PARKING CRASHES: THE RATIONALE FOR ACTION AND THE DEVELOPMENT OF TEST PROCEDURES

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Paper Number 15-0348

INTRODUCTION

During the last decade parking and manoeuvring accidents appear to be increasingly relevant in third party damage liability and first party or motor own damage claims; a trend evident in many countries around the world. At the same time, vehicle manufacturers have offered a rapidly increasing variety of advanced driver assist systems such that there is greater scope for the avoidance of collisions than ever before. The low speed nature of parking and manoeuvring crashes strongly suggests that this problem should be solvable using technologies similar to those already used in other applications. In fact, several systems directly influencing parking crashes already exist, including proximity based warning systems, systems that will detect parking spaces and park semi-automatically and automatic braking systems similar to AEB that function in reverse.

This paper aims to assess the scale of the problem with low speed manoeuvring crashes, identify the most common collision mechanisms, assess the potential of the different technologies to solve the problem and to describe the development of test procedures capable of characterising system performance in relation to real world crashes.

CHARACTERISING PARKING CRASHES

Objectives

The objective of this element of the work was to quantify the scale of parking crashes around the world in terms of their frequency and cost and to investigate the common crash mechanisms such that a detailed understanding could be developed of what would be required of a really effective avoidance system for such crashes.

Methods

Several Members of the RCAR network of insurance research centres analysed their individual data sets in order to answer the questions set out in the objectives. Crashes are classified differently in each data set but wherever possible the data have been compared on a consistent basis. The data sets included:

- Thatcham Research, UK: Analysis of 12,565 claims from a First Notification of Loss (FNOL) dataset involving collisions occurring in the UK in 2010. The data includes 1st and 3rd party claims, of which 7,687 (61%) are 1st party and single vehicle at fault cases. Crash categorisation was based on text analytics studies of collision descriptions.
- Allianz Centre for Technology, Germany: Analysis of 1,000 Third Party Liability (TPL) claims with material damage only and 983 Motor own Damage (MoD) claims from collisions occurring in Germany in 2011.
- German Insurers Accident Research (UDV), Germany: 345 Third Party Liability (TPL) claims with material damage and 219 Motor own Damage (MoD) claims with collisions only in Germany in 2004 to 2006 and 2012.
• Insurance Institute for Highway Safety, US: IIHS based their analysis on a retrospective analysis of data accumulated through a survey of 509 vehicles brought to drive-in insurance claims centers in the Washington D.C. metropolitan area in 2001 to 2002. The study examined the types and amounts of vehicle damage sustained in relatively minor front and rear crashes.
• Korea Insurance Development Institute, South Korea: 45,153 Third Party Liability claims (bodily injury & property damage) from 2007 to 2012 in Korea; Analysis was based on automatic extraction of parking related claims by using keywords such as ‘parking’ and ‘reversing’ etc.
• Jiken Centre, Japan: Analyses of insurance payment data from 2011.
• Insurance Australia Group, Australia: Data from in excess of 1million 1st and 3rd party insurance claims from 2010 to 2014 in Australia. Analysis was based on automatic extraction of parking related claims by using keywords such as ‘parking’ and ‘reversing’ etc.

Results

Despite the differences in data classification and analytical techniques used by the various RCAR partners in their independent analyses, the findings were remarkably consistent in the UK, Germany, US, Australia, Korea and Japan. Based on these analysis it can be confidently concluded that crashes while parking and manoeuvring at low speed:

• Represent a high proportion of all claims frequency, representing between approximately 15% and 40% of all claims;
• Are responsible for a large proportion (10% to 30%) of all motor insurance claims costs;
• Mostly (60% to 80 % of parking claims) result from reversing manoeuvres;
• Mainly involve collision with 3rd party vehicles (approximately 55% to 80%), poles and walls;
• Typically occur in car parks, and on private property and urban roads.

The findings above are valid internationally. More details were available in some of the individual national data sets. Although these cannot be strictly considered to be internationally valid, the high level of agreement where comparable data is available suggests that there is a good chance that results will be similar in other countries.

Analysis of the German data by Allianz and UDV shows that the main problem is not entering a parking space, but moving out of a parking space and manoeuvring (70% to 85%). Analysis of the UK data by Thatcham showed a comprehensive breakdown of the types of collision, as shown in Table 1 below.
In addition to this, the Thatcham analysis was able to identify the areas of damage on the vehicle more specifically for the main crash types:

- **Cases where the 1st party reverses and collides with another stationary vehicle (approx. 45% of all parking crashes)**
  - 1st party damage predominantly to the rear corners (>80% of rear damage with known location)
  - 3rd party damage distributed between all corners and the sides of the vehicle
  - Central damage to the front or rear of the vehicle was infrequent for both 1st and 3rd party vehicles
- **Cases where the 1st party reverses and collides with a “pole-like” object (approx 11% of all parking crashes)**
  - 56% of damage is to the rear of the vehicle
  - 28% to the sides of the vehicle
  - 16% to the front of the vehicle
- **Cases where the 1st party reverses and collides with a barrier or wall (8% of all parking crashes)**
  - 61% of damage is to the rear of the vehicle, corner damage slightly more common than central or distributed damage
  - 16% to the sides of the vehicle
  - 16% to the front of the vehicle
  - 3% unknown

One substantial difference between the countries was in relation to reversing and collisions with pedestrians. As can be seen from Table 1, UK collisions where cars reversed into pedestrians were rare, representing just 0.1% of all parking crashes. The US data available does not directly quantify the total number of parking and...
low speed manoeuvring crashes so it is not possible to produce a directly comparable percentage. However, it has been found (NHTSA, 2014) that on average there are 210 pedestrian fatalities as a result of “backover” accidents each year and a further 15,000 injuries. Of those killed, almost one third are children and just over a quarter are elderly adults of 70 years of age or more.

ASSESSING THE POTENTIAL EFFECTIVENESS OF PARKING SYSTEMS

Objectives

Having quantified the scale of the problem represented by parking crashes and characterised those crashes in a way that allows an understanding to be gained of what would be required to prevent them, the objective of this element of the work was to identify the different parking systems available and to try to quantify how effective they might be at preventing crashes.

Methods

A variety of different methods were used to try to provide the answers required to achieve the objectives:

• Consultation with vehicle manufacturers and a review of vehicle specification data was undertaken in order to identify available parking assistance systems. A comparison was undertaken of their specifications and functions as an initial indicator of their ability to prevent the common types of crashes identified;
• A literature search and, where possible, an analysis of RCAR members insurer data was undertaken in order to identify measurements of the effect of parking assist systems on insurance claims and these were reviewed;
• A short, subjective benchmarking study was undertaken to gain an initial overview of the capabilities of different vehicle technologies;
• A comprehensive and objective test procedure was developed and then used to assess the performance of one type of technology.

Results

Parking assistance availability and specification

The research showed that a wide variety of different driver support systems that could be classified as “parking assistance” were available. These have been grouped into the categories shown below:

• Parking sensors, or Park Distance Warning (PDW), provides proximity-based acoustic warnings to a driver during low speed manoeuvring and may also offer a visual display. This technology is widely available in the market and has been for many years, though it often remains an optional extra at additional cost or only available as standard on higher specification models.
• Rear view cameras: an in-vehicle screen shows the view from a camera mounted at the rear of the vehicle
• Surround view cameras: an in-vehicle screen shows a composite view derived from multiple cameras around the vehicle which shows a plan view of the vehicle and surrounding objects, sometimes combined with a direct rear view while reversing. Available on a few high specification models, such as Mercedes E and S class.
• Semi-automated parking: These systems can identify appropriate parking spaces and provide automated inputs to help manoeuvre the vehicle into the space. System specification varies considerably, some will detect only parallel spaces, some both parallel and perpendicular, some will only steer and some will control steering, throttle and brake. Where systems do brake, this function is typically not active unless the semi-automated parking function is used. Many manufacturers now offer this type of system, usually as an option, including Mercedes, Volvo, Ford, and VW.
• Reverse auto-brake is similar to Autonomous Emergency Braking (AEB) for front-to-rear crashes. This technology detects potential crashes behind a reversing vehicle and automatically applies the brakes to slow or stop the vehicle thus mitigating or preventing the crash. Unlike the semi-automated parking systems, this system is always active unless de-activated by the driver. Only a small number of manufacturers offer this type of system, at the time of writing, understood to be Infiniti, Mazda and Cadillac.

• Driverless parking: This is an autonomous valet parking function where the driver can leave the vehicle and use a phone app or other control to send the vehicle to find a parking space by itself and summon it again when needed. A small number of manufacturers have suggested this will become available on high specification models this year or next year.

Existing evidence of effectiveness

Although parking sensors, or Park Distance Warnings have been in production for a long time, there have been relatively few studies of their effectiveness. Since the introduction of rear view cameras there have been a few studies that have attempted to quantify the relative benefits of the different technologies experimentally by studying the responses of normal drivers with and without each technology when confronted by the unexpected presence of obstacles behind them while reversing. Kidd et al (2014) created an experiment where a child dummy was either positioned stationary, or moved into, the path of a reversing vehicle when the driver was not expecting it. It was found that when the child dummy was moving, most drivers (90%) avoided a collision even when they had no technology to support them and that there was no statistically significant difference to this when the drivers had any of the technologies available to them.

When the child dummy was stationary in the path of the vehicle, all of the drivers without technology collided with it. The addition of sensor systems giving a proximity warning reduced this very slightly to around 93% of drivers having a collision but this difference was not statistically significant. The use of a camera system reduced the incidence of collision to 56% and this was statistically significant. It was found that the effectiveness of the camera system was substantially reduced when the obstruction was in the shade. Counter intuitively, combining a sensor system with a rearview camera was found to be less effective than a camera alone. One explanation for this was that the participants looked at the in-vehicle screen less frequently when they also had the sensor system.

Although experimental studies of this are an extremely useful mechanism for predicting the potential of a system, operational factors such as the effects of shade, cited by Kidd et al (2014), as well as the possible effect of dirt on the camera lens etc., will affect the extent to which the systems are beneficial in real service. This can only really be measured by statistical comparison of collision or claims records of vehicles with and without the technology and, even then, the conclusions can be confounded by the wide range of interacting variables that affect crash frequency and severity. For example, the effect of a parking aid could be masked if parking aids were fitted only to vehicles with a very poor field of view or exaggerated if they were only selected as an option by very cautious and safe drivers. These factors can be hard to control for.

Statistical analysis of the effects on insurance claims of several parking systems has been undertaken for models of Toyota (Ydenius & Rizzi, undated) Mazda (HLDI, 2011a), Buick (HLDI, 2011b) and Mercedes (HLDI, 2012). The results of these analyses have been mixed:

• Ultrasonic parking sensors fitted to Toyota and Lexus Vehicles (model years 1999 to 2012) in Sweden were found to reduce the cost of damage while reversing by 27%;

• Ultrasonic parking sensors were found to be very effective for the Buick, reducing collision damage claims (insured vehicle) by 5% and property damage liability (typically 3rd party vehicle) claims by almost 17%. However, for the Mercedes version of the same system, the data suggested that collision claims were actually increased by 0.8% and property damage claims decreased by 1.8%, neither result being statistically significant;

• Rearview cameras fitted to Mercedes Vehicles were not found to have any statistically significant effect, while for Mazda vehicles they were found to produce a statistically significant 3.1% increase in collision claims and a non-significant 2.3% decrease in property damage liability claims;
Semi-automated parking systems, in the form of the Mercedes Active Parking Assist system, was found to produce non-significant increases in claims frequency (6.3% collision, 5.0% PDL).

It is not known whether the differences observed between experimental results and the various statistical analyses are the results of technical differences between systems, operational factors not replicated in the experimental environment, or confounding factors that could not be accounted for in the statistical analysis of claims rates. No effectiveness studies were identified that considered auto-brake systems for reversing.

**Technology Benchmarking**

An initial benchmarking exercise was undertaken by Thatcham in conjunction with Continental and Allianz. Three exemplary vehicles were selected, with a variety of technologies fitted, as defined below:

- **Infiniti Q50**
  - 360° Surround View
  - “Semi-guided” parking (scans for space and when driver selects a space provides the driver with instructions on movements and steering inputs required to get there)
  - Auto-brake while reversing

- **Mercedes E Class**
  - 360° Surround View
  - Semi-automated parking (steer, throttle and brake control, driver has to initiate system, initiate each movement and operate gear lever)
  - Auto-brake while semi-automated parking is in progress

- **Skoda Octavia**
  - Semi-automated parking (steering control automated, driver has to initiate system and operate accelerator, brake and gear lever)
  - Auto-brake while semi-automated parking is in progress

The tests undertaken were focused on the main needs identified by the data analysis rather than on a full exploration of the capabilities of different systems. As such, the test vehicle manoeuvres involved reversing in a straight line and reversing with full steering lock applied. The hazard objects considered were a stationary and moving vehicle target, a stationary and moving child pedestrian dummy, a traffic cone and a metal pole. The principle difference between the systems was that the Infiniti auto-brake system was always on, whereas for the Mercedes and Skoda it was active only when the semi-automated parking was activated. The claims data analysis reported in this paper showed that more than three-quarters of the reversing claims occurred when the vehicle was reversing out of a parking space, not reversing in. Neither of the semi-automated parking systems offer a function for reversing out of a space. While the presence of such a system may encourage more people to reverse into spaces, thus reducing the proportion that need to reverse out, the extent to which drivers will use the system in the long term is unknown. It is, therefore, likely that restricting the auto-brake function to only those times where the semi-automated parking is engaged will substantially reduce the potential benefit in the real world compared to a system that is “always on”.

The main findings of the exercise have been summarized below:

- **Infiniti Q50**
  - Always on
  - Impressive performance with all static objects
  - Some reduced performance with moving objects, particularly a crossing pedestrian
  - No false positive with grass or small bush
  - Effective at reversing speeds of up to approximately 8 km/h

- **Mercedes E class**
  - Only active with semi-automated parking
  - Impressive performance with both stationary and moving targets
  - False positive tests led to additional manoeuvring and delay but final decision was always correct
  - Effective at all reversing speeds permitted by the active park assist.
• Skoda Octavia
  - Only active with semi-automated parking
  - Avoided less collisions with static objects than the other systems, smaller objects in particular
  - Further reductions in performance with moving objects
  - No false positive with grass or small bush
  - Effective at reversing speeds of up to around 4 km/h, though with some inconsistency.

**Developing a parking test procedure**

A comprehensive parking test procedure was designed, based on the results of the claims data analyses, the effectiveness studies and the initial benchmarking tests. The test scenarios defined were intended to cover the most frequent claims type, including a car reversing into another car and reversing into a post. In each of the scenarios, reversing straight and with full steering in either direction was considered as well as different overlaps, and different configurations of corner impact.

![Figure 1: Illustration of the 30 different crash configurations defined.](image)

For each of these configurations it was considered important to consider the ability of systems to detect and respond both at short range (c. 2m) and when approaches were at higher speed (c. 6 km/h). In practice, this is likely to be achieved by an approach procedure that constantly relies on moving away from rest, in reverse gear and using only engine idle speed (or small throttle in the case of hybrid/electric drivetrains). Thus the higher speed objective is achieved with the same vehicle inputs but just starting from further away from the object.

The tests were designed such that the correct impact configuration was achieved by positioning the vehicle at the impact point and applying the appropriate steering lock. The vehicle would then be moved slowly forward the prescribed distance and stopped. While maintaining the exact same steering input, the vehicle would then be reversed at engine idle speed.

For the tests, the collision objects need to be representative of real world collisions as far as the sensor systems are concerned, currently these are predominantly ultrasonic, camera or radar sensors. However, it also needs to be soft or collapsible so as not to cause damage to the test vehicle. For the initial vehicle-to-vehicle test configurations, the Euro NCAP Vehicle Target was defined. This represents the rear end of a vehicle and was designed to be representative for in-line crashes seen through the “eyes” of lidar, radar and camera sensors. It was considered likely to be effective for ultrasonic sensors, possibly OK for camera sensors but unlikely to be realistic for radar sensors when approached from an angle or with an offset. Further development of a three dimensional target is likely to be required before the test procedure could be reliably implemented in a technology neutral rating scheme.

The collisions with a “post” are actually intended to represent a broad range of collision objects found in the insurance claims data, including metal and plastic bollards, concrete posts, trees etc. A brief exercise was undertaken to measure a sample of 38 different “post-like” objects. It was found that heights ranged from 0.4m to 1m, with a median of 0.9m and the diameter ranged from 76mm to 275mm, with a median of 150mm. For
the purposes of the initial test programme a bespoke post was used, which was 110mm in diameter, 900mm tall and constructed from plastic drain fittings and ballasted with gravel.

**Test results: Infiniti Q50 with Back-up Collision Intervention**

The test results for the car to car scenarios are shown in Figure 2, below.

![Figure 2: Car to Car Results of Short Range Tests (Top) and Higher Speed Tests (Bottom) for Infiniti Q50](image)

It can be seen that performance is generally lower at the higher speeds and on the inside of the curve when turning. The performance in the tests against a bollard are shown below.
It can be seen that performance was strong in the centre of the vehicle, avoiding collisions at up to around 7 km/h but that this dropped away slightly towards the corners of the vehicle (which is important because claims data shows the corners are frequently damaged). It is worth noting that the effectiveness is reduced or eliminated if starting from rest at very short distances to the collision partner.

One observational result of this range of tests was that when the auto-brake was activated and avoided a crash, the brake was only held on automatically for a period of around half a second and was then released. In the automatic vehicle to which this was fitted, this meant that the vehicle started to move backward again after a short period of time, if the driver had taken no action to brake themselves or place the vehicle in neutral. Subjectively, it was considered that some drivers, in real situations, may not react sufficiently quickly, potentially eroding some of the benefit.

DISCUSSION

The evidence shows that parking and low speed manoeuvring crashes represent a very substantial cost in terms of damage, representing up to 30% of all insurer claims cost. In some jurisdictions, they also represent a substantial cause of death and serious injury to some of the most vulnerable people in society, those aged less than 5 and more than 70. This does, therefore, represent a significant problem to solve.

A range of semi-automated parking systems are available but these are offered as a convenience feature and by focusing on assisting the driver to get into spaces, do not directly affect the mechanism (reversing out of parking spaces) that is responsible for the most claims. In addition to this, they rely on the driver deciding to use the system. It is not known how often drivers will choose to use the system in practice.

Technologies intended to more directly prevent or mitigate this type of crash have already been implemented. Simple proximity warnings have been widely available for many years and, in the US, rear view cameras have
been made mandatory for certain vehicle types. However, the evidence regarding their effectiveness is very mixed. Experimental studies suggest that camera systems will substantially reduce the incidence of reversing crashes but that proximity warnings do not (and lessen the effectiveness of cameras when used in combination). Statistical analyses of claims rates has found proximity warnings to be effective on some cars but not others and has found little evidence of the effectiveness of cameras.

There are a range of possible reasons for the mixed results, including the possibility that the effectiveness:
- relies on driver action to achieve its results;
- will be influenced by the way in which warnings are delivered;
- will be affected by the positioning and quality of screens, the cleanliness of camera lenses, and the external lighting conditions, where mixtures of light and shade can obscure objects.

Linking these detection systems automatically to the braking system such that the vehicle can be stopped without driver intervention would be expected to avoid many of these human factors difficulties and improve effectiveness. Such systems have been fitted to a very small range of vehicles and are similar to AEB systems. Although no post-hoc studies of effectiveness are yet available the analogous comparison that showed AEB systems were more effective than forward collision warning systems suggests that reverse auto-brakes should be an improvement on both cameras and sensors alone.

A comprehensive test programme has been developed to assess performance in situations that have been demonstrated to be highly relevant to real world insurance claims and it has been seen that one reverse auto-brake technology (Back-up Collision Intervention on the Infiniti Q50) proves highly effective in those tests. It is, therefore, considered that there is a compelling case for using this test programme as the basis of a scheme to incentivize the fitment of systems that perform well in situations representing real crashes. In order to achieve this, the test programme is likely to require:
- Rationalisation, to reduce the burden of testing while still promoting good performance
- Refinement to the methods to ensure accurate and repeatable results, in particular the methods for achieving consistent impact points.
- The development of a new car target providing an accurate, 3 dimensional visual and radar signature.

CONCLUSIONS

1. Parking and low speed manoeuvring crashes represent a significant cost to societies across the world, representing up to 30% of the cost of all insurance claims. Claims involving reversing out of parking spaces and colliding with other vehicles or fixed objects are the most common.
2. Existing measures to reduce the frequency of this type of crash show mixed results, with some promising signs of effectiveness but other evidence suggesting little evidence of effectiveness.
3. Many of the possible explanatory factors for the lower than expected effectiveness results are associated with human factors. These could be bypassed if the detection systems were linked to an autonomous braking function.
4. A handful of reversing auto-brake systems are already in production and tests undertaken during this research suggest they are capable of avoiding a large proportion of the the most common types of parking crash identified in the insurance data.
5. An initial test programme has been developed that is capable of assessing the performance of such systems in scenarios highly relevant to real world claims. Further refinements to this programme have been proposed to ensure it will be sufficiently robust to allow it to be implemented in suitable incentive schemes around the world.
REFERENCES


