OAPs. The amount of cases repaired by smart repair or repair varnish is 15.4 percent. In 20.5 percent of the cases slight structural damages occurred.

![Figure 2. Validating the system of damage units (SE)](image)

The systematic of damage points and damage units is suitable for model and manufacturer independent calculation of repair damages in property damage accidents. The damage extent is given well in the retrospective consideration. The methodology is based on one manufacturer and on a limited number of vehicle models. However, the validation...
shows the permissibility of assumptions and the transferability to other manufacturers and car models. The only larger deviation occurs in evaluating SUVs and high price models.

A use of the systematic for evaluating vehicles according to their class, materials and equipment in combination with an ADAS is possible and can be done while the development phase.

The methodology of evaluating the effectiveness of ADAS in property damage accidents should not serve as a new consultant-tool, but as a means to classify effects on vehicle damage in accident research. Up to now the methodology works for minor deformation depths which are very common in property damage accidents.

CONCLUSIONS

In property damage different characteristics of accidents appear compared to personal damage [4]. Main influence parameters regarding the occurring repair costs are beside the deformation area and deformation dimensions the material of OAPs and the equipment of the vehicle.

ADAS with fully automated intervening functions have influence on property damage scenarios in the low speed range. The material and the configuration of vehicles have influence on the resulting damage in an accident. The procedure outlined here is a possible approach for evaluating damages of vehicles in the low speed range and compare them to other configurations in combination with an ADAS. This serves as a prospective method for deriving the customer value of systems and functions. Effectiveness of a system is stated in property points and individually calculated for vehicles in damage units. A validation of the systematics could have been shown by means of real world damage data.

More and more automated driving functions become of increasing importance in the driver assistance sector. If the frequency of various conflict scenarios in which an assistance system may intervene, it is possible to create a corresponding damage prevention or reduction potential of systems.

A bottom-up approach is pursued which allows an increase in system installation rates having a high impact on cost advantage as to damage reduction and prevention in the low speed range. Driver assistance systems which exhibit reliable function in the low speed range require high-end sensors. These sensors may also be utilized for further safety functions beyond parking and maneuvering actions and thus may significantly reduce accident numbers in a long term.

Accident research units, insurers and associations have to come to an arrangement of harmonized variables which are imposed similarly. This ensures that each other can benefit from the insights. If there is a proof of the benefit of an ADAS a purchase incentive for the customer can be created. A basic precondition for this is in-depth knowledge of property damage scenarios [4].

REFERENCES