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Accident Characteristics of Severe Motorcycle Accidents in Germany

Unfallcharakteristik von schweren Motorradunfällen in Deutschland

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Abstract

The overall number of severely injured participants and fatalities in road traffic accidents has decreased enormously in the last decades. These casualties in the group of riders of motorcycles in traffic accidents have only decreased in a smaller percentage, in some countries there was even an increase registered.

The aim of this study is to analyze the accident situation of motorcycles with cubic capacity > 125 cm^3 in Germany, the so called heavy motorcycles, especially with severely injured and killed riders. The characteristic and reasons of these accidents shall be analyzed and countermeasures shall be developed.

The accident data of 1,580 drivers of motorcycles were analyzed, collected by a scientific research team of GIDAS (German In-Depth Accident Study) in the area of Hannover and Dresden within the years 2000 up to 2013. This data is a statistical representative sample of the real accident occurrence in Germany.

The study points out that 218 (13.7 %) motorcycle accidents lead to severe injured riders with MAIS 3+, whereas 46 (3.0 %) of the riders were killed. The most MAIS 3+ accidents with 45.1 % occurred in accidents with objects (including falls), 39.8 % in accidents with cars. Severely injured (MAIS 3+) riders with 22.1 % were clearly higher in the age group above 60 years compared to 13.4 % in the age group 41-60, 11.7 % in the age group 26-40 and the youngest below 26 years had the lowest amount of MAIS 3+ riders with 10.2 %. The causes for these differences will be described and discussed in the paper. It is shown that the majority of 34.5 % of MAIS 3+ riders resulted from driving accidents (so called single-vehicle accidents) without other involved participants which led to falls or object impacts, 19.8 % resulted from accidents in longitudinal traffic, 17.8 % from turning in and crossing accidents and 17.3 % from turning off accidents. The study shows which injuries occur in different accident conditions.

Countermeasures can be seen in the two different parts of driver and vehicle assistant systems to influence the driver behavior and to reduce the driving speed and give concrete information for the avoidance of accidents, especially with severely injured persons (MAIS 3+). There will also be suggestions regarding the optimization of the infrastructure design and the design of the peripheral areas to avoid severe injuries. The study will also show where such accidents happened within the different street structure and for which collision types the most effectiveness of such assistance systems is given.

Zusammenfassung

Die Gesamtanzahl von schwerverletzten und getöteten Personen bei Straßenverkehrsunfällen hat in den letzten Jahrzehnten stark abgenommen. Die Anzahl an Verunglückten Motorradfahrern hat hingegen nicht in gleichem Maße abgenommen, es kann sogar in einigen Ländern eine Zunahme registriert werden.

Das Ziel dieser Studie ist die Analyse der Unfallsituation von Motorrädern mit Hubraum > 125 cm^3 in Deutschland, den sog. schweren Motorräder, insbesondere mit schwerverletzten und getöteten Fahrern. Es sollen Charakteristik und Gründe für diese Unfälle analysiert und Lösungsvorschläge erarbeitet werden.

Unfalldaten von 1.580 Motorradfahrern wurden analysiert, die von einem wissenschaftlichen Forschungsteams im Rahmen des GIDAS Projekts (German In-Depth Accident Study) in Hannover und Dresden in den Jahren 2000 bis 2013 gesammelt wurden. Dabei handelt es sich um eine statistisch repräsentative Stichprobe aus dem realen Unfallgeschehen in Deutschland.

Die Studie zeigt, dass 218 (13,7 %) Motorradunfälle zu Schwerverletzten (MAIS 3+) geführt haben, wobei 46 (3,0 %) der Fahrer getötet wurden. Der Großteil der MAIS 3+ Verletzten mit 45,1 % trat bei Unfällen mit Objekten (inklusive Stürzen) auf, 39,8 % entstanden bei Unfällen mit Autos. MAIS 3+ Verletzte traten mit 22,1 % deutlich höher in der Altersgruppe über 60 Jahren auf verglichen mit 13,4 % in der Altersgruppe 41-60, 11,7 % in der Altersgruppe 26-40 und in der jüngsten Altersgruppe unterhalb 26 Jahren gab es mit 10,2 % die wenigsten MAIS 3+ Verletzten auf. Die Ursachen für diese Unterschiede werden in der Studie erläutert. Es zeigt sich, dass 34,5 % der MAIS 3+ Verletzten der Motorradfahrer aus Fahrunfällen ohne weitere Beteiligte resultieren (sog. Alleinunfälle), die zu Stürzen oder Anprall an Objekte führten, 19,8 % entstanden bei Unfällen im Längsverkehr, 17,8 % bei Einbiege- und Kreuzungsunfällen und 17,3 % bei Abbiegeunfällen. Die Studie zeigt welche Verletzungen bei unterschiedlichen Unfallbedingungen auftreten.

Gegenmaßnahmen können in zwei verschiedenen Ansätzen gesehen werden, nämlich in Fahrer- und Fahrzeugassistenzsystemen, die das Fahrerverhalten beeinflussen und die Fahrgeschwindigkeit reduzieren und konkrete Informationen geben, um Unfälle zu vermeiden, insbesondere mit MAIS 3+ Verletzten. Auch werden Vorschläge zur Optimierung der Straßengestaltung und des Seitenraumes zur Vermeidung von schweren Verletzungen gegeben. Die Studie zeigt außerdem wo diese Unfälle im Hinblick auf das Straßennetz passierten und für welchen Kollisionstyp die größte Effektivität für solche Assistenzsysteme besteht.

Unfallcharakteristik von schweren Motorradunfällen in Deutschland

Einleitung und Ziel

Die Gesamtanzahl von schwerverletzten und getöteten Beteiligten bei Straßenverkehrsunfällen hat in den letzten Jahrzehnten stark abgenommen. Während die Anzahl an Leichtverletzten bei Motorradfahrern sogar stärker als der allgemeine Trend gesunken ist, hat hingegen die Anzahl an Schwerverletzten und insbesondere getöteten Motorradfahrern nicht in diesem starken Ausmaß abgenommen.

Abbildung 1 zeigt die zeitliche Entwicklung der Leichtverletzten aller Verkehrsteilnehmer in Vergleich mit den leichtverletzten Motoradfahrern von 1991 bis 2012 in Deutschland [1]. Die Anzahl an Leichtverletzten aller Verkehrsteilnehmer nahm in dieser Periode um ca. 15 % ab und die Anzahl leichtverletzter Motorradfahrer um ca. 28 %.

Die Schwerverletzten aller Verkehrsteilnehmer haben im gleichen Zeitraum um ca. 49 % abgenommen, wohingegen sich die Anzahl an Schwerverletzten Motorradfahrer lediglich um ca. 36 % verringerte (Abbildung 2).

Noch drastischer fällt der Unterschied in der Entwicklung der Getöteten Verkehrsteilnehmer bei Straßenverkehrsunfällen aus. Während die Anzahl aller getöteten Verkehrsteilnehmer sich in dem analysierten Zeitraum um ca. 68 % verringerte, wurde bei den getöteten Motorradfahrern lediglich eine Verringerung von 41 % erzielt (Abbildung 3).

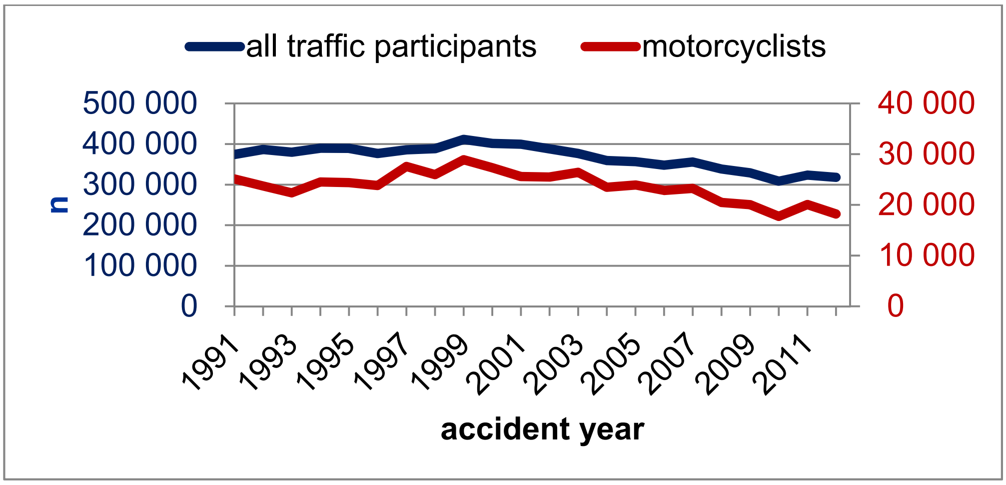


Abbildung 1. Entwicklung der leichtverletzten Verkehrsteilnehmer und leichtverletzten Motorradfahrer in Deutschland

Figure 1. Development of slightly injured traffic participants and slightly injured motorcyclists in Germany

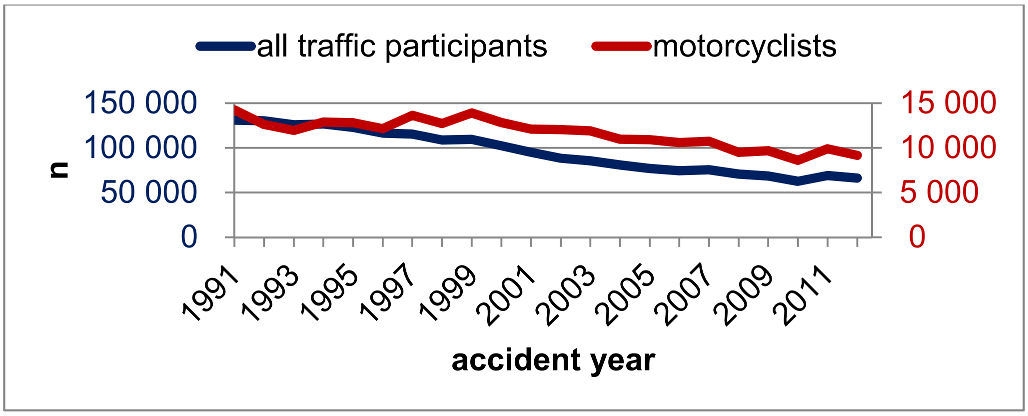


Abbildung 2. Entwicklung der schwerverletzten Verkehrsteilnehmer und schwerverletzten Motorradfahrer in Deutschland

Figure 2. Development of severely injured traffic participants and severely injured motorcyclists in Germany

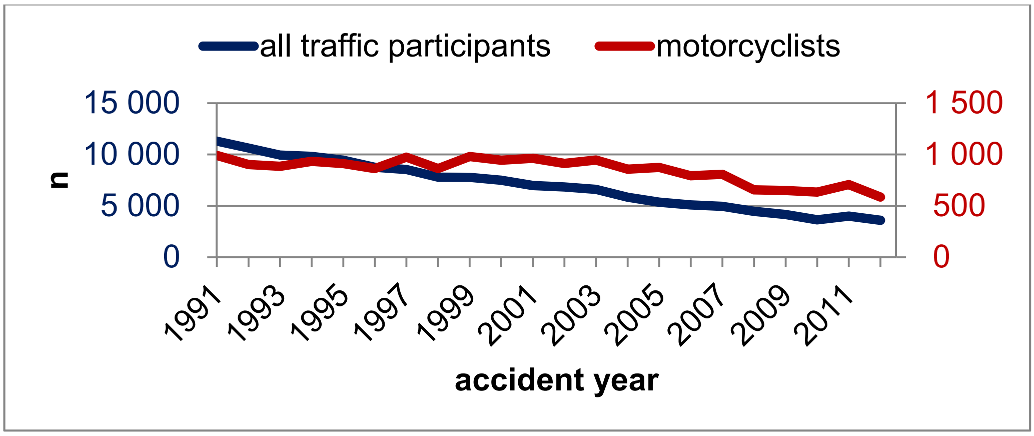


Abbildung 3. Entwicklung der getöteten Verkehrsteilnehmer und getöteten Motorradfahrer in Deutschland

Figure 3. Development of killed traffic participants and killed motorcyclists in Germany

Eine Erklärung dafür, dass die Anzahl an Leichtverletzten Verkehrsteilnehmer nur in geringem Ausmaß abgenommen hat, könnte daran liegen, dass eine Verschiebung von schweren Pkw Unfällen mit zuvor Schwerverletzten / Getöteten hin zu Unfällen mit Leichtverletzten Pkw Insassen stattgefunden hat.

Dies kann zurückgeführt werden auf die rasante Entwicklung von passiven und aktiven Sicherheitselementen sowie Fahrerassistenzsystemen bei Personenkraftwagen in dem untersuchten Zeitraum. Auch gesetzliche Vorgaben wie obligatorische Ausstattung der Neufahrzeuge mit ABS, ESP und Airbags haben zu diesem Trend beigetragen. Vergleichend dazu hat sich bei der Entwicklung von Motorrädern im Hinblick auf passive und aktive Sicherheitselemente in diesem Zeitraum wenig geändert. Natürlich muss hier beachtet werden, dass bei Motorrädern nicht die nahezu unbegrenzte Anzahl an Möglichkeiten für die Implementierung solcher Systeme gegeben ist wie bei Pkws. Bei Motorrädern existiert beispielsweise keine Knautschzone oder eine stabile Insassenzelle zum Schutz der Fahrer, weiterhin spielen Gewicht und vorhandener Bauraum möglicher Systeme eine weitaus größere Rolle als bei Pkws.

Auch Gwehenberger et al. [2] haben erkannt, dass die Reduktion von Schwerverletzten und Getöteten bei Pkw Insassen stärker ausfällt als die Reduktion bei Motoradunfällen. Die stärkere Reduktion getöteter Pkw Fahrer führen sie zurück auf die zunehmende passive und aktive Sicherheitsausrüstung von Pkws. Deshalb untersuchte 2006 das Allianz Zentrum für Technik 200 besonders schwere Motorradunfälle. Insbesondere sollte ermittelt werden, welches Nutzenpotenzial die Ausrüstung von Motorrädern mit ABS haben kann. Dafür wurden die 90 ABS-relevanten Fälle, bei denen eine Bremsung in der Precrashphase eindeutig nachweisbar war (z. B. durch Bremsspur), untersucht, wobei 48 Unfälle aufgrund ausreichender Dokumentation einer In-depth Analyse unterzogen wurden. Die Analyse würde einen hohen Nutzen von ABS bei Motorrädern belegen:

- ABS stabilisiere die Bremsung, verkürze den Bremsweg und verhindere das Überbremsen des Vorderrades und somit den gefährlichen Sturz beim Bremsen
- ABS sorge für geringere Stressbelastung des Motorradfahrers beim Bremsen, besonders in Grenz- und Notsituationen
- ABS vermeide ca. 8 % bis 17 % der schweren Motoradunfälle

Von den Autoren wird dringend die serienmäßige Ausrüstung der Motorräder mit ABS empfohlen.

Yildirim et al. [3] sehen als eine der Hauptursachen für Motorradunfälle die Fahrinstabilität infolge blockierter Räder bei starkem Bremsen oder beim Bremsen auf reibungsarmen Oberflächen. Das ABS verhindere das Blockieren und sorge dadurch für zusätzliche Fahrstabilität auch während des Bremsvorganges und verhindere in vielen Fällen einen Sturz. Eine weitere Ursache wird darin gesehen, dass Motorradfahrer aus Angst vor blockierten Rädern dazu neigen würden, in Notsituationen nicht mit der maximal möglichen Kraft zu verzögern und damit den Bremsweg unnötigerweise verlängern würden. Eine Bosch-Analyse auf Basis der GIDAS-Statistik (228 Motorradunfälle zwischen 2001 und 2004) habe ergeben, dass etwa die Hälfte aller Motorradunfälle eine Folge falscher Bremsmanöver sei. Mit dem Wissen, ein Motorrad mit ABS zu fahren, müsse der Fahrer keine blockierten Räder bei einer Gefahrenbremsung fürchten. Einer Bosch-Analyse zufolge würden sich 26 % aller Motorradunfälle mit Verletzungen oder Todesfällen in Deutschland verhindern lassen bei Ausstattung aller Motorräder mit ABS. Bei weiteren 31 % ließe sich durch ein ABS die durchschnittliche Kollisionsgeschwindigkeit um zwei Drittel reduzieren [4].

Eine Studie des Insurance Institute for Highway Safety (IIHS) in den USA zeigte, dass es mit einem ABS in Motorrädern über 250 cm^3 etwa 37 % weniger tödliche Unfälle geben würde [5].

Eine Studie der schwedischen Straßenbehörde Vägverket zeigte, dass sich 48 % aller schweren und tödlichen Motorradunfälle (Motorräder mit einem Hubraum größer 125 cm^3) durch ein Motorrad-ABS vermeiden lassen würden [6].

Die Europäische Kommission hat beschlossen, dass ab 2016 alle neu entwickelten Modellreihen und ab 2017 alle neu zugelassenen Motorräder mit einem Antiblockiersystem ausgestattet sein müssen [7]. Dies gilt für Motorräder mit einem Hubraum größer 125 cm^3. Erwartete Auswirkung ist eine deutliche Reduzierung der Zahl der im Straßenverkehr Getöteten oder Verletzten.

Das erste elektronische Stabilitätsprogramm (ESP) für Personenkraftwagen wurde 1995 in der Mercedes S-Klasse implementiert. Neue Automodelle müssen nach einer EU-Verordnung bereits seit November 2011 serienmäßig mit ESP ausgestattet sein. Ab November 2014 muss die Technik dann in allen in der EU angebotenen Neuwagen verbaut sein.

Bei Motorrädern gestaltet sich die Implementierung eines Stabilitätsprogramms bei vorhandenen zwei Reifen deutlich schwieriger als bei Pkws. Bosch [8] entwickelte die Motorcycle Stability Control (MSC), eine Motorrad-Stabilitätskontrolle, die 2013 in Serienfertigung ging und zunächst insbesondere in leistungsstarken Motorrädern verbaut werden sollte. Die Motorrad-Stabilitätskontrolle registriert mit einer umfangreichen Sensorik die Fahrdynamik der Maschine. Fortlaufend wird die Umdrehungsgeschwindigkeit von Vorder- und Hinterrad gemessen, sowie Schräglage und Nickwinkel des Motorrads. Anhand aller Sensordaten, einem Drehzahlvergleich zwischen Vorder- und Hinterrad sowie weiterer motorradspezifischer Parameter wie Reifengröße, Reifenform und geometrischem Einbauort des Sensors errechnet das ABS-Steuergerät die vom Neigungswinkel abhängigen physikalischen Grenzen der Bremskraft. Wird erkannt, dass ein Rad zum Blockieren neigt, wird der Bremsdruck automatisch innerhalb von Sekundenbruchteilen gesenkt und wieder aufgebaut, sodass bei ABS-Bremsungen an jedem Rad immer gerade soviel Bremsdruck anliegt, wie nötig, um das Rad kurz vor der Blockiergrenze zu halten.

Folgende Fahrdynamik-Sicherheitsfunktionen bietet das System:

- Verbesserung der Fahrstabilität und Bremswirkung in allen Fahrsituationen.
- Regelung des maximalen Motordrehmoments, sodass selbst bei wechselnden, glatten Fahrbahnbelägen die Antriebskraft effizient auf die Straße gebracht wird und das Antriebsrad nicht die Haftung verliert.
- Verringerung des Motorrad-Aufstellmoments beim starken Bremsen in Kurven und dadurch Stabilisierung bei Kurvenfahrt.

- Reduzierung der Gefahr von Kurvenunfällen, bei denen die Räder des Motorrads nach außen wegrutschen. Die maximal verfügbare Bremskraft zwischen den Rädern wird optimal verteilt.
- Sicherstellung der bestmöglichen Bremskraftverteilung, selbst wenn der Motorradfahrer versehentlich nur eine der beiden Bremsen oder mit zu viel Nachdruck bremsen sollte.
- Regelung des Motordrehmoments, um ein unkontrolliertes Aufsteigen des Vorderrads zu verhindern und gleichzeitig maximale Beschleunigung zu gewährleisten.
- Verhinderung eines ungewollten Abhebens des Hinterrads, indem bei hohen Reibwerten die maximale Bremskraft am Vorderrad reduziert wird und damit die Fahrstabilität unter Berücksichtigung von Nickrate und Längsbeschleunigung erhalten bleibt.

Ein Stabilitätsprogramm für Motorräder ist in der Lage weitere Verkehrsunfälle, insbesondere Alleinunfälle von Motorradfahrern zu verhindern. Dabei können hauptsächlich Fahrfehler der Motorradfahrer wie beispielsweise falscher Einsatz der Bremsen oder übermäßige Beschleunigung, insbesondere in Kurven, ausgeglichen werden, um einen Sturz zu vermeiden.

Nach Otte [9] zeichnen sich in vielen Unfallanalysen immer wieder Kopf und Extremitäten als besonders verletzungsgefährdet ab, da das Zweirad bislang nicht von einer schützenden Insassenzelle umgeben ist und der Zweiradfahrer im Falle einer Kollision sich von dem Zweirad löst und sodann auf gegnerische Fahrzeuge mit voller energetischer Energie aufschlägt bzw. auf der Straßenoberfläche anprallt. Es gebe grundsätzlich zwei anzustrebende Konzepte einer Verletzungsreduktion. Zum einen sei dies eine Veränderung der Abflugkinematik, um dem Zweiradfahrer zu ermöglichen über das Hindernis hinwegzukommen. Dies könne beispielsweise erreicht werden durch konstruktive Maßnahmen am Zweirad, u.a. Formgebung des Sitzes, Tanks sowie Anbringung von Knieanprallpolstern. Zum anderen sei dies, zur Reduktion von Kopfverletzungen, das Einbringen von Schutzelementen am Zweirad, die den Anprall an harten Teilen des gegnerischen Fahrzeuges verhindern sollen. Als Beispiel wird ein Airbag genannt, um die Bewegung des Rollerfahrers nach vorn aufzufangen bzw. sich zwischen Körper und gegnerischer Fahrzeugstruktur als Stoßdämpfungselement zu schieben.

Die DEKRA-Unfallforschung [10] hat von 2002 bis 2004 eigene sogenannte Full-Scale-Tests nach ISO 13232 mit Motorradairbags durchgeführt, um eine Risiko / Nutzen-Analyse durchzuführen. Im Einklang mit Erkenntnissen aus dem realen Unfallgeschehen hätten vergangene Versuchsreihen gezeigt, dass kritische oder lebensbedrohliche Belastungen des Motorradfahrers häufig direkt oder indirekt aus dem Anprall an der Seite von Personenkraftwagen resultieren. Dabei handele es sich insbesondere um Kopfverletzungen beim Anprall an die Dachkante, um Brustverzögerungen sowie um Halskräfte und Halsbiegemomente. Zu den vordringlichen Maßnahmen gehört somit der Schutz von Kopf, Hals und Brust des Motorradfahrers beim Anprall an der Seite eines Personenkraftwagens. Der Kopfanprall müsse entweder vollständig verhindert oder aber erheblich gemildert werden. Dafür müsse bei Beginn der Kollision das Belastungs-Niveau des auf dem Motorrad nach vorne rutschenden und dann am Unfallgegner anprallenden Aufsassen zunächst auf ein erträgliches Belastungsniveau gesenkt werden. Die nach dem ersten Anprall am Unfallgegner gegebenenfalls noch verbleibende kinetische Energie könne dann dazu genutzt werden, eine Aufwärts-Bewegung des Aufsassen einzuleiten, um bei hohen Anprallgeschwindigkeiten ein Überfliegen bzw. Gleiten über das Dach des angestoßenen Pkws zu ermöglichen. Bei den durchgeführten Tests habe bis auf das Halsbiegemoment und die Halsdruckkraft in allen anderen Fällen durch den Airbag eine Verringerung der gemessenen Dummybelastung erzielt werden können. In der Gesamtschau der bis dahin vorliegenden Ergebnisse wird ein erhebliches Nutzenpotenzial zur Vermeidung von Schwerstverletzungen durch den bei den Versuchen eingesetzten Airbag-Prototypen gesehen.

In einer Studie von Murri [11] aus dem Jahr 2007 wurden Lösungsansätze, Schutzpotenzial und Crashergebnisse eines Sicherheitsgurtes für Motorräder präsentiert. Der Stand der passiven Sicherheit heutiger Motorräder sei mit derjenigen von Automobilen der 60er Jahre vergleichbar. Das Dynamic Test Center in Vauffelin habe verschiedene technische Möglichkeiten untersucht, um den Freiflug des Motorradfahrers in eine verzögerte Bewegung umzuwandeln und damit das Verletzungsrisiko bei einem Unfall zu reduzieren. Als zukunftsträchtiges Rückhaltesystem sei ein Sicherheitsgurtsystem mit Gurtrollern entwickelt worden, welches Kollisionen in hohe Hindernisse überlebbar machen würde. Im Falle eines Sturzes oder ähnlichen Situationen, bei dem keine Ruckhaltekraft aufgebaut werden müsse, würde sich der Motorradfahrer wie gewohnt von seinem Motorrad trennen. In einer ersten Versuchsreihe von Full Scale Tests mit leichten und schweren Motorrädern in die Seite stehender Fahrzeuge (Lieferwagen und SUV) habe die Wirksamkeit des Gurtsystems erwiesen werden können, unter Normbedingungen (ISO 13232) und auch bei einer Kollision auf doppeltem Energieniveau mit 70 km/h.

Gesetzliche Regelungen für Motorradfahrer in Deutschland

In Deutschland wird für das Führen von motorisierten Zweirädern eine Fahrerlaubnis benötigt. Nach § 6 der Fahrerlaubnisverordnung (FeV) werden die motorisierten Zweiräder in folgende Fahrerlaubnisklassen (Tabelle 1) unterteilt [12].

Tabelle 1. Fahrerlaubnisklassen für motorisierte Zweiräder in Deutschland
Table 1. Type of driver's license for motorized two-wheelers in Germany

	Type of driver’s license			
criteria	**AM**	**A1**	**A2**	**A**
maximum speed	45 km/h	-	-	> 45 km/h
cubic capacity	< 50 cm³	< 125 cm³	-	> 50 cm³
performance	< 4 kW	< 11 kW	< 35 kW	-
power / weight ratio	-	< 0,1 kW/kg	< 0,2 kW/kg	-
minimum age	16 years	16 years	18 years	24 (20) years

In dieser Studie sind lediglich Zweiräder der Klassen A2 und A involviert, da nur Unfälle mit Zweirädern mit einem Hubraum größer 125 cm^3 untersucht wurden.

Für alle, die im Alter von 18-23 Jahren ihren Führerschein machen, gilt die leistungsbeschränkte Klasse A2. Um anschließend Motorräder der Klasse A fahren zu dürfen, muss eine Prüfungsvorbereitung absolviert und eine erneute praktische Prüfung abgelegt werden. Der Direkteinstieg in Klasse A ist ab dem Alter von 24 Jahren möglich oder ab 20 Jahren bei mindestens 2 Jahren Vorbesitz der Klasse A2.

Unfallanalyse basierend auf GIDAS (German-In-Depth Accident Study)

Für das GIDAS Projekt (German-in-Depth Accident Study) werden jährlich etwa 2000 Verkehrsunfälle direkt an der Unfallstelle aufgenommen. Diese werden von wissenschaftlichen Erhebungsteams in den Regionen Hannover und Dresden im Auftrag der Bundesanstalt für Straßenwesen (BASt) in Kooperation mit der Deutschen Forschungsgemeinschaft Automobiltechnik (FAT) dokumentiert und in einer Datenbank zusammengetragen. Die rekonstruierten Fahrgeschwindigkeiten und Kollisionsgeschwindigkeiten und auch die detaillierte Dokumentation der Verletzungen können dazu beitragen, Verletzungsschwerpunkte zu identifizieren. Basierend auf der Dokumentation der Verkehrsunfälle mit statistisch repräsentativen Auswahlverfahren der Unfälle, können diese als repräsentativ für Deutschland angesehen werden. Arbeitsmethode, Aussagefähigkeit und Repräsentativität der erhobenen Daten ist in der Literatur beschrieben ([13], [14], [15], [16]).

Bei der Rekonstruktion der Unfälle wurden die Bewegungen der Personen und Fahrzeuge vor, während und nach der Kollision ermittelt, sowie auch die Geschwindigkeiten der Fahrzeuge und Handlungen der involvierten Personen in den einzelnen Sequenzen. Für die Rekonstruktion der Geschwindigkeiten wurden die Unfallstellen inklusive vorhandener Spuren und Endlagen von Fahrzeugen und Personen jeweils in maßstäblichen Skizzen dokumentiert. Die Unfallstellen wurden dabei mit einem 3D-Laserscanner vermessen und die Kollisionsanalyse wurde mit der Simulationssoftware PC-Crash durchgeführt [14].

Die Verletzungen wurden detailliert dokumentiert und ausgewertet in Übereinstimmung mit der wissenschaftlich 6-fach abgestuften Skala der Verletzungsschwere, der Abbreviated Injury Scale (AIS) der "Association for the Advancement of Automotive Medicine" (AAAM, [17]). Bei dieser Bewertung wird jeder Verletzung ein AIS-Grad zugeteilt, was sowohl zu einer Verletzungsschwere für einzelne Körperregionen führt (beispielsweise AIS-Kopf) als auch zu einer maximalen Verletzungsschwere MAIS (maximaler AIS) des gesamten Körpers.

Weiterhin wurde eine neuartige Codierung von unfallverursachenden Faktoren verwendet, genannt „Accident Causation Analysis System” (ACAS), die es ermöglicht unfallrelevante Situationen zu identifizieren und präventive Gegenmaßnahmen zu definieren.

Das Ziel dieser Studie ist die Analyse der Unfallsituation von Motorrädern mit Hubraum > 125 cm³ in Deutschland, insbesondere mit schwerverletzten und getöteten Fahrern um die Charakteristik und Gründe für diese Unfälle zu finden und um Lösungsvorschläge zu erarbeiten.

Die nachfolgenden am Unfallort erhobenen Statistiken aus den GIDAS-Daten wurden auf das gesamte Unfallgeschehen in Deutschland gewichtet. Als Referenzdaten diente die Unfallbilanz von Deutschland des Statistischen Bundesamtes [1] aus dem jeweiligen Jahr des Unfalls. Als Wichtungsfaktoren wurde die Ortslage (innerorts, außerorts), der Haupt-Unfalltyp (1 bis 7) sowie die Verletzungsschwere (leicht verletzt, schwer verletzt, getötet) verwendet. Demnach ergaben sich für die Auswertung 2 x 7 x 3 = 42 Wichtungsfaktoren. Das heißt, dass die in dieser Studie verwendeten n-Zahlen und die Prozentangaben nicht direkt ineinander umgerechnet werden können.

Datenbasis

Es wurden Unfälle aus der GIDAS Datenbank der Jahre 2000 bis einschließlich 2013 ausgewertet. Bei der statistischen Analyse der Datenbank fanden sich 3.703 motorisierte Zweiräder, in die Studie gingen nur die 1.739 Fahrzeuge ein, welche einen Hubraum größer als 125 cm³ aufweisen. Weitere 56 Fahrzeuge wurden aus der Studie entfernt, da diese zum Zeitpunkt der Kollision keinen Aufsassen hatten (beispielsweise geparkte Motorräder). Damit ergaben sich 1.683 Fahrer von motorisierten Zweirädern mit einem Hubraum über 125 cm². Davon mussten 103 Fahrer aus der Studie eliminiert werden, da die Verletzungsschwere MAIS bei diesen unbekannt war.

Nach dieser Stichprobenauswahl verblieben 1.580 Fahrer von motorisierten Zweirädern (Hubraum größer 125 cm³) mit bekannten Verletzungen.

Abbildung 4 zeigt den Auswerterahmen der Studie mit allen zugehörigen Zahlen und ausgeschlossenen Fällen.

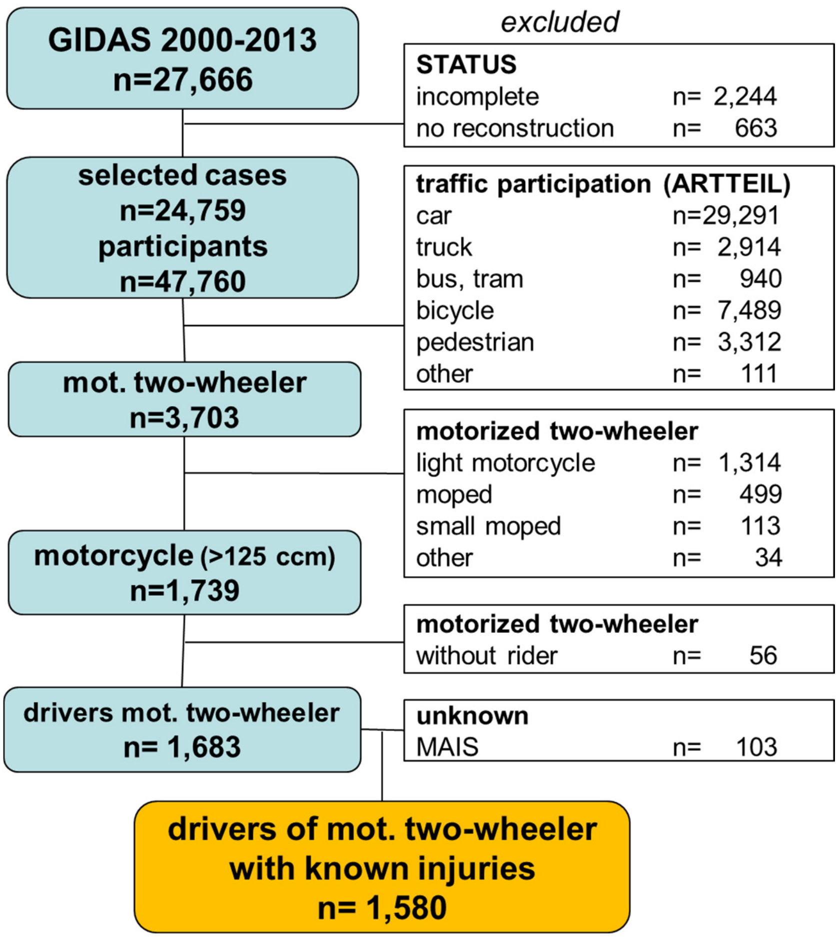


Abbildung 4. Auswerterahmen und Stichprobenauswahl der Studie
Figure 4. Evaluation frame of the study

Analyse und Ergebnisse

Für die Studie wurden folgende Kriterien hinsichtlich der verunfallten Motorradfahrer untersucht:

- Verletzungsschwere
- Unfallsituation und Unfallkonstellation
- Verletzungsursache und Unfallsituation
- Kollisionspartner bei schwere Motorradunfällen
- Relativgeschwindigkeit bei Kollision schwerer Motorräder
- Hubraum der Motorräder
- Alter der Motorradfahrer
- Kollisionstyp und Verletzungsschwere

Ziel war es, die Charakteristik von schweren Motoradunfällen herauszuarbeiten und Gründe bzw. Risikofaktoren zu identifizieren.

Verletzungsschwere

Abbildung 5 zeigt die Verteilung der Verletzungsschwere aller verunfallten Motorradfahrer. Dabei konnte ein Anteil von 13,7 % an MAIS+3 Verletzten ermittelt werden.

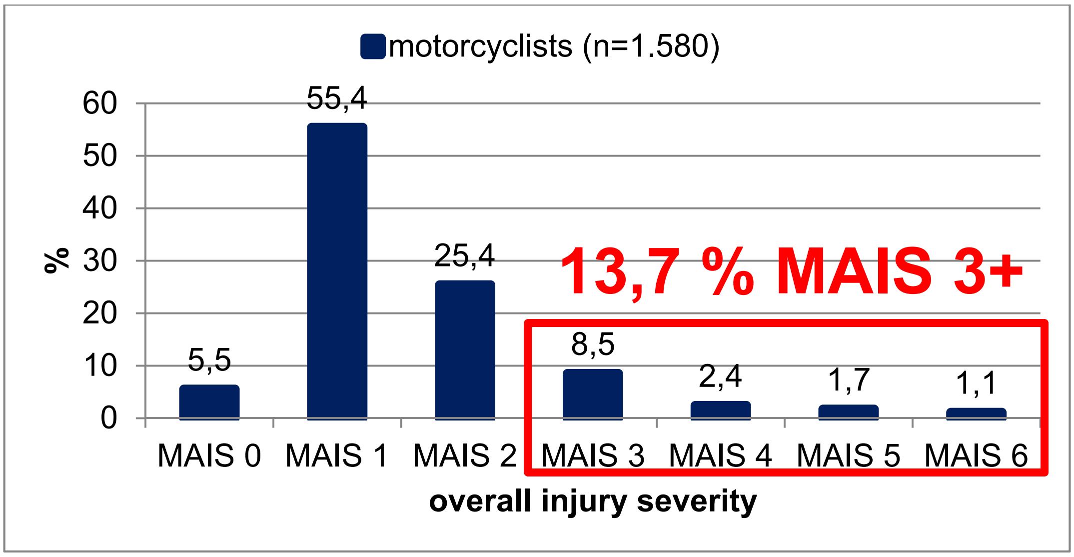


Abbildung 5. Verteilung der Verletzungsschwere von verunfallten Motorradfahrern
Figure 5. Distribution of injury severity of motorcyclists after accidents in Germany

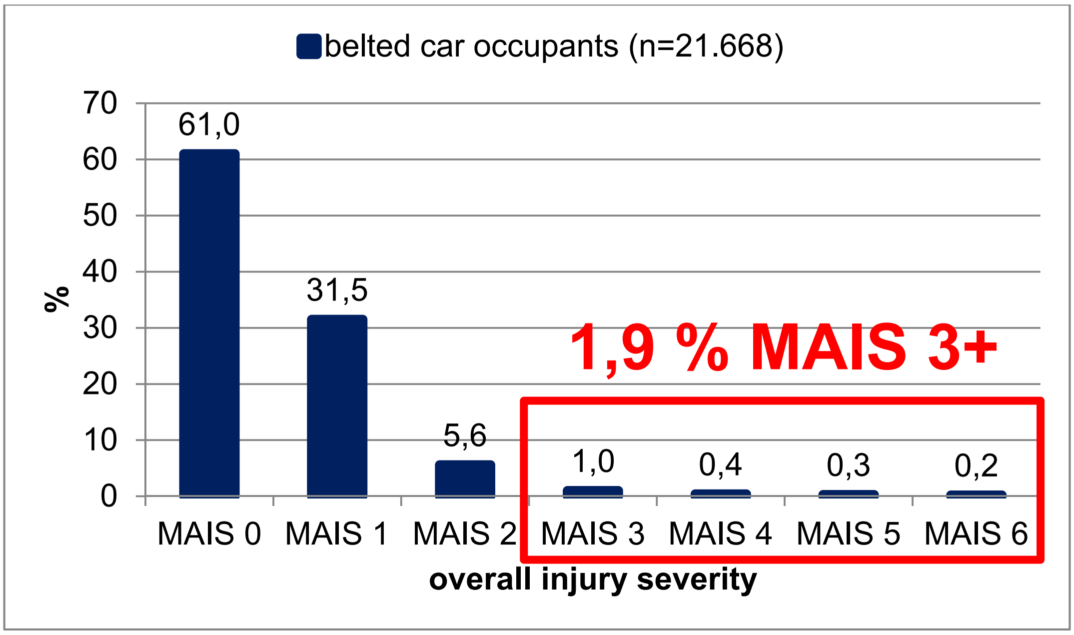
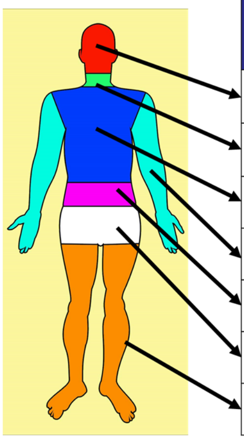


Abbildung 6. Verteilung der Verletzungsschwere von angegurteten Pkw-Insassen, hierzu ein Vergleichskollektiv aus GIDAS
Figure 6. Distribution of injury severity of motorcyclists after accidents, compared for another case sample from GIDAS

Im Vergleich dazu zeigt die Abbildung 6 die Verteilung der Verletzungsschwere von angegurteten Pkw-Insassen nach einem Verkehrsunfall. Es ist zu erkennen, dass MAIS 3+ Verletzte hier nur mit einem sehr geringen Anteil von 1,9 % auftreten im Gegensatz zu 13,7 % bei Motorradfahrern.

Im den folgenden Abschnitten dieser Studie sollen die Ursachen und Zusammenhänge für die schweren Verletzungen untersucht werden.

Abbildung 7 zeigt die Verletzungsschwere der einzelnen Körperregionen der verunfallten Motorradfahrer. Hier zeigt sich, dass insbesondere die Beine mit 6,2 %, der Thorax mit 5,2 % und der Kopf mit 2,7 % stark gefährdet sind, schwere AIS 3+ Verletzungen zu erleiden.



AIS 0	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 6	AIS 3+
82,4 %	12,8 %	2,1 %	1,0 %	0,7 %	0,6 %	0,4 %	2,7 %
90,7 %	7,3 %	1,0 %	0,6 %	-	0,2 %	0,2 %	1,0 %
64,1 %	21,5 %	9,2 %	3,1 %	1,0 %	0,9 %	0,2 %	5,2 %
56,2 %	32,8 %	10,7 %	0,3 %	-	-	-	0,3 %
92,0 %	4,2 %	2,5 %	0,6 %	0,4 %	0,3 %	-	1,3 %
86,2 %	10,8 %	1,9 %	0,6 %	0,4 %	0,1 %	-	1,1 %
34,4 %	48,7 %	10,7 %	6,0 %	0,2 %	-	-	6,2 %

Abbildung 7. Verletzungsschwere der einzelnen Körperregionen von verunfallten Motorrädern in Deutschland

Figure 7. Injury severity of individual body regions of motorcyclists after accidents in Germany

Unfallsituation und Unfallkonstellation

Die Einteilung der Unfalltypen in GIDAS erfolgt in Anlehnung an den Unfalltypen-Katalog des Gesamtverbandes der Deutschen Versicherungswirtschaft e. V. (GDV) [18]. Dabei sind die Unfalltypen in sieben Haupttypen:

- Fahrunfall,
- Abbiegeunfall,
- Einbiegen / Kreuzen,
- Überschreiten-Unfall,
- Unfall durch ruhenden Verkehr,
- Unfall im Längsverkehr,
- sonstiger Unfall

und weitere Untertypen kategorisiert. Der Unfalltyp wird mit einer dreistelligen Zahl angegeben, wobei die erste Ziffer einen der sieben Haupttypen beschreibt, die zweite und dritte Ziffer den jeweiligen Haupttyp noch detaillierter darstellt.

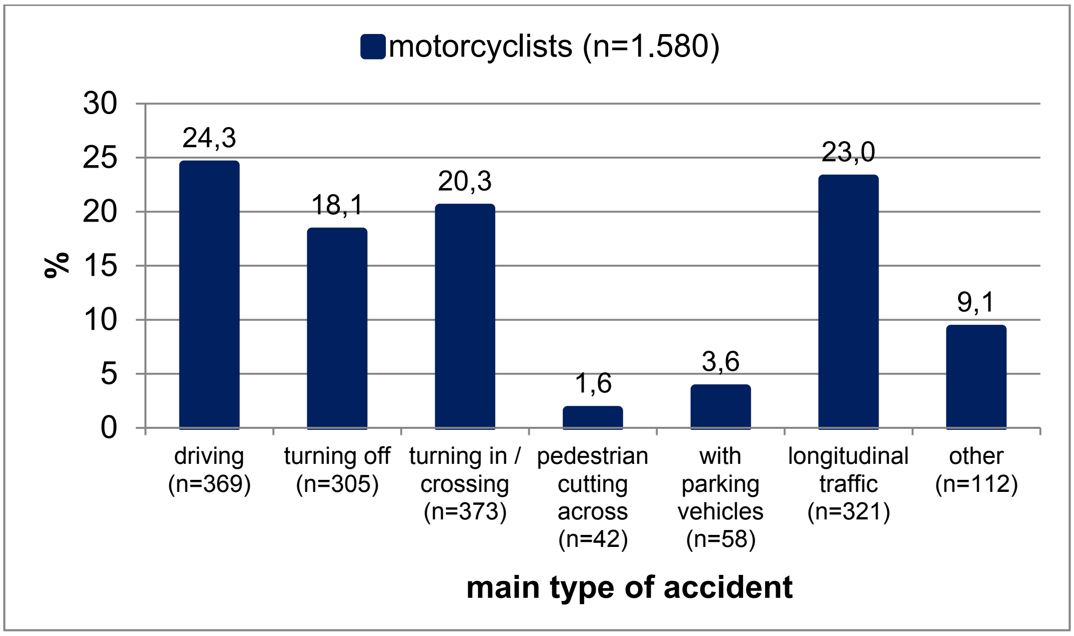


Abbildung 8. Haupt-Unfalltypen von verunfallten Motorradfahrern
Figure 8. Distribution of main type of accident for motorcyclists in Germany

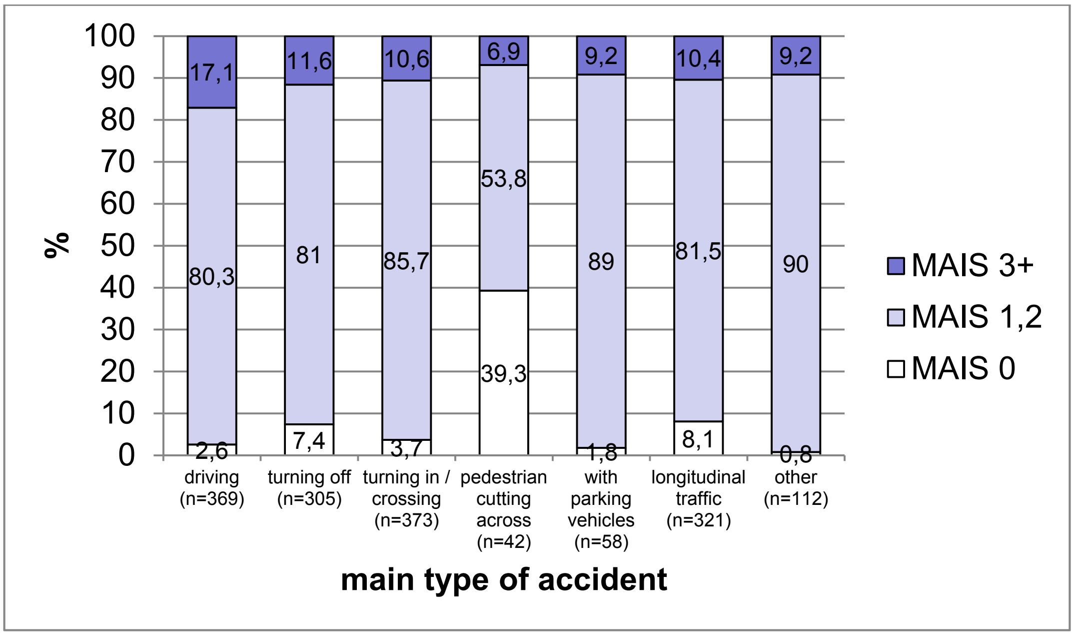


Abbildung 9. Verteilung der Verletzungsschwere MAIS über den Haupt-Unfalltypen von verunfallten Motorradfahrern
Figure 9. Distribution of injury severity MAIS over main types of accident for motorcyclists in Germany

Abbildung 9 zeigt die Verteilung der Verletzungsschwere MAIS der Haupt-Unfalltypen von verunfallten Motorradfahrern. Es wird deutlich, dass Schwerverletzte MAIS 3+ bei Fahrunfällen mit etwa 17 % am häufigsten auftreten. Die Kategorien Abbiegeunfall, Einbiegen und Kreuzen, ruhender Verkehr, Längsverkehr und Sonstige liegen auf einem vergleichbaren niedrigeren Niveau um 10 %. Bei den Überschreiten-Unfällen ist der Anteil an MAIS 3+ Verletzten mit 6,9 % am geringsten.

Abbildung 8 zeigt die Haupt-Unfalltypen von verunfallten Motorradfahrern. Es zeigt sich dabei, dass die Fahrunfälle (Unfall eines Motorradfahrers ohne Beteiligung anderer Verkehrsteilnehmer, meistens Stürze oder Objektkollisionen) mit 24,3 % leicht dominieren, gefolgt von 23,0 % Unfällen im Längsverkehr. Mit etwa 20 % folgen dann die Unfälle beim Einbiegen, Kreuzen und mit etwa 18 % die Abbiege-Unfälle.

Verletzungsursache und Unfallsituation

Tabelle 2. Verletzungsverursachende Teile über Haupt-Unfalltypen für verunfallte Motorradfahrer mit MAIS 3+

Table 2. Cause of injury over main accident types for motorcyclists involved in accident and injury severity MAIS 3+

cause of injury	injury severity		main accident type		
		all	driving accident	turning off	turning in / crossing
		n=150	n=72	n=39	n=39
		100 %	*100%*	*100%*	*100%*
street surface	injured	54,1 %	52,2 %	54,5 %	57,6 %
	AIS 1,2	25,9 %	23,5 %	37,4 %	19,3 %
	AIS 3+	28,2 %	28,7 %	17,1 %	38,3 %
meadow, field, ditch	injured	6,0 %	10,8 %	2,5 %	-
	AIS 1,2	2,0 %	2,8 %	2,5 %	-
	AIS 3+	4,0 %	8,0 %	-	-
guardrail	injured	9,5 %	19,3 %	-	-
	AIS 1,2	1,2 %	2,5 %	-	-
	AIS 3+	8,3 %	16,8 %	-	-
tree, pole	injured	15,0 %	26,3 %	0,5 %	7,2 %
	AIS 1,2	0,7 %	1,4 %	-	-
	AIS 3+	14,3 %	25,0 %	0,5 %	7,2 %
other object	injured	6,6 %	7,6 %	5,3 %	5,7 %
	AIS 1,2	1,2 %	2,4 %	-	-
	AIS 3+	5,4 %	5,2 %	5,3 %	5,7 %
own vehicle	injured	19,2 %	16,3 %	15,7 %	28,3 %
	AIS 1,2	9,6 %	6,7 %	5,8 %	19,0 %
	AIS 3+	9,6 %	9,6 %	9,9 %	9,3 %
opposing vehicle	injured	40,9 %	15,9 %	64,4 %	66,6 %
	AIS 1,2	8,4 %	4,4 %	4,4 %	20,1 %
	AIS 3+	32,5 %	11,5 %	60,0 %	46,5 %

Es wurde untersucht, welche verletzungsverursachenden Teile für die Verletzungen der Motorradfahrer mit MAIS 3+ verantwortlich sind. Diese wurden über den Haupt-Unfalltypen aufgetragen. Hierbei wurden nur der Fahrunfall, der Abbiegeunfall und das Einbiegen / Kreuzen untersucht, da die n-Zahlen bei den übrigen Unfalltypen nach Aufteilung auf die verletzungsverursachenden Teile sehr niedrig waren. Die Ergebnisse sind in Tabelle 2 dargestellt.

Es zeigt sich, dass AIS 3+ Verletzungen mit sehr hohem Anteil bei Anprall am gegnerischen Fahrzeug (32,5 %), bei Abbiege-, Einbiege- und Kreuzungsunfällen (46,5 %) auftreten. Weiterhin ist zu erkennen, dass ein Anprall an starre und steife Hindernisse in der Verkehrsinfrastruktur, wie beispielsweise Bäume, Pfähle und Schutzplanken oft zu schweren AIS 3+ Verletzungen bei den verunfallten Motorradfahrern führt. Auffallend sind Verletzungen durch die Straße mit immerhin 28,2 % bei allen hier betrachteten Unfällen.

Kollisionspartner bei schweren Motorradunfällen

Bei der Analyse der Kollisionspartnern von Motorrädern zeigt sich eine deutliche Dominanz von Pkw mit 46,6 % und Objekten mit 40,1 %, die anderen Kollisionspartner sind alle mit unter 4 % auf seinem sehr niedrigen Niveau. Die Verteilung der Kollisionspartner zeigt die Abbildung 10.

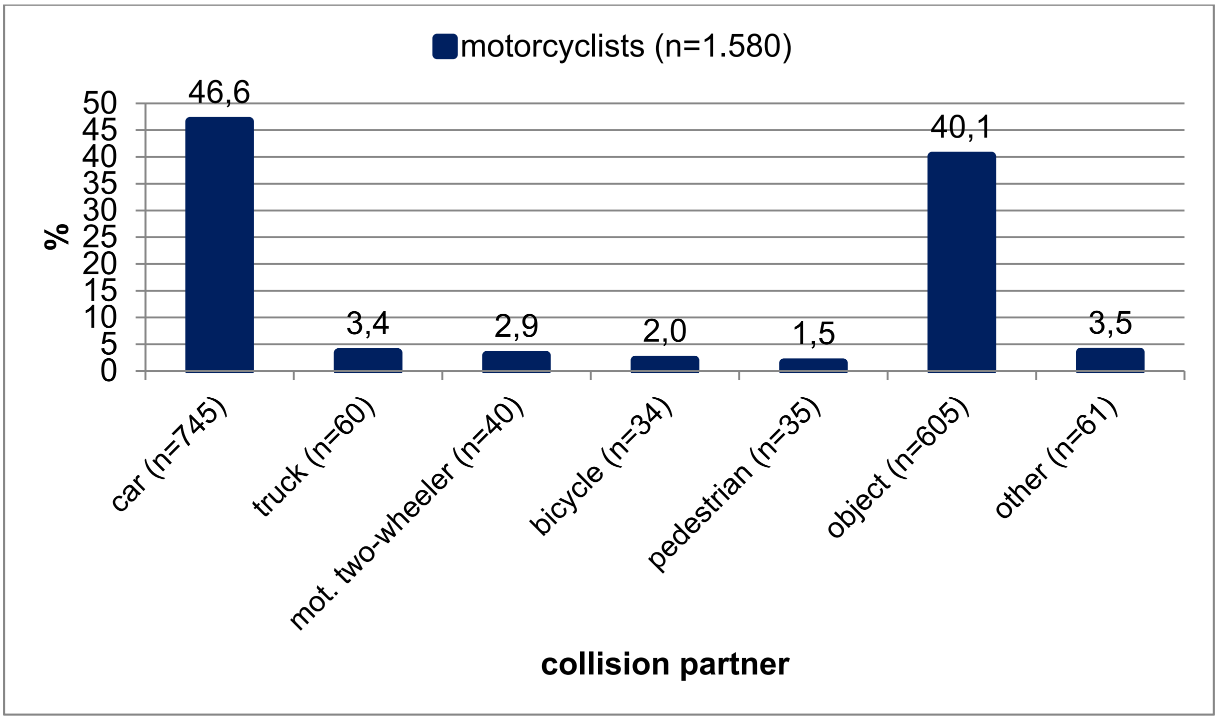


Abbildung 10. Kollisionspartner von verunfallten Motorradfahrern
Figure 10. Collision partners of motorcyclists involved in an accident in Germany

Abbildung 11 zeigt die Verteilung der Verletzungsschwere über den Kollisionspartnern der verunfallten Motorradfahrer. Den höchsten Anteil an MAIS 3+ Unfällen stellen die Nutzfahrzeuge als Kollisionspartner der Motorräder mit 42,4 %, gefolgt von 16,1 % motorisierter Zweiräder, 13,6 % Objekte und 10,3 % Pkw.

Der Anteil an MAIS 3+ Verletzten bei Kollisionen mit Fahrrädern oder Fußgängern ist sehr niedrig. Hier muss allerdings darauf hingewiesen werden, dass bei Kollisionen mit Nutzfahrzeugen und motorisierten Zweirädern keine hohen n-Zahlen gegeben sind, sodass ein Großteil der gesamten MAIS 3+ Verletzten bei Pkw- (45,1 %) und Objektkollisionen (39,8 %) auftreten, bei Nutzfahrzeugkollisionen (6,9 %) und Kollisionen mit motorisierten Zweirädern (3,9 %) fällt der Anteil deutlich geringer aus.

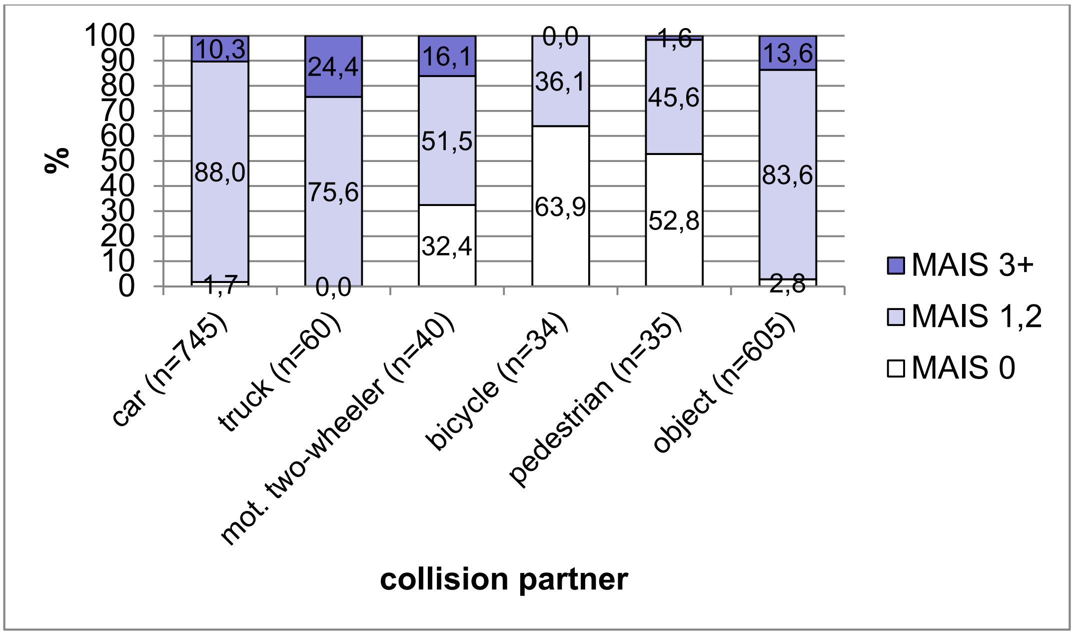


Abbildung 11. Verteilung der Verletzungsschwere MAIS über den Kollisionspartnern von verunfallten Motorradfahrern
Figure 11. Distribution of injury severity MAIS over collision partner for motorcyclists in Germany

Relativgeschwindigkeit bei Kollision schwerer Motorräder

Abbildung 12 zeigt die Relativgeschwindigkeit der verunfallten Motorräder bei Kollision. Bei Alleinunfällen bzw. Objektkollisionen wurde die Kollisionsgeschwindigkeit des Motorrades verwendet.

Es zeigt sich deutlich, dass bei den unverletzten Motorradfahrern die weitaus niedrigsten Relativgeschwindigkeiten bei Kollision ermittelt wurden. Bei den MAIS 1 und MAIS 2 Verletzten zeigt sich bereits eine höhere Relativgeschwindigkeit bei Kollision und bei den schweren MAIS 3+ Verletzten eine deutlich höhere Relativgeschwindigkeit bei Kollision.

Damit kann bestätigt werden, dass die Verletzungsschwere maßgeblich von der Relativgeschwindigkeit der Kollisionskontrahenten bei Kollision abhängt.

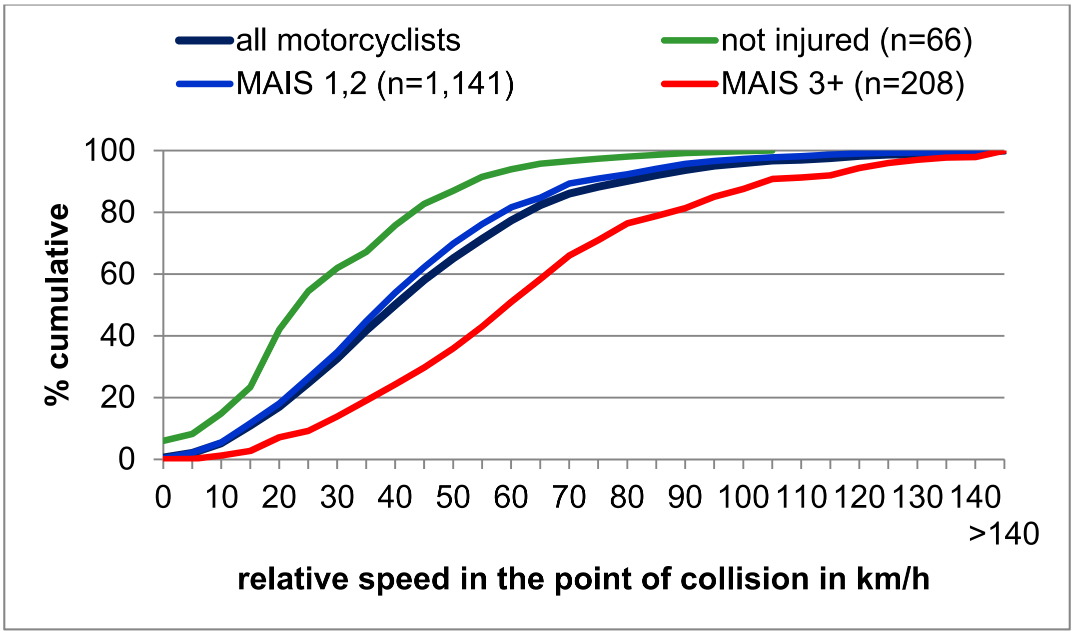


Abbildung 12. Relativgeschwindigkeit bei Kollision zum Unfallzeitpunkt bei Motorradunfällen in Deutschland
Figure 12. Relative speed in the point of collision for motorcycle accidents in Germany

Hubraum der Motorräder

Es kann vermutet werden, dass es bei der Involvierung von hubraumstarken Motorrädern zu schwereren Verletzungen der Motorradfahrer kommt.

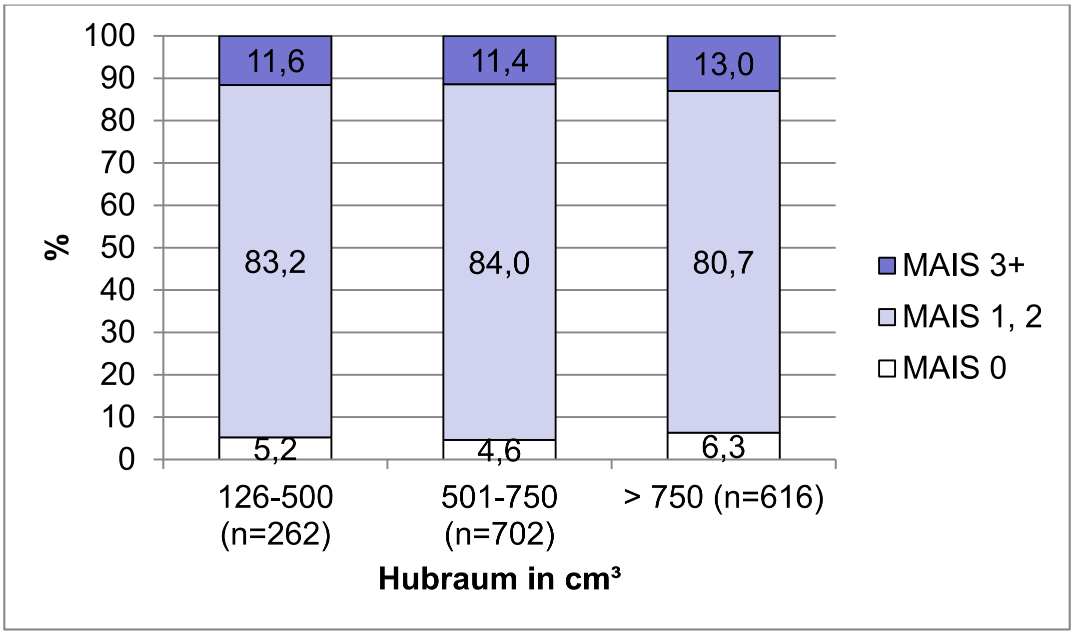


Abbildung 13. Verteilung der Verletzungsschwere MAIS der verunfallten Motorradfahrer über dem Hubraum des Motorrads
Figure 13. Distribution of injury severity over cubic capacity of the motorcycles in Germany

Abbildung 13 zeigt die Verteilung der Verletzungsschwere MAIS der verunfallten Motorradfahrer über dem Hubraum der Motorräder.

Es zeigt sich, dass höhere Hubräume der verunfallten Zweiräder nicht zwangsläufig zu schwereren Verletzungen führen. In den analysierten Fällen konnte lediglich eine sehr leichte Steigerung der MAIS 3+ Verletzten ermittelt werden.

Alter der Motorradfahrer

Abbildung 14 zeigt die Verteilung der Verletzungsschwere über den Altersgruppen der verunfallten Motorradfahrer. Auffällig ist hier, dass die Altersgruppe unter 25 Jahren mit 10,2 % den geringsten Anteil an MAIS 3+ Verletzten zeigt. Dieser Anteil steigt mit höherem Alter, er beträgt für die Altersgruppe 26-40 Jahre 11,7 %, für die Altersgruppe 41,60 Jahre 13,4 % und für die Altersgruppe mit Alter > 60 Jahren 22,1 %. Es zeigt sich also ein deutlicher Trend zu einem höheren Anteil an MAIS 3+ Verletzten mit zunehmendem Alter. Hier muss allerdings erwähnt werden, dass die Fallzahl in der Altersgruppe über 60 Jahren mit 51 Fällen recht klein ist im Vergleich zu den anderen Altersgruppen. Dies ist erklärbar, durch die höhere Eintretenswahrscheinlichkeit von Verletzungen mit Zunahme des Alters aufgrund niedrigerer biomechanischer Belastungsgrenzen von älteren Personen [19].

Dennoch ist bemerkenswert, dass gerade die jungen Fahrer unter 25 Jahren den geringsten Anteil von MAIS 3+ Verletzten zeigen. Hier wäre aufgrund der geringen Fahrpraxis und oftmals vorliegender Selbstüberschätzung ein hoher Anteil an Schwerverletzten MAIS 3+ zu erwarten.

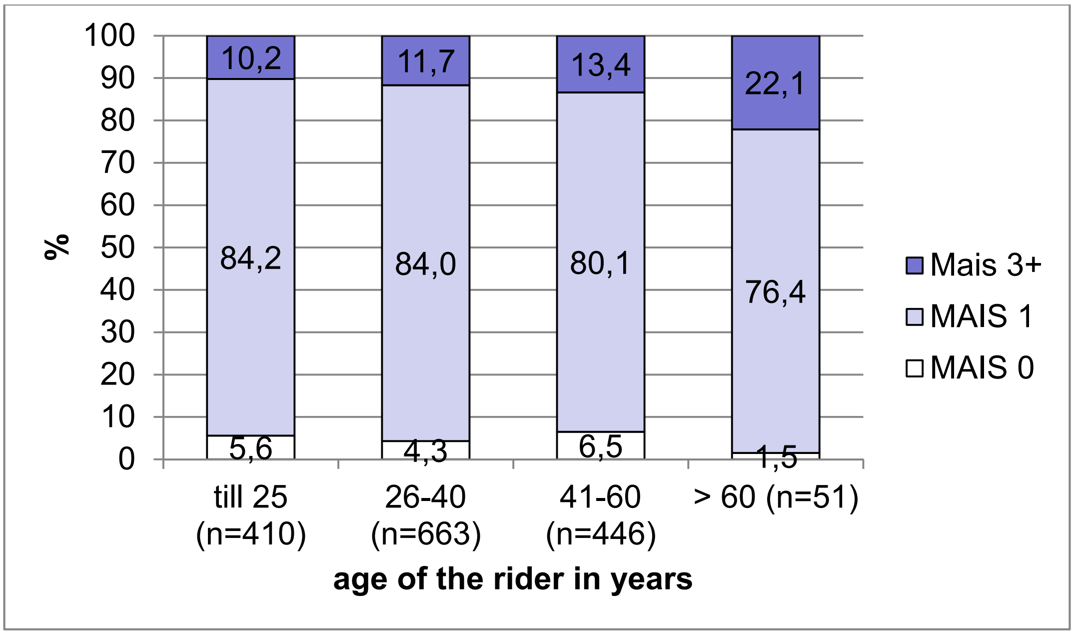


Abbildung 14. Verteilung der Verletzungsschwere MAIS über den Altersgruppen der verunfallten Motorradfahrer

Figure 14. Distribution of injury severity MAIS over age groups of motorcyclists involved in an accident in Germany

Kollisionstyp und Verletzungsschwere

Weiterhin soll untersucht werden, ob der Kollisionstyp einen Einfluss auf die Verletzungsschwere der verunfallten Motorradfahrer hat. Bei den Kollisionstypen 1 bis 6 handelt es sich um Kollisionen mit anderen Fahrzeugen unter bestimmten Winkeln zwischen den Fahrzeuglängsachsen. Der Kollisionstyp 7 beschreibt Objektkollisionen.

Abbildung 15 zeigt die Häufigkeitsverteilung der Kollisionstypen und Abbildung 16 die Verteilung der Verletzungsschwere MAIS über den Kollisionstypen.

Mit knapp 50 % tritt die Objektkollision am häufigsten auf, gefolgt von Kollisionstyp 4 (Motorrad schräg in Seite Pkw) mit ca. 20 %. Die anderen Kollisionstypen weiten einen Anteil von unter 10 % auf.

Der Anteil an MAIS 3+ Verletzten ist bei Kollisionstyp 2 (Motorrad frontal gegen Fahrzeug frontal) mit 21,3 % am höchsten. Dies ist verständlich, da hier bei zwei sich bewegenden Fahrzeugen die höchste Relativgeschwindigkeit bei Kollision erwartet werden kann.

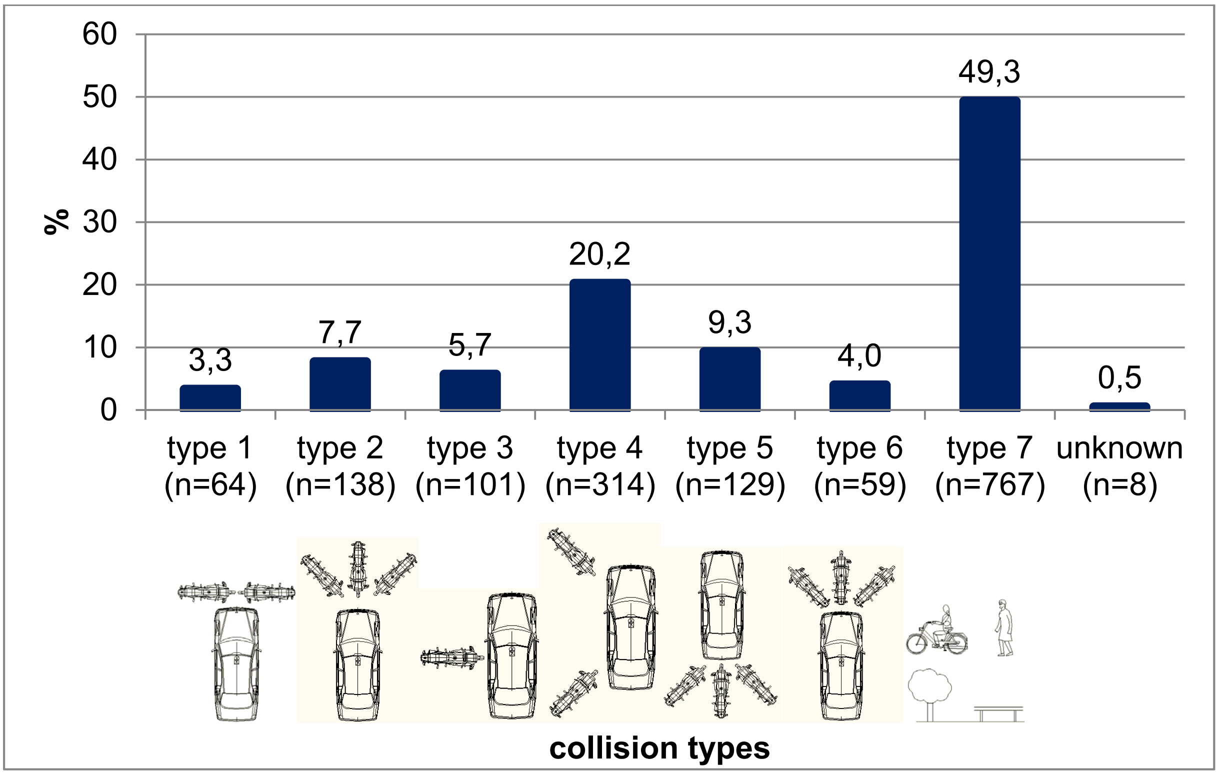


Abbildung 15. Verteilung der aufgetretenen Kollisionstypen für verunfallte Motorradfahrer
Figure 15. Distribution of collision types for motorcycles involved in an accident in Germany

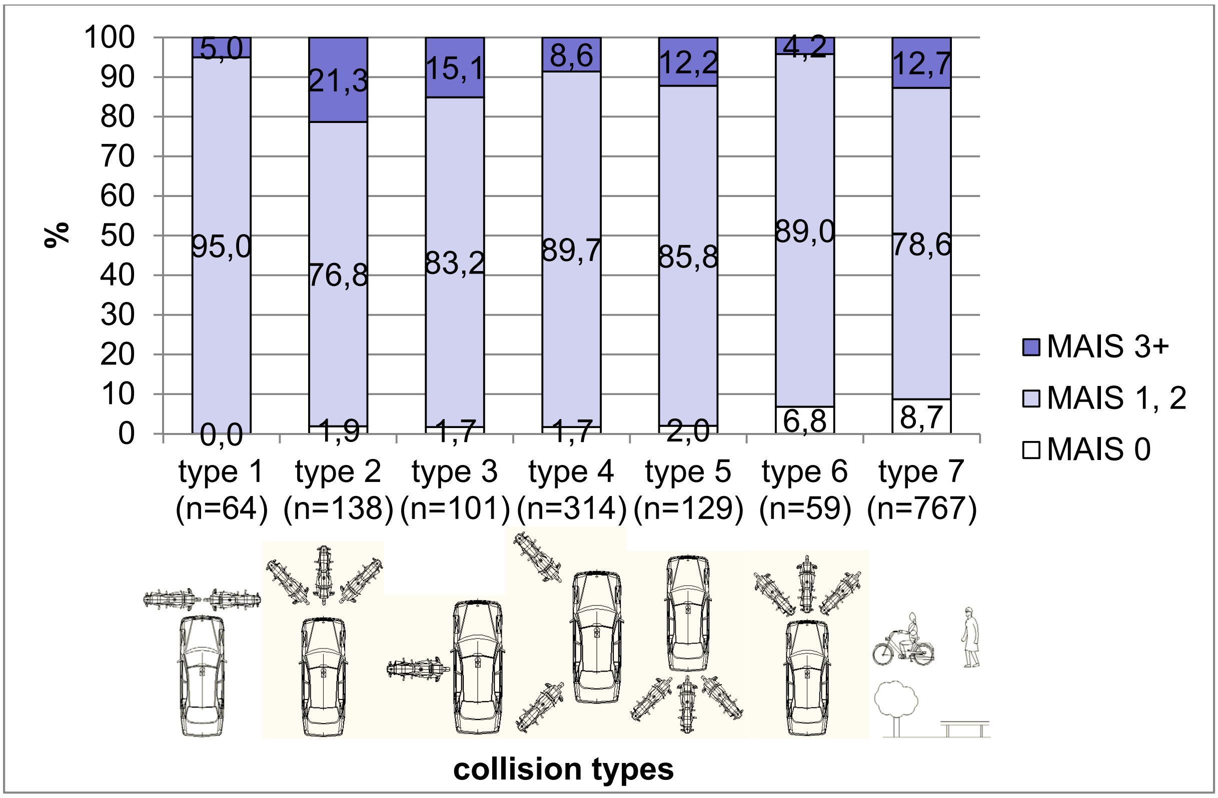


Abbildung 16. Verteilung der Verletzungsschwere MAIS der verunfallten Motoradfahrer über den Kollisionstypen

Figure 16. Distribution of injury severity MAIS over the type of collision for motorcyclists involved in an accident in Germany

Diese korreliert wie zuvor bereits gezeigt mit der Schwere der Verletzungen. 15,1 % MAIS 3+ Verletzte traten auf bei Kollisionstyp 3 (Motorrad kollidiert unter 90° mit Seite Pkw). Hohe MAIS 3+ Anteile wurden auch bei Kollisionstyp 7 (Objektkollision) mit 12,7 % und bei Kollisionstyp 5 (Motorrad kollidiert frontal gegen Heck Pkw) mit 12,2 % erreicht.

Schlussfolgerung und Diskussion

In der vorstehenden Studie wurden 1580 Unfälle mit Motorrädern mit einem Hubraum über 125 cm³ ausgewertet, die in GIDAS durch ein wissenschaftliches Team mittels Datenerhebung am Unfallort in den Jahren 2000 bis einschließlich 2013 dokumentiert wurden. Dabei sollte die Charakteristik von schweren Motorradunfällen mit schwerverletzten und getöteten Fahrern herausgearbeitet werden, um Gründe für diese Unfälle zu finden und um Lösungsvorschläge zu erarbeiten.

Die ausgewerteten Unfälle wurden analysiert nach Verletzungsschwere, Unfalltyp, Kollisionspartner, Relativgeschwindigkeit bei Kollision, Hubraum der Motorräder, Alter der Motorradfahrer, Kollisionstyp, Art des Schutzhelms und Ausstattung mit Antiblockiersystem.

Bei der Analyse der Verletzungsschwere zeigte sich, dass aus 13,7 % der untersuchten Motorradunfälle schwerverletzte MAIS 3+ Motorradfahrer resultierten. Bei der Auswertung der Verletzungsschwere der einzelnen Körperregionen der verunfallten Motorradfahrer zeigte sich, dass insbesondere die Beine mit 6,2 %, der Thorax mit 5,2 % und der Kopf mit 2,7 % stark gefährdet sind, schwere AIS 3+ Verletzungen zu erleiden.

Bei den Unfallsituationen, untersucht hierzu an verschiedenen Unfalltypen, dominierten die Fahrunfälle (Unfall eines Motorradfahrers ohne Beteiligung anderer Verkehrsteilnehmer, meistens Stürze oder Objektkollisionen) mit 24,3 % leicht, gefolgt von 23,0 % Unfällen im Längsverkehr. Mit etwa 20 % folgen dann die Unfälle beim Einbiegen, Kreuzen und mit etwa 18 % die Abbiege-Unfälle. MAIS 3+ Verletzte gab bei Fahrunfällen mit etwa 17 % am häufigsten. Die Unfalltypen Abbiegeunfall, Einbiegen und Kreuzen, ruhender Verkehr, Längsverkehr und Sonstige liegen auf einem vergleichbaren Niveau um 10 %. Bei den Überschreiten-Unfällen ist der Anteil an MAIS 3+ Verletzten mit 6,9 % am geringsten.

Bei der Analyse der Kollisionspartnern von Motorrädern zeigt sich eine deutliche Dominanz von Pkw mit 46,6 % und Objekten mit 40,1 %, die anderen Kollisionspartner sind alle mit unter 4 % auf seinem sehr niedrigen Niveau. Den höchsten Anteil an MAIS 3+ Unfällen stellen die Nutzfahrzeuge als Kollisionspartner der Motorräder mit 42,4 %, gefolgt von 16,1 % motorisierter Zweiräder, 13,6 % Objekte und 10,3 % Pkw. Der Anteil an MAIS 3+ Verletzten bei Kollisionen mit Fahrrädern oder Fußgängern ist sehr niedrig. Hier muss allerdings darauf hingewiesen werden, dass bei Kollisionen mit Nutzfahrzeugen und motorisierten Zweirädern keine hohen n-Zahlen gegeben sind, sodass ein Großteil der gesamten MAIS 3+ Verletzten bei Pkw- (45,1 %) und Objektkollisionen (39,8 %) auftreten, bei Nutzfahrzeugkollisionen (6,9 %) und Kollisionen mit motorisierten Zweirädern (3,9 %) fällt der Anteil deutlich geringer aus.

Es zeigte sich bei der Untersuchung des Geschwindigkeitsniveaus, dass basierend auf der für die resultierenden Verletzungen verantwortlichen Relativgeschwindigkeiten, bei den unverletzten Motorradfahrern die weitaus niedrigsten Relativgeschwindigkeiten bei Kollision ermittelt wurden. Bei den MAIS 1 und MAIS 2 Verletzten zeigte sich bereits eine höhere Relativgeschwindigkeit bei Kollision und bei den schweren MAIS 3+ Verletzten konnte eine deutlich höhere Relativgeschwindigkeit bei Kollision festgestellt werden. Damit kann bestätigt werden, dass die Verletzungsschwere maßgeblich von der Relativgeschwindigkeit der Kollisionskontrahenten bei Kollision abhängt. Bis zu einer Relativgeschwindigkeit von etwa 30 km/h erscheinen kaum Schwerverletzte MAIS 3+ (etwa 15%), dagegen sind 60 % aller MAIS 3+ oberhalb von 50km/h eingetreten.

Es zeigte sich, dass höhere Hubräume der verunfallten Zweiräder nicht zwangsläufig zu schwereren Verletzungen führen. Allerdings konnte eine leichte Zunahme MAIS 3+ Verletzter bei größerem Hubraum ermittelt werden.

Auffällig ist bei der Untersuchung der Verletzungsschwere über dem Alter, dass die Altersgruppe unter 25 Jahren mit 10,2 % den geringsten Anteil an MAIS 3+ Verletzten zeigt. Dieser Anteil steigt mit höherem Alter, er beträgt für die Altersgruppe 26-40 Jahre 11,7 %, für die Altersgruppe 41,60 Jahre 13,4 % und für die Altersgruppe mit Alter > 60 Jahren 22,1 %. Es zeigt sich also ein deutlicher Trend zu einem höheren Anteil an MAIS 3+ Verletzten mit zunehmendem Alter. Hier muss allerdings erwähnt werden, dass die Fallzahl in der Altersgruppe über 60 Jahren mit 51 Fällen recht klein ist im Vergleich zu den anderen Altersgruppen. Dies ist erklärbar, durch die höhere Eintretenswahrscheinlichkeit von Verletzungen mit Zunahme des Alters aufgrund niedrigerer biomechanischer Belastungsgrenzen von älteren Personen [19]. Es ist somit bemerkenswert, dass gerade die jungen Fahrer unter 25 Jahren den geringsten Anteil von MAIS 3+ Verletzten zeigen. Hier wäre aufgrund der geringen Fahrpraxis und oftmals vorliegender Selbstüberschätzung ein hoher Anteil an Schwerverletzten MAIS 3+ zu erwarten gewesen.

Bei der Untersuchung der Kollisionstypen konnte ermittelt werden, dass die Objektkollision mit knapp 50 % am häufigsten auftrat, gefolgt von Kollisionstyp 4 (Motorrad schräg in Seite Pkw) mit ca. 20 %. Die anderen Kollisionstypen weisen einen Anteil von unter 10 % auf. Der Anteil an MAIS 3+ Verletzten ist bei Kollisionstyp 2 (Motorrad frontal gegen Fahrzeug frontal) mit 21,3 % am höchsten. Dies ist verständlich, da hier bei zwei sich bewegenden Fahrzeugen die höchste Relativgeschwindigkeit bei Kollision erwartet werden kann. Diese korreliert wie zuvor bereits gezeigt mit der Schwere der Verletzungen. 15,1 % MAIS 3+ Verletzte gab es bei Kollisionstyp 3 (Motorrad kollidiert unter 90° mit Seite Pkw). Hohe MAIS 3+ Anteile wurden auch bei Kollisionstyp 7 (Objektkollision) mit 12,7 % und bei Kollisionstyp 5 (Motorrad kollidiert frontal gegen Heck Pkw) mit 12,2 % erreicht.

Von den in dieser Studie ausgewerteten Unfällen, waren lediglich 8,8 % der Motorräder mit einem Antiblockiersystem (ABS) ausgestattet. Dies hängt aber auch damit zusammen, dass bereits Unfälle ab dem Jahr 2000 ausgewertet wurden, als die Marktdurchdringung von Motorrad-ABS noch auf einem deutlich niedrigeren Niveau lag als heutzutage. Es zeigte sich, dass der Anteil an Schwerverletzten MAIS 3+ bei ABS-Motorrädern mit 10,7 % auf einem leicht niedrigeren Niveau liegt als bei Motorrädern ohne ABS mit 12,4 %. Es ist zu vermuten, dass der durch ABS gesenkte Anteil an Schwerverletzten deutlich höher liegt als die hier dargestellten Prozente bei verunfallten Motorradfahrern, da viele Unfälle bei ABS-Motorrädern von vorneherein verhindert werden können ([4], [5], [6]).

Zusammengefasst sind es insbesondere die Fahrunfälle (alleinbeteiligte Motorradfahrer mit Sturz / Objektkollision) und die Motorrad-Pkw Kollisionen, die häufig zu schwerverletzten Motorradfahrern führen mit einem überwiegenden Anteil von etwa 85 % der MAIS 3+ Verletzten. Es müssen also insbesondere für diese Kollisionssituationen Lösungsvorschläge erarbeitet werden.

Die Europäische Kommission hat beschlossen, dass ab 2016 alle neu entwickelten Modellreihen von Motorrädern und ab 2017 alle neu zugelassenen Motorräder mit einem Antiblockiersystem ausgestattet sein müssen [7]. Dies gilt für Motorräder mit einem Hubraum größer 125 cm^3. Erwartete Auswirkung ist eine deutliche Reduzierung der Zahl der im Straßenverkehr Getöteten oder Verletzten. Diverse Studien ([4], [5], [6]) haben gezeigt, dass bei flächendeckender ABS-Ausstattung ein enormes Potential besteht, einen großen Anteil von insbesondere schweren und tödlichen Motorradunfällen zu vermeiden. Diese Maßnahme zielt vor allem auf die hohe Anzahl an Fahrunfällen ab, da Stürze ohne blockierende Räder weniger häufig vorkommen aber es kann auch bei Motorrad-Pkw Kollisionen hilfreich sein, da das Fahrzeug hier bei Gefahrenbremsung lenkbar bleibt und ein Ausweichvorgang in einigen Fällen möglich ist.

Ein nächster Schritt um weitere Fahrunfälle zu vermeiden, ist die flächendeckende Einführung eines elektronischen Stabilitätsprogramms für Motorräder. Dieses System ist in der Lage weitere Verkehrsunfälle, insbesondere Fahrunfälle von Motorradfahrern zu verhindern. Dabei können hauptsächlich Fahrfehler der Motorradfahrer wie beispielsweise falscher Einsatz der Bremsen oder übermäßige Beschleunigung, insbesondere in Kurven, ausgeglichen werden, um einen Sturz zu vermeiden.

Um den hohen Anteil an Fahrunfällen weiter zu senken, könnte auch direkt bei der Fahrausbildung angesetzt werden in Form von obligatorischen Sicherheitstrainings, beispielsweise nach Führerscheinerwerb. Dabei können die Motorradfahrer Grenzsituationen auf einem gesicherten Gelände erleben und die richtigen Verhaltensweisen (Bremsverhalten, Ausweichvorgang, usw.) erlernen.

Es zeigt sich, dass schwere Verletzungen AIS 3+ mit sehr hohem Anteil bei Anprall am gegnerischen Fahrzeug (32,5 %), bei Abbiege-, Einbiege- und Kreuzungsunfällen (46,5 %) auftreten. Damit sind Maßnahmen der Passiven Sicherheit an Fahrzeugen wie PKW und LKW auch für Motorradfahrer von Bedeutung. Auch Maßnahmen am eigenen Zweirad erscheinen wichtig, da immerhin etwa 10 % aller schweren Verletzungen hier entstehen. Weiterhin ist zu erkennen, dass ein Anprall an starre und steife Hindernisse in der Verkehrsinfrastruktur, wie beispielsweise Bäume, Pfähle (14,3 %) und Schutzplanken (8,3 %) oft zu schweren AIS 3+ Verletzungen bei den verunfallten Motorradfahrern führt. Auffallend häufig sind Verletzungen durch die Straße mit immerhin 28,2 % bei allen hier betrachteten Unfällen. Dort sind das Tragen geeigneter Schutzkleidung u.a. mit Protektoren sinnvolle Schutzelemente. Passive Sicherheitssysteme wie Motorradairbags und Beinschutz am Motorrad([9], [10]) sind insbesondere bei Kollisionen mit Pkw und Objekten in der Lage die Aufsassenkinematik so zu verändern, dass schwere bzw. tödliche Verletzungen vermieden werden. Hier sind allerdings noch weitere Forschungsarbeiten nötig, um die Wirkung bei allen möglichen Kollisionsszenarien zu untersuchen.

Eine weitere Möglichkeit der Unfallvermeidung liegt in der Implementierung von Warn- und Informationssystemen für den Motorradfahrer, da hierdurch sowohl Maßnahmen der Unfallvermeidung wie auch der Verletzungsminderung adressiert werden.

Danksagung

Die Autoren bedanken sich für die Möglichkeit, Daten aus GIDAS (German In-Depth Accident Study) für die Studie nutzen zu können. Dabei handelt es sich um die größte „In-Depth" – Datenbank in Deutschland. Diese wird finanziert durch die Bundesanstalt für Straßenwesen und die Forschungsvereinigung der Deutschen Automobilindustrie FAT des VDA (Verband der Deutschen Automobilindustrie). Der Gebrauch der Daten ist ausschließlich den Teilnehmern des Kooperationsverbandes erlaubt. Weitere Informationen über GIDAS können der Webseite entnommen werden http://www.gidas.org.

Acknowledgement

GIDAS collects records and processes data from accidents of all kinds and, due to the on-scene investigation and the full reconstruction of each accident, gives a comprehensive view on the individual accident sequences and their causation. The project is funded by the Federal Highway Research Institute (BASt) and the German Research Association for Automotive Technology (FAT), a department of the VDA (German Association of the Automotive Industry). Use of the data is restricted to the participants of the project. Further information on GIDAS can be found at http://www.gidas.org

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Risk of serious motorcycle accidents among ordinary motorcyclists – A nationwide register-based cohort study.

Das Risiko von schweren Motorradunfällen – Eine landesweite bestandsdatenbasierte Kohortenstudie

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Abstract

Question

Present knowledge on serious motorcycle accidents mainly derive from in-depth studies of lethal cases. These motorcyclists tend to differ from the majority of motorcycle drivers. To assess serious accident risk among ordinary motorcyclists in general we performed a nationwide cohort study including all Swedish motorcycle owners.

Methods

From national registries of road traffic vehicles during 2003 to 2009 were identified 313,271 licensed motorcycle owners and their 319,547 motorcycles registered for road traffic, as well as information on mileage.

Information from national health care registries on all treatment of injuries, or death from motorcycle accidents were linked to the motorcycle owners. Serious accidents were defined as any injury requiring medical care.

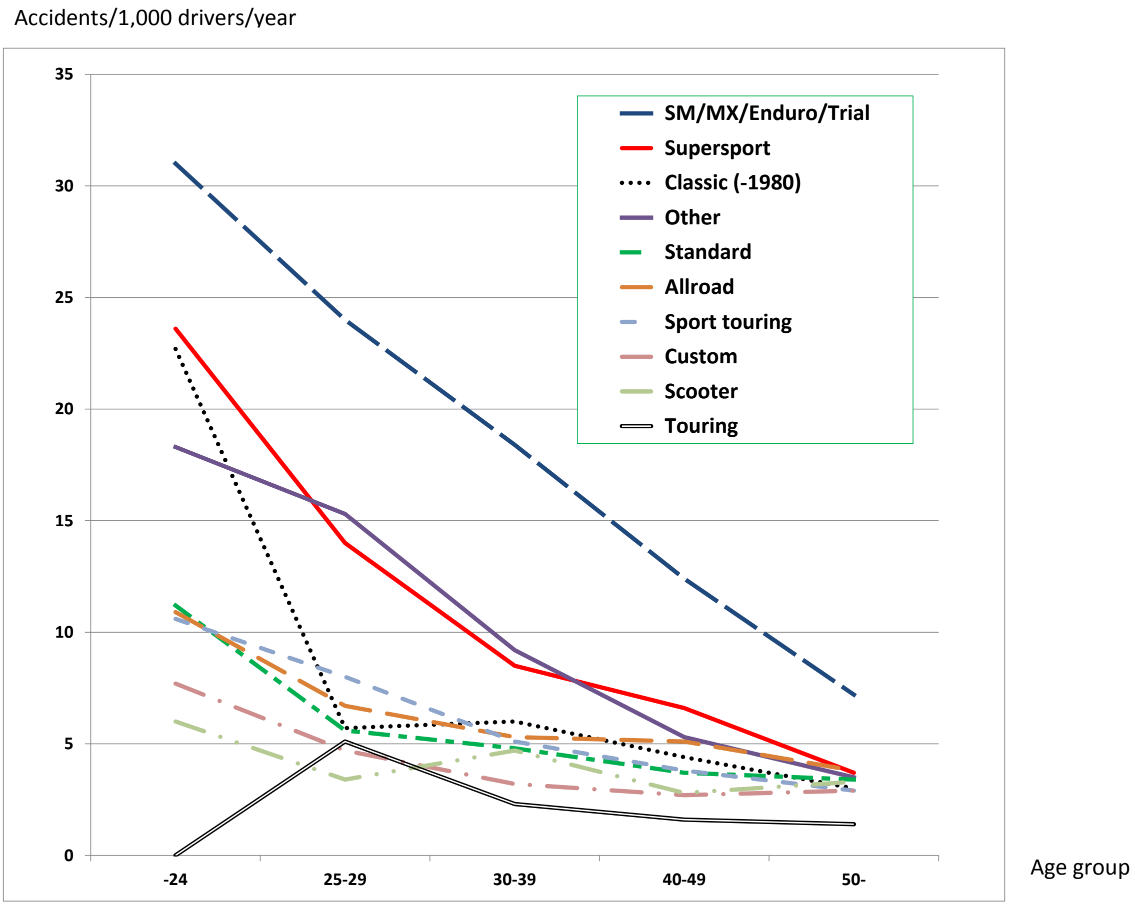
Absolute risk was estimated from the observed number of injuries divided by the total mileage. Accident risk with respect to the risk factors investigated was analysed in Poisson regression models with mileage as offset.

Results

The total number of serious accidents was 6,296 and the total mileage was 3.6 billion kilometres, meaning 1.8 serious accidents per 1,000,000 kilometres, or 4.5 serious accidents per 1,000 motorcycle drivers, per year.

Women had a 10% non-significant lower relative risk than men. In relation to drivers 30-39 years of age, the youngest drivers had twice the risk (age -24; 2.1 (1.6-2.6)) while drivers' age of 25-29 year was associated with a 40% risk increase (1.4 (1.2-1.7)). Relative crash risk continued to decrease with increasing drivers' age with a 40% decrease among the oldest (50+, 0.6 (0.5-0.7)).

Only small risk differences were seen between owners of different motorcycle types, except among the owners of motorcycles classified as "Supermotard (SM) / Motocross (MX) / Enduro / Trial" who had a tripled risk (3.3 (2.7-4.0)) in relation to "Standard motorcycle" owners. The corresponding relative risk among owners of a "Supersport motorcycle" was 1.8 (1.4-2.2), an 80% risk increase. The risk differences between motorcycle types were increased among younger owners.



Impacts

Risk assessment within well-defined cohorts of motorcyclist provide valuable knowledge on the general risk of motorcycling. We have shown that motorcycle accident risk strongly decreases with drivers' age. Motorcycle type risk difference is highest among the younger drivers.

Risk of serious motorcycle accidents among ordinary motorcyclists – A nationwide register-based cohort study.

1 Introduction

To prevent crash and injury occurrence among motorcyclists, increased knowledge is needed on motorcycle accident risk factors (Lin and Kraus 2009). Present knowledge on motorcycle accidents mainly derive from in-depth studies of crashes with serious outcome. Motorcyclists involved in such crashes tend to differ from the majority of motorcycle drivers (Kraus, Anderson et al. 1991, Lin and Kraus 2009). Difficulties in previous studies in defining the population at risk, and the vehicle mileage may have result in misidentification of motorcycle crash risk groups (Lin and Kraus 2008).

To assess serious accident risk among ordinary motorcyclists in general we performed a register-based nationwide cohort study including all Swedish licensed owners of a motorcycle in use.

2 Material and Methods

This is a register-based record-linkage study connecting information from national registers on vehicles, motorcycle ownership, licensing, health care, and death. Linkage was made using the Swedish personal identity numbers (Ludvigsson, Otterblad-Olausson et al. 2009).

2.1 Study cohort

Study subjects were every owner of at least one motorcycle in use, holding a valid motorcycle license during the study period from January 1, 2003 to December 31, 2009 (n=313,271).

Of all motorcycle owners in the registry of vehicles, 27% were excluded for not holding a valid motorcycle driving license. The study cohort included 319,547 registered motorcycles ever in use during the study period after excluding All-Terrain Vehicles (ATVs) registered as motorcycles, and motorcycles never in road traffic use (Figure 1.).

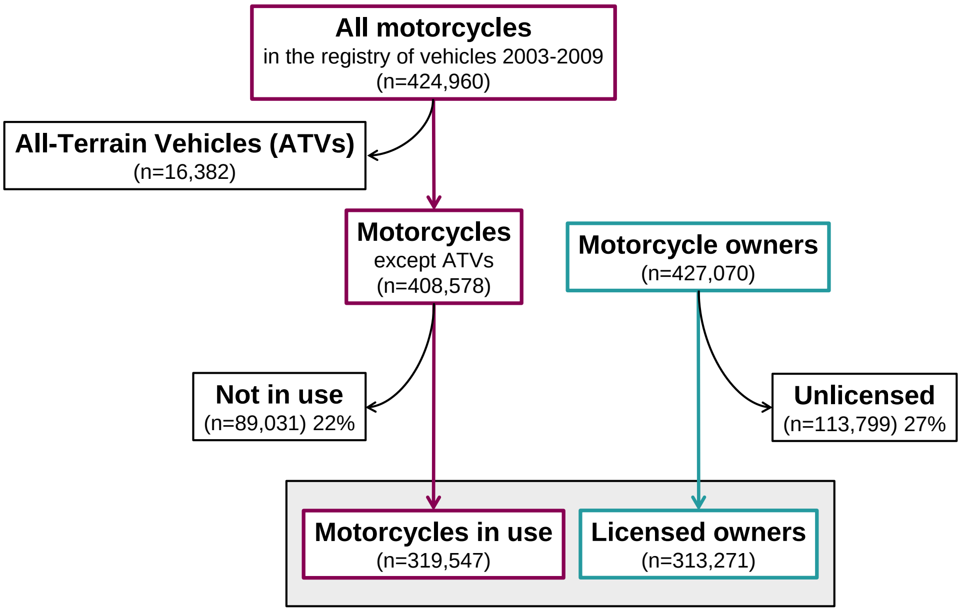


Figure 1. The study cohort

2.2 Outcome

Hospital care registered in the National Patient Register (Socialstyrelsen 2014) as a “motorcycle transport accident” (The International Classification of Diseases codes, version 10, ICD-10, codes V20-V29) was regarded as a serious motorcycle accident. The register includes all in-patient, and outpatient care including day-surgery in Sweden. Primary care is not covered. Passenger injuries and accidents during motorsport events were excluded. For study subjects with multiple hospital visits, a sequence of visits or admissions coded as motorcycle driver accidents, separated by less than 90 days, were assigned as a single accident. Accident severity was classified according to length of stay in; outpatient care, 1 to 6 days, and 7+ days (including lethal accidents).

2.3 Risk factors studied

1. Sex; Twelve percent of the study subjects were women (n=36,174).

2. Age; Age at the time of a motorcycle accident. The mean and median age among the study subjects at the start of follow-up were 45 years.

Table 1. Age distribution among study subjects at start of follow-up.

Age (years)	%
-24	4.2
25-29	8.1
30-39	22.7
40-49	27.4
50+	37.6

3. Motorcycle type; All motorcycles identified in the register of vehicles were classified (Table 2.), and Study subjects were classified according to their choice of motorcycle type.

Table 2. Distribution of motorcycle types registered in the register of vehicles, and in use, and average motorcycle weight (kilogram) per engine power (horse power).

Motorcycle Type	%	Weight (kg) / Power (hp)
Custom	26.0	4.8
Standard	18.7	3.3
Classic (-1980)	13.3	4.7
Sport touring	11.7	2.6
Allroad	7.5	3.9
Scooter	6.3	9.2
SM/MX/Enduro/Trial	6.3	4.1
Supersport	4.8	2.1
Touring	2.8	3.6
Other	2.6	4.3

2.4 Statistical methods

Absolute risk was estimated from the observed number of injuries divided by the total mileage. This risk estimate is expressed as number of observed accidents per 1,000,000 kilometres, alternatively as number of accidents per 1,000 motorcycle drivers per year (average yearly mileage per driver estimated by modelling to 2,590 kilometres (Trafikanalys 2011)).

Accident risk with respect to the risk factors investigated was analysed by Poisson regression modelling with mileage as offset. This entails an assumption of the accident risk being proportional with respect to the measured or estimated mileage of each motorcycle. Results are presented as relative risks for each of the investigated factors. Adjusted relative risks derive from a multiplicative model including all the investigated factors. Confidence intervals (95%) were calculated adjusting for over-dispersion. The observed over-dispersion shows an accident risk heterogeneity between drivers not explained by the investigated factors.

Accidents to owners of several motorcycles have been allocated to the owner's different motorcycles. A distribution weight for each motorcycle was calculated by dividing the specific mileage by the sum of mileage from all the owner's motorcycles, avoiding multiple counting of accidents.

3 Results

During the study period (January 1, 2003 to December 31, 2009), 5,574 motorcycle drivers in the study cohort suffered from injury or death by a serious motorcycle accident (1.8%). The total number of recorded accidents was 6,296. Ninety percent of the drivers had a single accident (n=4998), and another 9% (n=478) had two crashes during follow-up. The total estimated mileage during the study period for all 313,271 study subjects was 3.6 billion kilometres, and the overall accident risk was 1.8 per million kilometres. When applying the average annual mileage among Swedish motorcyclists, estimated by modelling and used in national official transport statistics (SIKA 2010), the risk estimate corresponds to 4.5 observed accidents per 1,000 motorcycle drivers, per year.

Eighty-eight percent of the study subjects were men while 93% (n=5,854) of the observed accidents occurred among male drivers. The overall male absolute crash risk was 4.6 accidents per 1,000 drivers, per year, and the corresponding female absolute risk was 3.5 accidents per 1,000 drivers, per year (1.8 and 1.4 accidents per million kilometres, respectively). The relative risk estimate between sexes, adjusted for age and motorcycle type showed a 10% non-significant lower accident risk among female drivers (adjusted relative risk = 0.9 (95% confidence interval 0.7 – 1.1)).

A continuous decrease of motorcycle accident risk was seen with increasing motorcycle driver age. The observed accident risk varied by age, from 16.6 per 1,000 driver, per year among the youngest (-24 years) to 3.1 among the oldest (50+ years). The observed accident risk among drivers aged 30 to 39 years was 6.4 per 1,000 drivers, per year (2.5 per million kilometres). In relation to this age group, drivers' age from 25 to 29 years was associated with a 40% increased adjusted relative accident risk, while the corresponding risk among the youngest (-24) was doubled. Drivers' age of 40 to 49 years, and 50+ years was associated with a 20%, and 40% risk decrease, respectively (Table 3.).

The distribution of adjusted relative risk estimates across age groups did not materially change when stratifying the outcome on the length of hospital accident care, as a proxy for accident severity. The stratified analysis possibly showed a tendency of increased relative risk among the eldest drivers in the 7+ days in-hospital care group (Table 3.).

Table 3. Adjusted relative risks of observed accident care, by age class, and length of stay.

Age Class (years)	All		Outpatient care		1-6 days in-hospital care		7+ days in-hospital care**	
	Adjusted Relative Risks* (95% Confidence Interval)							
-24	2.1	(1.6-2.6)	2.1	(1.5-2.9)	2.1	(1.5-2.9)	2.1	(1.2-3.5)
25-29	1.4	(1.2-1.7)	1.4	(1.1-1.8)	1.3	(1.0-1.7)	1.6	(1.1-2.4)
30-39	Reference							
40-49	0.8	(0.6-0.9)	0.7	(0.6-0.9)	0.7	(0.6-0.9)	0.9	(0.7-1.3)
50+	0.6	(0.5-0.7)	0.6	(0.5-0.7)	0.6	(0.5-0.8)	1.0	(0.7-1.3)

*Adjusted for sex and motorcycle type, ** Including lethal accidents

The differences in accident risk between owners of different motorcycle types generally were small, except among the owners of motorcycles classified as “SM (Super Motard)/ MX (Moto Cross)/ Enduro/ Trial” who had a tripled risk in relation to “Standard motorcycle” owners. The corresponding adjusted relative risk estimate among owners of a “Supersport motorcycle” showed an 80% risk increase, while owning a Touring type motorcycle was associated with a 40% decrease of accident risk (Table 4.).

When stratifying the outcome, the adjusted relative risk among owners of Supersport motorcycles increased with the length of stay, and driving a Supersport motorcycle was associated with a near three-fold increased risk of a most severe accident (7+ days in-hospital care, or death), in relation to driving a Standard motorcycle (adjusted relative risk 2.7 (1.8-4.2)). In the most severe accident group, the relative risks associated with driving either SM/MX/Enduro/Trial, Supersport, or Other (mainly custom built) motorcycles, where in the same magnitude. Among motorcycle owners of the remaining types, the relative risk was mainly unchanged, with a tendency of increased risk for the most severe accidents also among drivers of Classical motorcycles (made in 1980 or earlier) (Table 4.).

Table 4. Adjusted relative risks of observed accident care, by motorcycle type, and length of stay.

Motorcycle Type	All		Outpatient care		1-6 days in-hospital care		7+ days in-hospital care**	
	Adjusted Relative Risks* (95% Confidence Interval)							
SM/MX/Enduro/Trial	3.3	(2.7-4.0)	3.5	(2.7-4.5)	2.8	(2.1-3.6)	3.2	(2.1-4.8)
Supersport	1.8	(1.4-2.2)	1.5	(1.1-2.1)	2.0	(1.5-2.6)	2.7	(1.8-4.2)
Other	1.5	(1.1-2.1)	1.4	(0.8-2.2)	1.4	(0.9-2.3)	2.9	(1.7-5.1)
Allroad	1.2	(0.9-1.5)	1.1	(0.8-1.6)	1.2	(0.9-1.6)	1.2	(0.8-2.0)
Classic (-1980)	1.1	(0.8-1.4)	1.0	(0.7-1.4)	1.1	(0.8-1.5)	1.6	(1.0-2.5)
Sport touring	1.0	(0.8-1.3)	1.0	(0.7-1.3)	1.0	(0.8-1.3)	1.3	(0.9-2.0)
Standard	Reference							
Scooter	1.0	(0.7-1.3)	0.9	(0.6-1.4)	0.9	(0.6-1.4)	1.3	(0.8-2.3)
Custom	0.8	(0.7-1.0)	0.8	(0.6-1.0)	0.8	(0.6-1.0)	1.0	(0.7-1.4)
Touring	0.4	(0.3-0.7)	0.4	(0.2-0.8)	0.4	(0.2-0.7)	0.8	(0.4-1.6)

*Adjusted for sex and driver age class, **Including lethal accidents

The greatest observed absolute risk of accidents was found among the youngest drivers (-24 years), across all motorcycle types, except for Touring which had no accidents among the youngest, and generally few accidents across all drivers' age groups. The difference in absolute risks between owners of different motorcycle types were also greatest among the youngest (31 accidents/1,000 drivers/year), and decreased with increasing age (5.8 accidents/1,000 drivers/year in 50+) (Figure 2.).

The greatest difference in absolute accident risk across age groups was seen among owners of SM/MX/Enduro/Trial motorcycles (23.8 accidents/1,000 drivers/year). The difference in absolute risk between the youngest and the oldest age groups, within motorcycle type was similar among Supersport motorcycle owners (19.9 accidents/1,000 drivers/year), owners of "Other type" (14.8 accidents/1,000 drivers/year), and owners of a Classic motorcycle built before 1981 (19.7 accidents/1,000 drivers/year), but the risk estimate decrease differed across age groups. For the latter motorcycle type the absolute risk was high among the youngest and decreased greatly in the 25-29 years group. The absolute risk differences across age groups among the remaining motorcycle types were lower, and similar, varying in risk difference between the youngest and the oldest from 2,7 among Scooter owners to 7,8 among owners of a Standard motorcycle (Figure 2.).

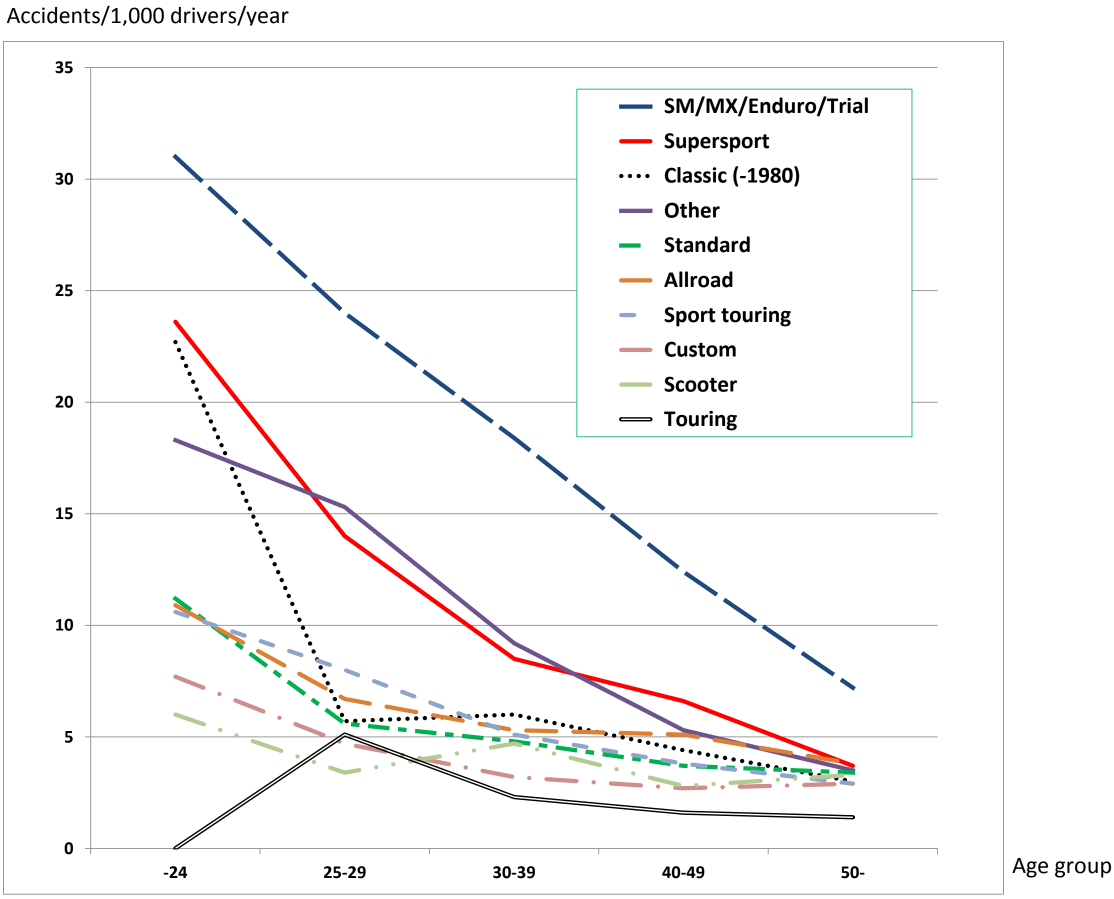


Figure 2. Observed absolute accident risks by motorcycle owner type and driver age group

4 Discussion

In this nation-wide register based cohort study of motorcyclists, defined as motorcycle owners licensed to drive a motorcycle, we have shown that younger age is a strong risk factor for hospital care from motorcycle accidents. We have also shown that risk varies with the choice of motorcycle type, and that the risk associated with motorcycle type choice varies with driver age. When adjusting for age and motorcycle type, we found no statistically significant difference in serious motorcycle accident risk between female and male drivers.

Important strengths in this study is the cohort design with a well-defined study population at risk of the outcome, and mileage used as offset in the risk calculations. For effective prevention of motorcycle accidents, it is essential to include drivers representative of the entire motorcyclist population in studies of accident risk factors. Findings in studies limited to describing the characteristics among motorcycle drivers engaged in serious or lethal crashes cannot easily be generalised to the common motorcyclists. By design, our study excludes accidents among unlicensed motorcycle drivers as well as among drivers borrowing a motorcycle who are at a greater risk of having a crash, and are overrepresented in lethal motorcycle crashes (Kraus, Anderson et al. 1991, Moskal, Martin et al. 2012). Despite this, our finding of drivers' age being the most important risk factor is similar to the findings of previous studies (Bjornskau, Naevestad et al. 2012, Vlahogianni, Yannis et al. 2012). The way different motorcycle types are defined varies greatly between studies. Almost all motorcycles in our study have an engine volume larger than 125cc and would be defined as "high-powered" according to the definition used in a recent study suggesting tighter engine size restrictions to prevent motorcyclist casualties (Rolison, Hewson et al. 2013). Our motorcycle type definition is similar to the classification used by Bjørnskau et al., and the findings of driving a Supersport motorcycle being associated with an increased accident risk coincide (Bjornskau, Naevestad et al. 2012). In our study including all accidents involving hospital care, driving a motorcycle classified as SM/MX/Enduro/Trial, however appeared most strongly associated with increased accident risk.

Linkage between different national registers gave us information on several important factors, but no data on the circumstances around the actual accidents, other than the injuries, was available. In addition, we have no information on accidents not resulting in injuries in need of hospital care. These limitations could partly be corrected adding information from police traffic crash records, insurance companies, or traffic accident data acquisition systems (Transportstyrelsen 2011, Wilson, Begg et al. 2012).

5 Impacts

Risk assessment within well-defined cohorts of motorcyclist provide valuable knowledge on the general risk of motorcycling. We have shown that motorcycle accident risk strongly decreases with drivers' age. The difference in risk associated with various motorcycle type is most pronounced among younger drivers.

6 Acknowledgement

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Riding Left Hand Corners: Facts and Measures

Motorradfahren in Linkskurven: Fakten und Maßnahmen

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Abstract

According to the official police-recorded Austrian road accident database, run-of-the road accidents in left hand corners are the second most frequent accident type with motorcycles involved. "Corner-cutting" is a potential reason in particular where forward visibility is poor and was, hence, made subject of two independent studies. For both studies, Naturalistic Observation was found to best suit the task. Video Cameras were placed at four different corners along typical motorcycle routes. The corners were selected based on accident records and previous experience in observation of riders, mainly taking place during on-road rider training.

For study 1, two corners with low forward visibility were selected and observed for almost 40 hours. Stills were extracted from the video and the lane position of more than 800 riders at the vertex of the corner was validated against the lane position of oncoming buses and trucks. Only 5% of the riders kept a safe path, reasonably close to the right side of the road. That means, for the remaining 95%, they would have had to change their path and swerve around an oncoming bus or truck.

The corners selected for study 2 had neither a particular accident record nor low forward visibility, but were known as typical places for corner-cutting by PTW riders (and car drivers as well). A simple before/after method was applied. It was found that placing different kinds of floor markings effectively reduces the number of riders within the dangerous area close to the centre line.

The two studies prove that corner-cutting is a quantitative problem and a potential reason for the large number of run-off-the-road accidents in left hand corners. It may be assumed that a majority of riders is not fully aware of the problem; hence, dissemination of this issue to the riders is urgently required by any channels available. Floor markings can be considered a very effective way to keep PTW riders away from oncoming vehicles in left hand corners. "Corner-cutting" is probably not the best term, since most of the riders remain on their own side of the road, but ride too close to the centre line.

Keywords (ITRD)

1221 Motorcycle, 1752 Motorcyclist, 1665 Safety, 2872 Bend (Road), 1855 Driving, 9112 Impact Study, 0562 Road Marking

Kurzfassung

Abkommensunfälle in Linkskurven sind – der amtlichen Unfallstatistik für Unfälle mit Personenschaden in Österreich zufolge – der zweithäufigste Unfalltyp mit Motorradbeteiligung. Kurvenschneiden wurde als eine mögliche Unfallursache identifiziert und deshalb in zwei unabhängigen Studien untersucht. Für beide Studien wurde naturalistische Beobachtung als passendste Methode gewählt. In vier verschiedenen Kurven an typischen Motorradstrecken wurden Videokameras aufgestellt. Diese Kurven wurden auf Basis der Unfallstatistik und früheren Beobachtungen bei Motorradfahrern, hauptsächlich den Teilnehmern von Straßentrainings, ausgewählt.

Für die erste Studie wurden zwei sehr unübersichtliche Kurven ausgewählt und zusammen für fast 40 Stunden beobachtet. Aus den Videos wurden Standbilder der Motorradfahrer auf dem Kurvenscheitel ausgeschnitten. Deren Fahrlinie wurde gegen den Platzbedarf entgegenkommender Schwerfahrzeuge bewertet. Nur 5% der Motorradfahrer hielten eine sichere Fahrlinie am Außenrand der Kurve ein. 95% hingegen hätten bei Gegenverkehr ihre Fahrlinie ändern müssen, um eine Kollision zu vermeiden.

Die beiden Kurven die für die zweite Studie ausgewählt wurden, sind übersichtlich und keine Unfallhäufungsstellen, aber bekannt dafür, dass Motorradfahrer (genauso wie Autofahrer) dort besonders oft links der Mitte fahren. Hier wurde ein einfacher Vorher-Nachher-Vergleich angestellt. Es stellte sich heraus, dass Bodenmarkierungen, die unmittelbar neben der Mittellinie auf der kurvenäußeren Seite aufgebracht werden, ein sehr effektives Mittel sind, die Anzahl der Motorradfahrer im Gefahrenbereich nahe der Mittellinie zu verringern.

Die beiden Studien beweisen, dass Kurvenschneiden ein quantitatives Problem und mögliche Ursache für die große Zahl von Abkommensunfällen in Linkskurven ist. Es lässt sich annehmen, dass die Mehrheit der Motorradfahrer sich dieses Problems nicht bewusst ist. Daher ist Meinungsbildung auf allen Kanälen dringend erforderlich. Ferner wurde festgestellt, dass sich die Anbringung von Bodenmarkierungen hervorragend dazu eignet, Motorradfahrer von der Gefahrenzone entlang der Mittellinie fern zu halten. Und letztlich, „Kurvenschneiden“ ist möglicherweise gar nicht das richtige Wort; die meisten Fahrer fahren auf ihrer eigenen Straßenseite, aber eben zu nah an der Mittellinie.

Schlüsselwörter (ITRD)

1221 Motorrad, 1752 Motorradfahrer, 1665 Sicherheit, 2872 Straßenkurve, 1855 Fahrzeugführung, 9112 Wirksamkeitsuntersuchung, 0562 Fahrbahnmarkierung

Riding Left Hand Corners: Facts and Measures

1 Introduction

KFV is currently running a large research program on PTW (powered two wheeler) rider behaviour. In general, this is – like it is in the whole of Europe and probably also globally – motivated by the fact that PTW crashes, although their total number is decreasing, take an increasing share of road traffic fatalities and injuries (Yannis et al, 2012). This paper describes the results of two studies, which were carried out independently, but with a common trigger: Among all accidents involving a motorcycle within the official Austrian police-recorded accident database, run-off-the-road-accidents in left hand corners are the second most frequent crash type. The most frequent accident type is "falling off the vehicle", which is quite unspecific. From 2007 to 2011, 1875 rider fell off their vehicle, 1621 left the road to the right side in a left hand bend.

Previous investigations were triggered by the experience in on-road rider training, that riders tend to move their vehicles too far to the left side in left hand corners, which could be called "corner-cutting", but, to a certain extent is not. In close corners, oncoming heavy vehicles need much more space than their own lane. Even if a rider is moving on his own lane, he may be forced to quickly change his trajectory to the right, if e.g. a bus comes the other way. At two locations in Carinthia, fatal accidents happened, where riders crashed into the guardrail in upright position, and were ejected into the river next to the road. Several measures were taken to avoid accidents at these location, e.g. installing underrun-protection, huge warning signs, corner markings, etc., but all these were of limited success. In the end, it was assumed that "single vehicle accident" in not quite the correct classification. It was assumed that the riders were able to avoid a crash with an oncoming vehicle, but after adjusting their trajectory, they were not able to cope with re-entering the corner. Figure 1 shows skid and scratch marks after a motorcycle crash, which clearly indicate such a scenario. Hence, it was only logic to investigate trajectories of riders at these locations and assess them against the space needed by oncoming heavy vehicles.

Figure 1. Skid marks after Crash

At the same time, different shapes of floor markings were tested at two other locations in Carinthia. This was the scientific follow-up of a first successful attempt of reducing PTW accidents in left hand corners on one of the most popular motorcycle routes in Carinthia. V-shaped markings were painted next to the centre line in left hand corners, where numerous motorcycle crashes had happened before.

Figure 2. First application of floor markings, B69, „Soboth"-Route[1]. Source: Höher, 2012.

[1] In Austria, roads with „B"-numbers are national roads („Bundesstraße"). However, this is somewhat misleading, since responsibility for all these road was transferred to regional governments in 2002. "Soboth" is the name of a mountain pass road leading from Lavamünd to Eibiswald. http://de.wikipedia.org/wiki/Soboth_(Pass)

There was no scientific research carried out to assess the impact of this first application, but it was obvious that crashes involving motorcycles at this location drastically decreased.

2 Hypotheses

The common denominator of the two studies was to classify the lane position of PTW riders. Both classification and assessment were done in different ways in the two studies. However, in both cases, a camera was placed close to the corner and the assessment was done later by video annotation.

2.1 Corners with poor forward visibility

In the two corners with poor forward visibility, the main issue was finding appropriate criteria for a "correct" trajectory. These two corners were narrow with a radius of 17 m at the centre line and a width of 6 m. With the eyes placed at the very edge of the corner, the visible distance is about 23 m, with the rider's eyes right above the centre line it is about 20% shorter (Figure 3).

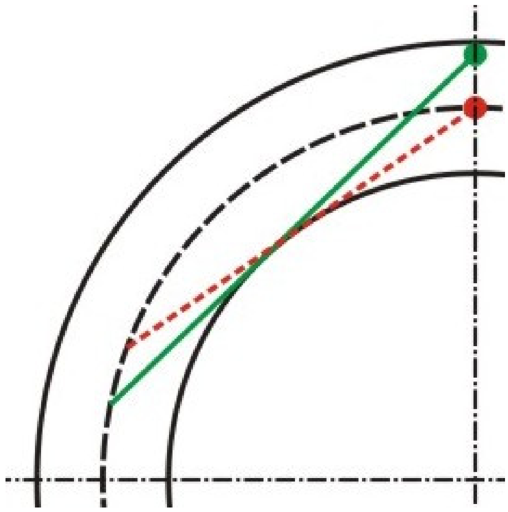

Figure 3. Visualisation of forward visibility

It had to be considered that oncoming heavy vehicles require much more space than just their own side of the road to be able to pass these corners, depending on the length and, to a certain extent, also depending on their drivers' skills.

Figure 4. Oncoming heavy vehicles

The research question for this first study: How many riders move too far to the left, in particular, within an area, where a collision with an oncoming vehicle would be likely or at least possible?

2.2 Testing of Floor Markings

In earlier times, floor markings were slippery, in particular in wet condition. Since 1995, it is a legal obligation that floor markings have to be almost as skid-resistant as the surrounding road surface[2]. Nevertheless, PTW riders still avoid riding on floor markings. The intervention makes use of this quite common behaviour.

Hence, it was assumed that riders would also avoid riding on floor markings, if they are painted close to the centre line and, consequently, would ride further away from oncoming traffic. The research question for this second study: Do PTW riders change their corner trajectory to avoid passing over floor markings painted close to the centre line?

[2] § 2 Abs 3 Bodenmarkierungsverordnung (by-law on road markings), BGBl 1995/848 idF BGBl II 2002/370

3 Intervention

For study one, there was no intervention.

For study two, in two corners along two different popular motorcycle routes, three different layouts of floor markings were tested. Those corners were selected from experience, i.e. corners, which were well known for numerous PTW riders riding closer to the left edge than they probably should.

Figure 5. Bend on B95 "Turracherstrasse"

Figure 6. Bend on B105 "Mallnitzerstrasse"

Three different designs of floor markings were tested. The first one was a simple line of dots (Figure 7).

Figure 7. Floor marking design "line of dots"

This idea followed a previous trial with a simple line painted with green colour spray (see Figure 8).

Figure 8. Earlier trial with green coloured line

To make this more visible and to keep riders from moving between the centre line and the line of dots, additional dots were added within this area (see Figure 9).

Figure 9. Floor marking design "lots of dots"

Finally, a third design was tested using elliptic markings (Figure 10).

Figure 10. Elliptic floor marking

4 Methodology

4.1 Corners with poor forward visibility

There is no particular rule in the Austrian road code, which defines a reasonable distance to oncoming vehicles. There are rules of thumb, which are taught in the Austrian driving schools referring to passing by objects (50 cm to fixed objects, 1 m to pedestrians, 1.5 m to bicyclists) and to overtaking (two-wheeler: 1 m plus 1 cm per km/h of own driving speed, four-wheelers 50 cm plus 1 cm per km/h of own driving speed). However, neither the syllabus nor the teaching books contain any particular information about minimum distance to an oncoming vehicle. We could not even find a single court decision, which would have proposed anything referring to this issue. Hence, the extreme case was made the threshold. A white bar was copied into the stills, which were extracted from the videos. This bar has a width of 50 cm, which covers the extreme case of the semitrailer-truck and provides a reasonable safety distance of about 50 cm to an oncoming bus (see Figure 11).

Figure 11. White bar for assessment

Figure 12. Camera position

Video cameras were placed at both of the corners for two days (Figure 12). Footage of 38 hours and 44 minutes was collected. During this period, 811 motorcycle and moped riders passed by. For each of them, a screenshot was taken. After anonymisation it was assessed, whether they were right of the white bar, left of the white bar or if their silhouette was partly covered by the white bar.

4.2 Testing of Floor Markings

In principle, this experiment was done – more or less - in a simple before-and-after-design. However, the two different designs using dots were applied one after the other, i.e. first “line of dots” was tested and additional dots were added later to create “lots of dots”.

This investigation required a slightly more sophisticated way of assessment than the one in the bends with low forward visibility. The road was divided into four areas, from left to right (Figure 13):

1. Lane for oncoming traffic (red colour)
2. Dangerous area along the centre line (amber colour)
3. Intermediate areas (yellow colour)
4. Right hand third of the rider’s own lane (green colour)

Figure 13. Assessment scheme for second study

Riders counted for the area, which they were predominantly moving in.

5 Results

5.1 Corners with low forward visibility

- 811 Riders were observed.
- 39 (5%) selected a safe trajectory (right of the white bar with their complete silhouette).
- 133 (16%) moved with 100% overlap to oncoming heavy vehicles (completely left of the white bar).
- 79% would have had to change their trajectory for an oncoming heavy vehicle (partly covered by the white bar).

5.2 Testing of Floor Markings

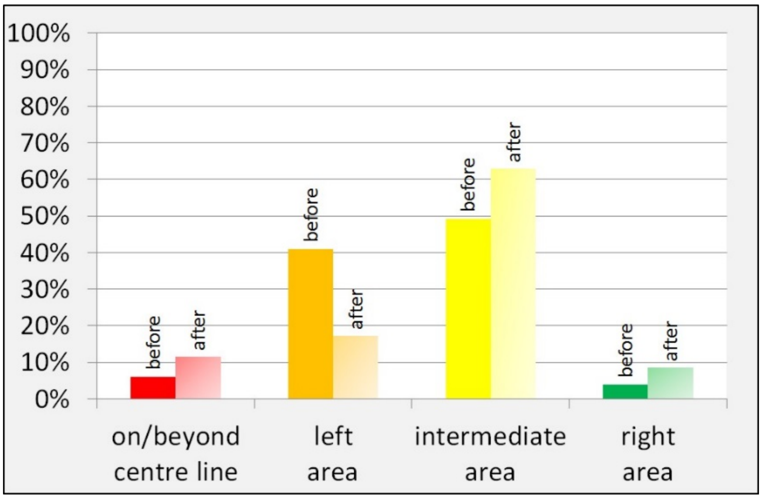

Figure 14. Before/After Comparison "Line of Dots"

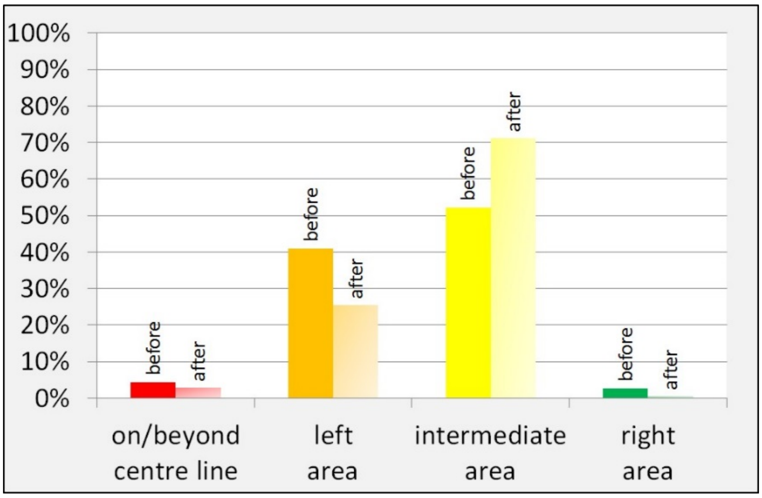

Figure 15. Before/After Comparison "Lots of Dots"

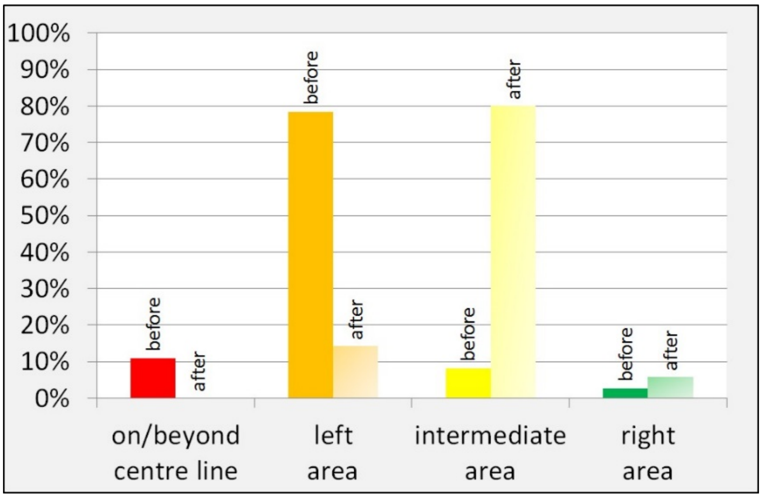

Figure 16. Before/After Comparison "Elliptic Marking"

The elliptic marking prevented 100% of trips on the wrong side of the road and massively reduced the number of trips within the dangerous area along the centre line. Almost 85% of the riders travelled on a safe path. With the "line of dots" design, the number of riders travelling on the wrong side of the road even slightly increased. However, less than half of the number of riders moved within the dangerous areas on the left side of the road and in the area close to the centre line in the after-period.

Table 1. Before/After Comparison, all designs

Line of dots	**before**		**after**	
on/beyond centre line	11	6%	4	11%
left area	74	41%	6	17%
intermediate area	89	49%	22	63%
right area	7	4%	3	9%
Total	181		35	

Lots of dots	**before**		**after**	
on/beyond centre line	10	4%	5	3%
left area	95	41%	46	25%
intermediate area	121	52%	129	71%
right area	6	3%	1	1%
Total	232		181	

Elliptic marking	**before**		**after**	
on/beyond centre line	4	11%	0	0%
left area	29	78%	5	14%
intermediate area	3	8%	28	80%
right area	1	3%	2	6%
Total	37		35	

6 Conclusions and recommendations

The results of the survey in the corners with low forward visibility give reason for worries. It cannot be supposed that riders deliberately put themselves at risk, in particular not at this kind of risk. Most of the rider were travelling with rather low roll angles. This is an indication for a low number of high-speed riders among those observed. In other words, a rider searching thrill and sensation would quite unlikely travel slowly, but far to the left. Our conclusion: The average rider thinks, (s)he will be able to swerve around an oncoming vehicle if necessary. If adverse conditions accumulate, they manage to swerve and then fall off their vehicle (four cases at these two corners within five years from 2007 to 2011) or crash into the barriers (one case in five years). More likely, they will either hit (two cases) or rub against the oncoming vehicle (five cases).

Given our assumption is correct that riders do not put themselves at risk deliberately, they need to be informed about the risk of riding too close to the centre line. Any channel should be used for that purpose. The photos and videos created within this project could be used for that purpose, like the montage in Figure 17.

Figure 17. Photomontage of rider and oncoming bus

The Austrian Automobilist Club ÖAMTC counted about 4,400 participants in voluntary rider training in 2013. There will be a lot more riders passing other kinds of training, e.g. with several of the training courses offered by police riders at various places in Austria. However, compared to about 450,000 motorcycles registered in Austria, this number of retrained riders seems rather low. Hence, measures should be taken to encourage riders to take such retraining.

Floor markings are an effective way of influencing riders' trajectories in left hand corners. The elliptic design was by far the most effective one. Unfortunately, it requires a lot of the relatively expensive sheet material[3]. The line of dots is least effective, but with some additional dots between the line of dots and the centre line, the impact drastically improves, however, it remains far less effective than the elliptic design. Testing of alternative shapes is advisable, as a first step, the design initially used (V-shape, see Figure 2 in the introduction) should be evaluated. Probably using different colours for the floor markings could also improve effectiveness.

Both studies together provide a clear indication that riding speed is probably overestimated as a moderating factor to risk. Even with rather low speed limits, riders may exceed appropriate speed in bends with low forward visibility without exceeding the legal speed limit. Even riding at appropriate speed is not sufficient to avoid risk from riding too close to the centre line in left hand corners. As already denoted above, awareness raising seems a good alternative to prevent motorcycle crashes in left hand corners.

7 Acknowledgement

The Regional Government of Carinthia had commissioned the Evaluation study on different designs of floor markings. Special thanks go to Gerald Höher, who mandated use of the results for this paper and to Caroline Wollendorfer and Martin Kobald, my colleagues at KFV, for providing their work and experience. Many thanks also go to Hannes Bagar ("Varahannes"), who is a driving teacher and road safety trainer for many years, who had the idea for the study on left hand corners, who did all the practical work of shooting the videos, extracting stills, cutting videos, and in particular, providing his experience of 70,000 km p.a. on motorcycles and hundreds of days providing practical training on both tracks and roads.

[3] Up to here, „painting" of floor markings was used figuratively. Practically – also because this was a temporary measure, which had to be easily reversible – adhesive sheet material (removable line marking material) was used.

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Motorcycle Sliding Friction for Accident Investigation

Erkenntnisse über Motorrad-Rutschverzögerungen für Unfalluntersuchungen

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Abstract

The subject research examined 15 actual crashes of motorcycles equipped with frame sliders and established the related drag factor using 5 and 10Hz GPS data acquisition systems. The crashes occurred during track days or races and many were also documented with on-board video, which was synchronized with the GPS data when available. 14 controlled tests were then performed with different motorcycles and the sliding friction values were determined using GPS data acquisition and traditional methods for validation. The average drag factor for the 15 track crashes was -0.45 g's (SD = 0.09) and -0.48 g's (SD = 0.08) in the 14 controlled tests, where none of the motorcycles were equipped with frame sliders. These results align with previously published research. Of importance, this data showed frame sliders do not lower the drag factor of a sport bike, but actually increase it. Moreover, a relationship between certain collision dynamics and the sliding friction became apparent. This research will help accident investigators more accurately quantify the pre-impact speed of downed motorcycles.

Motorcycle Sliding Friction for Accident Investigation

Introduction

Many studies have been performed to establish the drag factor of a downed motorcycle sliding across typical roadway surfaces. However, available literature does not address real-world incidents where an operator is involved and may interact with the motorcycle and roadway. Furthermore, the dynamics of an actual crash certainly differ from quasi-static tests seen in past research [1, 2], and may differ from sliding tests where a motorcycle is dropped from a moving truck or trailer [2-6].

Research on the subject to date has been relatively elementary, lacking the technology capable of detailing the behavior of a sliding motorcycle throughout its travel. Typical methodology involves dropping an upright motorcycle at a known speed and documenting the sliding distance by noting initial contact with the roadway and final rest. This process allows for the calculation of the average drag factor of the motorcycle during a slide, but does not provide information about the initial acceleration or changes throughout the slide. McNally and Bartlett worked to gain more information about the initial deceleration of a motorcycle striking the ground using frame-by-frame video analysis, though that project only involved two motorcycles and three tests [5].

There is little information regarding the sliding behavior of motorcycles equipped with frame sliders. Frame sliders are often installed on sport and sport-touring motorcycles and are comprised of metal or plastic pucks designed to slide across the roadway to prevent damage to the fairings and frame. Some accident investigators opine the sliding friction factor of motorcycles equipped with frame sliders is much lower than those without the feature. At the time of this writing though, no published research on the topic exists.

The goal of this project is to produce information to fill the voids mentioned above. To do so, data from real crashes was sought using current GPS technology. The GPS data collection process was validated via controlled testing where the sliding friction value was established using both traditional and updated GPS-based methods. The controlled testing also serves to add to the current sliding friction database.

Procedure

The advent of an inexpensive, robust, accurate GPS data-logging device by QSTARZ sparked the concept of the present study (Figure 1). The QSTARZ BT-Q1000eX logs position at 5 or 10Hz, depending on the model, with speed calculation accuracy of ±0.1m/s, and timing accuracy of 50 ns, which creates an uncertainty of 0.01g in the calculated result.

Figure 1. QSTARZ BT-Q1000eX GPS lap timer / data logger.

Track Crashes

The aforementioned GPS devices were distributed at track days and race events, and also grew in popularity naturally. As a result, a notable population of track riders were in a position to provide crash data in the event of an incident. Data sets were collected at two paved racetracks in the United States over a period of three years: New Jersey Motor Park (NJMP) and New Hampshire International Speedway (NHMS). The motorcycles were standard street-going motorcycles with the usual minor modifications to meet track requirements. These modifications often included removal of the mirrors, the addition of frame sliders, and at times, the use of race tires. However, the majority of motorcycles analyzed within were equipped with DOT approved tires (Figure 2).

Figure 2. Typical motorcycle examined in the track crashes.
This motorcycle was involved in Event 1.

The GPS devices were attached firmly to the upper triple clamp or fairings of the motorcycle. Only instances where the device remained solidly attached throughout the collision sequence were considered for analysis. The deceleration of the motorcycle was calculated by considering the change in speed and slide duration, thereby capitalizing on the accuracy strengths of the GPS device. This method consolidates the behavior of the motorcycle during an entire slide, reporting it in a single average value. This method is most relevant in accident investigation since investigators will likely only know where the motorcycle first struck the ground, and where it came to final rest.

Several of the involved motorcycles were equipped with on-board video recording devices. In those cases, the video was synchronized with the GPS data using DashWare, a software package developed for this purpose. Synchronization allowed for straightforward determination of the motorcycle speed at first contact with the track. In cases were no video was available, the rider's dataset was analyzed to establish the expected behavior in a specific section of the track, which was then compared to the motorcycle behavior in the case of the crash. The slide was considered to terminate when the speed dropped below 0.9 m/s to eliminate error associated with GPS noise at low speeds.

The drag factor during the initial portion of the slide was calculated to determine if there was any notable difference in the initial drag as seen by Bartlett, McNally [5]. When the data came from 10Hz units, the first 0.5 seconds (five samples) were examined. If the data was retrieved from a 5Hz model, the first 0.6 seconds (three samples) were examined.

Controlled Testing

Controlled drop-tests were conducted at an asphalt-paved, police training facility in Roseville, California. 14 motorcycles of varying condition and type were acquired for testing (see Appendix A for a full list). The make, model, year and vehicle identification number (VIN) of each motorcycle was recorded, and the motorcycles were photographed in a pre-collision condition. In addition, each motorcycle was weighed using portable digital scales (Figure 3). For consistency each motorcycle was prepared in the same fashion: fuel and oil was drained, tires were inflated to the manufacture's specification, and the drive chain or belt was removed. Any preexisting damage to components that interfered with the rotation of the tires was mitigated by removal or adjustment of the offending part.

Figure 3. Yamaha FJ1200 being weighed using digital scales.

A pneumatic vise, designed to mount in a trailer hitch receiver, was used to capture the front tire of the motorcycle (Figure 4). The front tire of the motorcycle was elevated fewer than three inches, while the rear tire remained in contact with the asphalt. Steel wire or chain was used to prevent the front wheel from rotating more than a fraction of a rotation after being released. This was performed to ensure an immediate capsize. As with the track crashes, the QSTARZ GPS unit was mounted to the upper triple clamp or bodywork of the motorcycles. A speed trap was positioned in the drop zone to corroborate the drop speed reported by the GPS unit. The average difference in reported speeds was 1%. All tests were documented with video, which allowed synchronization of GPS data and video via DashWare.

Figure 4. Pneumatic vise designed to capture the front tire of the test motorcycle.

The deceleration of the motorcycle was calculated using two methodologies. The GPS-based calculation was performed as described above. In these tests, the GPS data was consistently synchronized with video, again, allowing for straightforward determination of the speed of the motorcycle at first contact with the ground. Traditional calculations were also performed. In these calculations, the sliding distance of the motorcycle (first contact with the asphalt to center of gravity at final rest) was considered along with the initial drop speed, which was determined using the speed trap and GPS device. The sliding distance and drop speed can be used to calculate the drag factor using the following equation:

$$f = \frac{Ve^2 - Vo^2}{2dg}$$

Where:

f = drag factor (g's)

Ve = final velocity (m/s)

Vo = initial velocity (m/s)

d = sliding distance (m)

g = standard gravity (m/s^2)

The geometry of the course was measured using a Topcon GPT-2005 total station to establish grade and superelevation.

Results

Track Crashes

15 crashes suitable for analysis were obtained. 14 slid on dry pavement, one slid on wet pavement, and three of those motorcycles slid on grass or dirt for a portion of the event. A summary of the results is presented in Table 1 below.

Table 1. Summary of track crashes.
Location indicates track and turn where the event occurred.

ID	Vo (m/s)	GRADE	LOCATION	DRAG (-*g*'s)	INITIAL DRAG (-*g*'s)	SURFACE
1	22	0.1%	NHMS 1	0.37	0.27	ASPHALT
2	27	0.5%	NHMS 6	0.49	0.82	ASPHALT
3	23	1.6%	NHMS 1	0.60	0.65	ASPHALT
4	25	2.9%	NHMS 4	0.45	0.29	ASPHALT/DIRT
5	25	1.8%	NHMS 9	0.56	0.42	ASPHALT
6	10	3.6%	NHMS 12	0.23	0.13	ASPHALT
7	19	4.3%	NHMS 4	0.50	0.31	ASPHALT
8	27	0.4%	NJMP	0.33	0.34	ASPHALT
9	24	0.1%	NJMP	0.41	0.41	ASPHALT
10	14	0.0%	NHMS 11	0.52	0.72	ASPHALT
11	20	0.9%	NHMS 2	0.41	0.67	ASPHALT
12	41	0.0%	NHMS 1	0.52	0.78	ASPHALT
13	19	2.0%	NHMS 2	0.41	0.61	WET ASPHALT
14	16	0.6%	NHMS12	0.44	0.21	ASPHALT
15	30	-4.7%	NHMS1	0.49	0.27	ASPHALT
8A	17	1.4%	NJMP	1.11	N/A	DIRT
9A	12	3.0%	NJMP	0.61	N/A	DIRT

The average sliding drag factor for the track crashes on asphalt was -0.45 *g*'s (SD = 0.09), while the average initial drag factor was -0.46 *g*'s (SD = 0.22). The event that occurred on wet asphalt resulted in a drag factor of -0.41 *g*'s, which aligns with the dry asphalt data.

In Event 4, the motorcycle slid for a considerable distance on asphalt and hard packed dirt before coming to rest. However, despite the change in surface, there was no notable change in the drag factor. Therefore, the drag factor was determined to be -0.45 *g*'s for *both* the asphalt and dirt (Figure 5). The other two events involving dirt slides, 8A and 9A, resulted in drag factors of -1.11 *g*'s and -0.61 *g*'s, respectively.

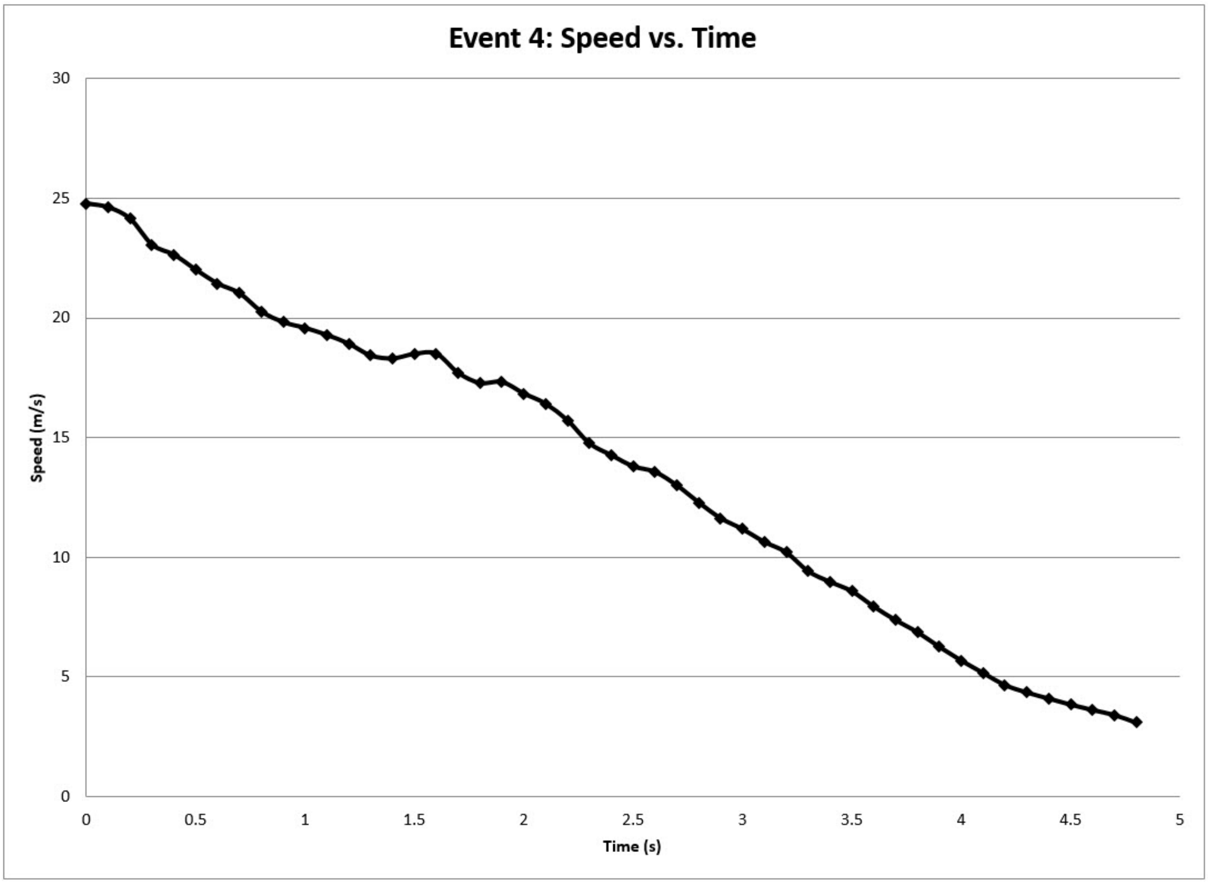

Figure 5. Event 4 speed (m/s) versus time (s).

Controlled Tests

The average drag factor for the controlled tests calculated via GPS methodology was -0.48 *g*'s (SD = 0.08) and -0.51 *g*'s (SD = 0.13) via traditional methodology. A summary of the results is shown below (Table 2) and an exemplar graph is shown in Figure 6. While the GPS derived drag factor agreed with the traditional methodology in most cases, there were two events where the numbers were substantially different (Events 18 and 20). In both of those events, the traditional calculations resulted in a significantly higher drag factor. Overall though, the average disparity was only 8%. If Events 18 and 20 are excluded, that disparity dropped to 5%.

Table 2. Summary of controlled tests.

ID	Vo (m/s)	INITIAL DRAG (-*g* 's)	DRAG GPS (-*g* 's)	DRAG TRADITIONAL (-*g* 's)	DIFF. (%)
16	13.0	0.33	0.50	0.49	1%
17	15.2	1.17	0.60	0.60	0%
18	16.1	0.46	0.45	0.54	20%
19	17.9	0.67	0.47	0.47	0%
20	9.4	0.84	0.66	0.90	36%
21	22.4	0.76	0.47	0.48	2%
22	19.2	0.21	0.54	0.54	0%
23	15.6	0.25	0.48	0.55	15%
24	12.5	0.57	0.41	0.46	12%
25	20.6	0.46	0.39	0.37	6%
26	22.4	0.34	0.42	0.43	3%
27	21.9	0.28	0.55	0.47	15%
28	21.0	0.79	0.43	0.41	4%
29	21.0	0.40	0.41	0.41	0%

The average initial drag factor for the controlled testing was -0.54 *g*'s (SD = 0.28). The drag factor during the first 0.5 or 0.6 seconds of the slide was compared to the average drag factor for the entire slide. A paired comparison is shown in Figure 7.

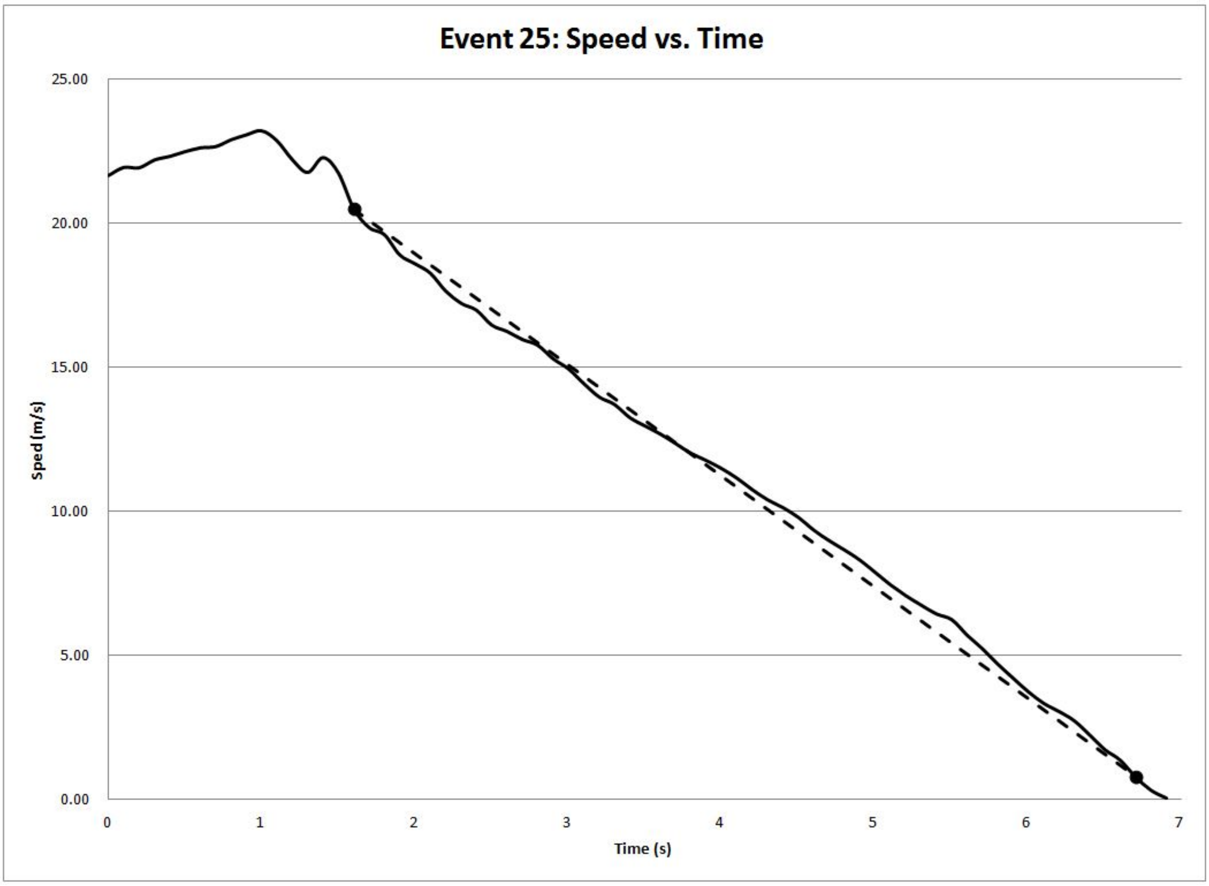

Figure 6. Event 25 speed versus time, showing beginning and end of slide and slope of speed change (calculated drag factor). The acceleration spike seen prior to initial selection point is a result of the front tire contacting the roadway prior to the motorcycle capsizing.

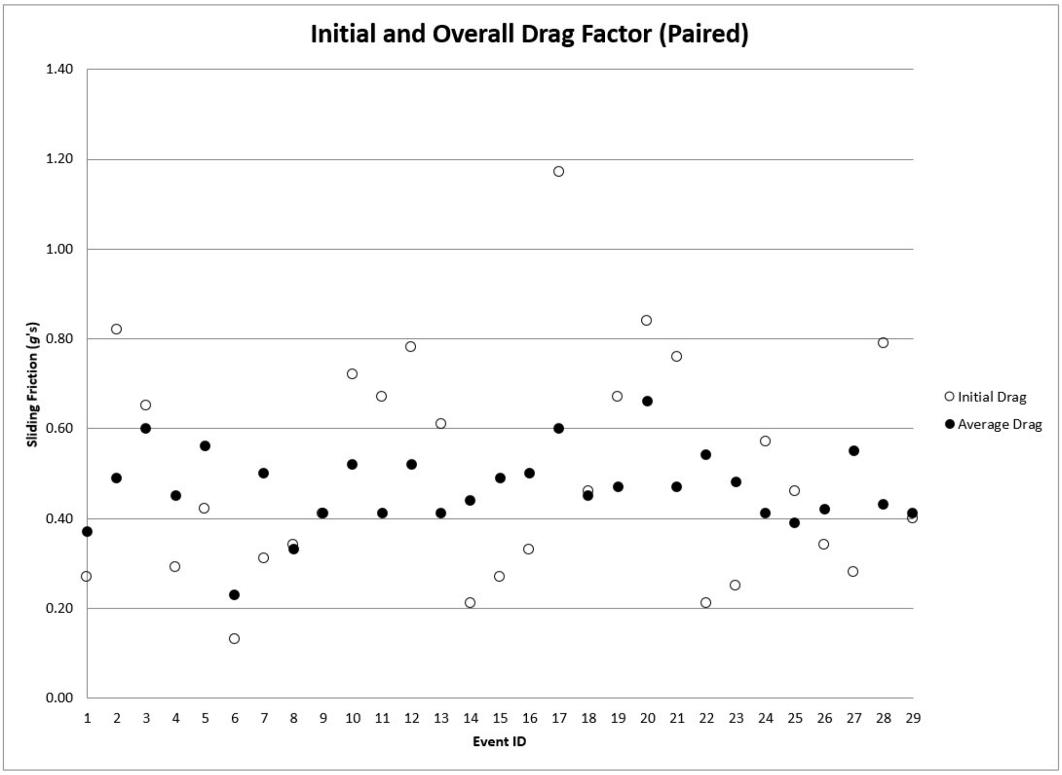

Figure 7. Paired initial drag factor versus average drag factor for entire slide.

Finally, a histogram was prepared for the entire data set to illustrate the distribution, and is shown in Figure 8.

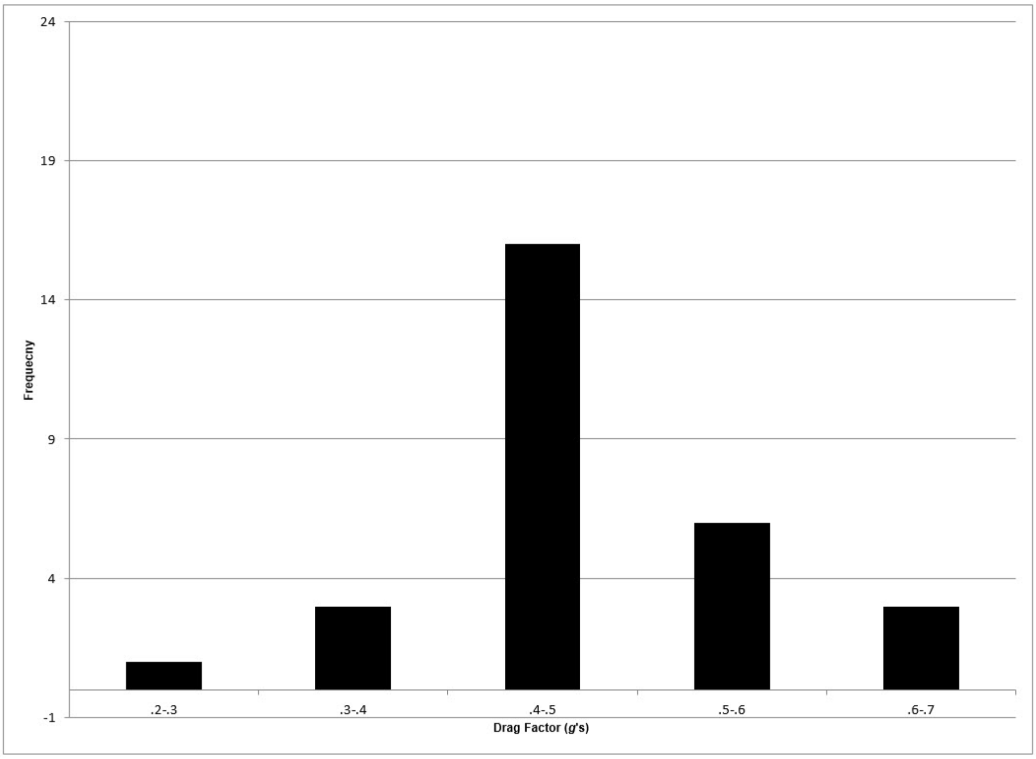

Figure 8. Drag factor distribution for entire data set.

Discussion

The data presented within is consistent with available literature relating to un-faired motorcycles [1-6]. However, if the track crashes are compared to prior data for sportbikes equipped with fairings, there is a clear disparity. For example, Raftery conducted two tests with a motorcycle equipped with Suzuki Katana fairings and obtained a drag factor of -0.26 *g*'s [3]. Similarly, Medwell performed two tests where a fully faired 1992 Kawasaki Ninja ZX-7 slid across an asphalt roadway and obtained drag factors of -0.29 and -0.36 *g*'s [4]. Bartlett et al compiled all sportbike data available from I.P.T.M. testing and combined that with the tests mentioned here to calculate an average drag factor of -0.37 *g*'s (SD = 0.08) for sportbikes [6]. Recall, the average drag factor for the track crashes presented above, which were all sportbikes, was -0.45 *g*'s (SD = 0.09). This increase in the drag factor is thought to be a result of the installed frame sliders, which often prevent contact with nearby fairings, thereby inducing behavior more consistent with a standard, non-faired motorcycle. It should be noted that all the track-crash motorcycles included in this study were equipped with plastic frame sliders. Metallic frame sliders may behave differently.

Two of the controlled tests were performed with fully faired motorcycles without frame sliders (Event 21: 1991 Suzuki GSX600F, Event 26: 1989 Suzuki GSX-R750) and the drag factors were -0.47 *g*'s and -0.42 *g*'s, respectively, which aligns with the frame slider data set. Of course, these values also align with the totality of the small sportbike sample set, where one standard deviation above the mean is -0.45 *g*'s.

Excluding the two sportbikes mentioned above from the controlled testing data set yields an average drag factor of -0.49 *g*'s (SD = 0.09). This agrees with the totality of data presented by Bartlett et al in a 2007 review paper, where the average was reported to be -0.48 *g*'s (SD = 0.13) [6].

One moped was included in the controlled tests (Event 20: Peugot 101SP). Unfortunately, this was one of the two tests where the GPS based calculations did not agree with the traditional methodology. Specifically, the GPS based calculations yielded a drag factor of -0.66 *g*'s while the traditional method yielded a drag factor of -0.90 *g*'s. Considering the low initial speed (9.4 m/s) and therefore short sliding distance (4.9 m), any error identifying the area of initial contact with the roadway or the position at final rest could translate into a substantial error in the drag factor. This factor may be accountable for the large disparity. This theory is supported by comparing the standard deviations of the traditional methodology and GPS-based method, 0.13 *g*'s and 0.08 *g*'s, respectively. Namely, these standard deviations show there is more variance in the traditionally obtained data, likely a result of the human element.

There was one other major disparity in the calculation methodologies, Event 18. The GPS based drag factor was -0.45 *g*'s while the traditional calculation method resulted in a drag factor of -0.54 *g*'s (20%

difference). In that test, the GPS device was mounted to the tail of the motorcycle, as a more appropriate position was not available. Additionally, the motorcycle nearly completed one entire revolution while sliding across the asphalt. This movement, combined with the distance between the GPS device and the motorcycle Center of Gravity could be responsible for the drag factor disparity.

Lambourn concluded when a motorcycle falls to the ground from an upright position, the drag factor may be dependent on the drop speed [2]. The theory is that at lower speeds, an acceleration spike from initial contact with the roadway would be significant, but at higher speeds that spike would play less of a role considering the overall slide distance. McNally and Bartlett investigated this concept using frame-by-frame video analysis and found the drag factor in the first 4.6 m was more than twice the remaining drag factor in three tests they performed [5].

With respect to the track crashes presented within, those with on-board video were analyzed to qualitatively establish the roll rate of the motorcycle as it fell to the ground. In the cases where roll rate was high and the motorcycle fell a considerable distance (i.e., not at full lean) an initial drag factor spike was consistently observed. The spikes observed in this dataset were never as substantial as those observed by McNally and Bartlett. In the controlled tests, the motorcycles were all dropped from an upright position, but there was no consistency with respect to the initial drag factor compared with the overall drag factor. In the most extreme case, the initial drag factor was nearly twice the overall drag factor, but there were three instances where the initial drag factor was closer to half of the overall drag factor.

Figure 7 shows a paired compilation of the initial drag factor compared to the overall drag factor for all events presented here. For a total of 29 events, the initial drag was higher in 14, lower in 14, and the same in 1. This data suggests the dynamics of the motorcycle must be considered when determining if an initial spike is likely. For accident investigators, it is likely not worth considering for high-speed slides. However, if the motorcycle was known to have a high roll rate prior to contacting the ground, and the initial speed was low, utilizing a higher drag factor would be appropriate.

As discussed, the initial acceleration was calculated over a period of 0.5 (five data samples) or 0.6 seconds (three data samples), depending on the specific GPS device. It is possible the initial acceleration spike is so short that it was imperceptible in some instances. Further testing with higher frequency equipment could provide further insight on that front. Though, if the spike is of such short duration that it was not detected by the devices used here, it would rarely be worth considering in the field of collision reconstruction.

Conclusions

1) The GPS-based methodology used in this study produced drag factors consistent with previous research and was confirmed via controlled testing.

2) Sliding sportbikes equipped with frame sliders will behave more like a standard, non-faired bike, since the sliders prevent the nearby fairings from contacting the roadway.

3) There will not always be an initial spike in the drag factor as the motorcycle contacts the roadway. The behavior of the motorcycle prior to contacting the roadway must be considered.

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Appendix

ID	MAKE	MODEL	YEAR	WEIGHT (Kg)
16	YAMAHA	MIDNIGHT MAXIM 650	1981	210
17	YAMAHA	YZFR1	2002	164
18	YAMAHA	XV750	1990	183
19	HONDA	GL500	1982	242
20	PEUGOT	101SP	UNK	44
21	SUZUKI	GSX600F	1991	193
22	HONDA	SHADOW	1984	185
23	HONDA	ELITE	UNK	80
24	LANCE	CHARMING	2008	75
25	HONDA	GL1100	c. 1979	326
26	SUZUKI	GSXR750	1989	203
27	YAMAHA	XS750	c. 1979	215
28	YAMAHA	XJ650	1982	260
29	YAMAHA	XJ650	1982	260

Motorcycle Velocity Determination from Impact Damage

Rekonstruktion der Fahrgeschwindigkeit von Motorrädern anhand der Deformation am Fahrzeug

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Abstract

Powered Two Wheeler (PTW) accident reconstruction involves analyses of pre-impact dynamics, impact/crush evaluation and post-crash dynamics. Reliable methods to assess PTW impact damage and deformation along with damage to the crash partner are necessary to determine velocity at impact. Previous research (References [1], [2] and [3], among others) has provided some guidance, but the complexity of computing the impact speed by assessing PTW component (and crash partner) energy dissipated during impact has not been well addressed.

The purpose of this research is to provide a methodology of relevant computations in common real-world PTW (motorcycle) crashes to assess or evaluate the energy dissipated in the motorcycle and the crash partner (or other vehicle; OV). To assess this one must consider the energy dissipated during the crash, most importantly the bending and breaking of various parts and structures. The computations presented are from real-world collisions and a full-scale controlled 80-kph experimental impact test of a motorcycle onto the side of a panel truck. An additional experimental component test; namely deformation data for a motorcycle fuel tank, is also presented.

The presented data and calculations will provide the accident reconstructionist with tools to evaluate real world crashes, particularly the assessment of a deformed, dented, bent and/or broken vehicle. This permits the analyst the ability to determine velocity associated with impact speed.

Motorcycle Velocity Determination from Impact Damage

Introduction

Determining motorcycle pre-crash and crash speeds often involves calculations including kinematic and dynamic equations, work and energy relationships, friction, ballistics, and others that govern the reactions and interactions of the vehicles throughout the duration of the event. To analyze the impact phase, the analyst must quantify the energy dissipated during the deformation and breaking of materials.

Motorcycle energy dissipation (related to speed change) has previously been shown to be related to the change in wheelbase of the damaged motorcycle ([1], [2], [3]). This approach combines all of the energy dissipation associated with the deformation and breaking of the frontal components of the motorcycle into a single parameter. This method, however, requires additional calculations for the other vehicle (OV) dissipated energy and energy dissipation due to motorcycle component damage unrelated to wheelbase shortening. These might be localized deformations or damaged material, such as dents and cracks on the frame, fuel tank, broken foot pegs, broken handle bars or dented and/or broken panels, broken wheel or suspension parts, and bent or missing OV bumpers panels or supports, etc. These component energies can be significant and need to be analyzed to more thoroughly quantify the dissipated energy.

This research presents a methodology whereby these component energies can be included in an analysis and used to get a more detailed estimate of the impact phase dissipated energy. The paper discusses a two vehicle collision (motorcycle versus an OV with negligible velocity in the direction of the motorcycle); however, the general approach is applicable to other crash modes too.

Methodology

In order to determine motorcycle velocity leading to a crash event, energy dissipations during the pre-crash, post-crash and crash phases are analyzed. This requires assessing the energy dissipated during the crash (or impact). In order to evaluate the energy dissipated during the impact, the damage or deformation must be examined and then related to speed. To affect this, one considers the energy required to create the observed changes in state of the motorcycle and the OV, including changes in the positions and speeds of the vehicles during the impact, bending and breaking of various parts and structures on both vehicles, as well as damage to the occupants and surroundings.

Combining the crash phase energy dissipation with kinematic and dynamic equations for vehicle motions allows for the evaluation of the speeds throughout the event. Speeds calculated from this approach, which is founded and based in engineering principles, establishes to a reasonable degree of engineering certainty the range of values calculated for the initial and impact speeds of the motorcycle.

During an impact, energy is dissipated resulting in damage to deformed structures. Whenever a material is permanently deformed, whether it only bends or is deformed until it fractures, the energy required to effect this damage can be characterized by the area under a force-deflection curve for the loading environment that occurred. In order to determine the force-deflection characteristics and associated dissipated energy, the analyst has several possible approaches. Either a full scale crash test or smaller scale exemplar component tests under similar loading conditions can be performed, or a full dynamic FEM (Finite Element Model) or lumped-parameter model can be developed and utilized. Other analytical techniques to be presented here can also be employed.

This current research presents a full scale dynamic crash test of a motorcycle into a panel delivery van. Damage energy is quantified due to known impact speeds along with response measured with instrumentation. Also presented here is an example of a pendulum impact test to determine the dynamic loading behavior of a motorcycle fuel tank impacting a truck tire and wheel. The test successfully duplicated a damage pattern and extent of deformation as seen on an actual accident motorcycle and allowed the dissipated energy to be quantified. The authors have performed similar small scale pendulum tests on handlebars, other motorcycle components, and OV components such as vehicle body panels and have found replicating damage to be a reliable (accurate and repeatable) method to quantify energy dissipation. The advantage of this type of testing is that engineering assumptions are minimized and tests can be repeatedly performed until the damage extent matches. Using vehicle components, rather than full scale vehicle crash tests in an established test facility, allows cost and complexity to be controlled.

Robust techniques, such as FEM or lumped-parameter modeling, are capable of yielding accurate results too, however, they require significant engineering resources. A simplified analytical approach, presented here, recognizes that dissipated energy can be characterized as the area under the stress-strain curve for the material being deformed/damaged and the volume of material involved in the deformation [4]. The energy required to take a material to fracture is captured in a material property, the *Modulus of Toughness* [4]. References interpret the modulus of toughness variously as the work done per unit volume, the ability to absorb energy, or the energy required to bring a material to failure. Units for the Modulus of Toughness are force per area, such as Pascals or PSI (pounds per square inch). Heuristically, one can see that the product of modulus of toughness and volume have units of N-m or foot-pounds which is an energy value. The equation for the dissipated energy for a fracture, E_{af}, is simply the following:

$$E_{af} = (\text{Modulus of Toughness})*(\text{Volume}) \tag{1}$$

The modulus of toughness is calculated as the area under the stress-strain curve up to fracture. An example calculation is given in an appendix. Typical values for the modulus of toughness for aluminum and steel are: 55-65 MPa and 95-105 MPa, respectively. If a part does not fracture but only permanently deforms, then the energy absorbed can be approximated from the area under the stress-strain curve up to the strain associated with the deformation. If the stress-strain relationship follows the model predicted by the Modulus of Toughness for the material under study, then the dissipated energy is approximated by using the product of the modulus of toughness and a reduced volume (see appendices for sample calculations) to account for the fact that the material did not dissipate energy all the way to fracture. This is shown below for the energy dissipated in a deformation, E_{ad}:

$$E_{ad} = \text{(Modulus of Toughness)*(Reduced Volume)} \quad (2)$$

Whether component tests are performed or calculations made, the total dissipated energy can be determined for all of the damaged parts on the motorcycle and OV and summed to obtain a total energy. This energy summation can include component energy determination from testing or analytical models (or a combination of both methods):

$$E_{Total} = \Sigma(E_{af})_{\text{Each Part}}\ \text{Fractured} + \Sigma(E_{ad})_{\text{Each Part Deformed}} \quad (3)$$

For the case of a large relative mass OV such as a heavy truck, the motorcycle change of speed associated with the impact, Δv, can be calculated by equating the kinetic energy with the dissipated energy:

$$½m(\Delta v)2 = ETotal,\ \text{or} \quad (4)$$

$$\Delta v = \sqrt{2E_{Total}/m}, \quad (5)$$

where m is the total mass of the motorcycle and rider(s) [if the riders are well coupled with the motorcycle during the impact], and gear. The authors caution that for a crash involving a passenger vehicle and a motorcycle, particularly with a larger touring style motorcycle, Equation 4 must be applied with care as the OV has its own, not negligible, speed change that is accounted for in a control volume energy analysis.

One of the uncertainties associated with this analytical approach is the volume involved in the deformation and/or fracture. This uncertainty is controlled by careful observation and measurement of the vehicles following an accident. Due to the 3-dimensional nature and complexity of the structures, it is recommended to utilize a range rather than a single value for volume. One approach to address this uncertainty in the calculations is to use a Monte Carlo analysis [5]. The reconstructionist provides reasonable ranges associated with the volumes, and also the material properties if desired, and makes the energy and speed calculations numerous times by randomly selecting values from the volume and property ranges. The statistics associated with the distribution of change in speed resulting from this Monte Carlo approach converge on solution and define a confidence interval. The approach is summarized in the following steps.

1. Estimate the volumes associated with the damage as a range with upper and lower values and assume a uniform probability of selecting volumes between those values.

2. Determine the material being deformed and/or fractured for each respective analyzed component and determine a range for the modulus of toughness for the respective material for each component (from reference information and/or stress-strain data), again assuming a uniform probability of values within the range. Conducting staged stress-strain, or force-deflection tests of the components under study, under similar load path and load surface conditions, can provide improved representations and/or validation of the deformation energy or energies.

3. Determine energy associated with each damaged area using test data developed or calculations from equations (1) or (2) depending upon whether the damage is a fracture or deformation.

4. Calculate the total energy associated with the impact using equation (3).

5. If the OV has significant mass as to have negligibly small Delta V (change in speed), then calculate the motorcycle change in speed, Δv, due to the impact from equation (5).

6. Repeat steps 3 through 5 until sufficient replications are made such that a reasonable statistical conclusion can be made. Often a 95% confidence interval is a good choice. (Since these equations can easily be set up in a spreadsheet it is not unreasonable to do 100 or more replications.)

This approach is illustrated in the following section for a full-scale experimental test, an example, and two field studies. A component part experimental test is also presented.

Results

Full-Scale Experimental Test: Collision of Middle Weight Motorcycle and Medium Duty Panel Truck

A controlled experimental crash was performed with a middle weight motorcycle (2004 Harley-Davidson Sportster XL 883) and crash dummy released from a sled into the side of a panel truck (a two-axle rear wheel drive medium duty delivery van with a 1995 Oshkosh MT/Commercial AFT Medium Duty, Model MT14FD-U, chassis). The speed of impact was 80.5 km/hr or 50 miles/hr. Figures 1-5 show interaction and post-crash conditions.

Figure 1. Interaction of the motorcycle, rider and crash partner at initial contact, maximum crush and at rest.

Figure 2. Interaction of the motorcycle, rider and crash partner at maximum crush.

Figure 3. The post-crash rest positions.

Figure 4. Deformation to the motorcycle.

Figure 5. Deformation to the crash partner.

Table 1 and Figure 5 show the results of the analysis for this test.

Table 1. Energy (kN-m) and percent of total energy attributed to each damage in experimental tests.

Location	Energy (kN-m)	% Total
1. Wheel	0.06	0.37 %
2. Left Fork Fracture	3.54	20.64 %
3. Right Fork Fracture	3.52	20.52 %
4. Gas Tank Dents (Deep)	4.32	25.14 %
5. Gas Tank Dents (Shallow)	1.53	8.92 %
6. Gas Cap	0.11	0.66 %
7. Light	0.03	0.20 %
8. Left Mirror	0.02	0.10 %
9. Right Mirror	0.02	0.10 %
10. Brake Control	0.02	0.12 %
11. Fender	3.99	23.24 %
Total:	17.17	100.00 %

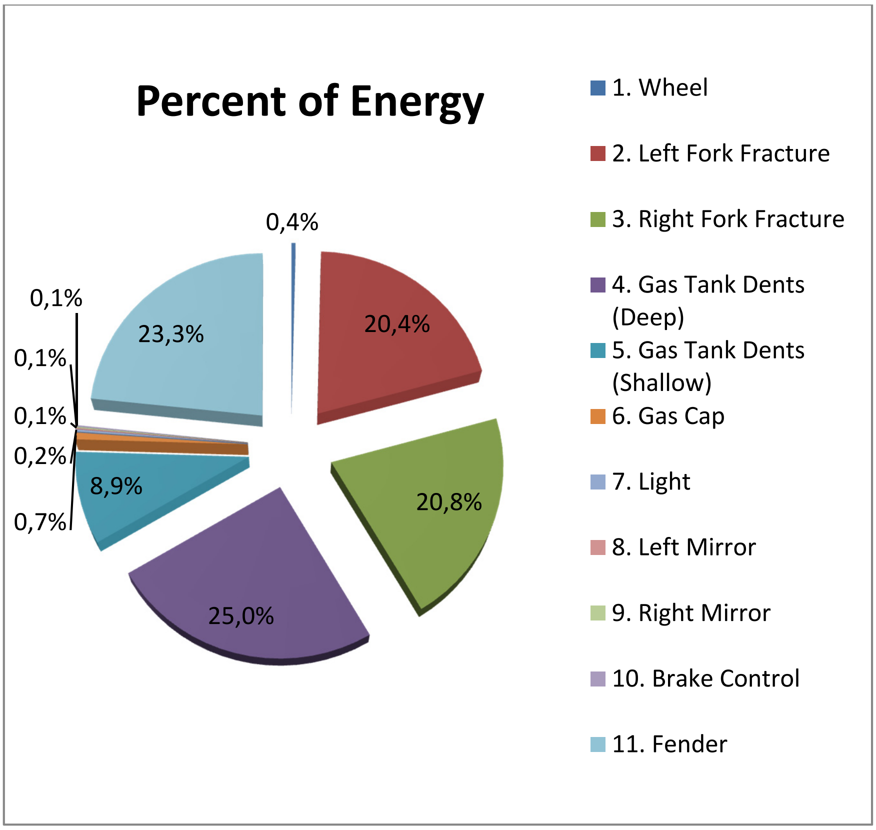

Figure 6. Percent of total energy attributed to each damage in experimental test.

This energy relates to a change in speed of approximately 69-71 km/hr or 43-44 miles/hr. The speed right before impact for the motorcycle was measured during the test at approximately 51 mph. The difference can be explained by energies not accounted for in the calculated value. In order to determine the speed before impact analytically additional energies can be accounted for, including: 1) movement of the truck, 2) movement of the suspension of the truck, 3) yaw of truck, and 4) energy lost in other metal damage, noise and ejected parts (although some are negligibly small).

Component Part Experimental Test:
Motorcycle Fuel Tank and Truck Wheel Impact

A collision occurred where a motorcycle 'high sided' resulting in the motorcycle upper surface (handlebar, tank, seat) impacting a truck wheel. The collision energy was primarily dissipated by deformation to the fuel tank.

Figure 7. Impacted truck and motorcycle tank damage.

Two pendulum impact tests (16 kph and 12.8 kph) were performed in order to match the damage extent measured on an accident vehicle. Pendulum mass matched the subject motorcycle that impacted the truck. Acceleration was measured and using pendulum mass, the collision force was derived and compared to the pendulum displacement during the impact. The resulting collision force versus displacement was integrated for dissipated energy versus displacement. Repeatability between the tests was verified. The damage extent was closely matched by the 12.8 kph test which corresponded to a dissipated energy of approximately 1100 N-m.

Figure 8. Test setup for 12.8kph Test.

Figure 9. Test Tank Damage for Both Tests. Grey Tank was tested at 12.8 kph. Blue tank was tested at 16 kph.

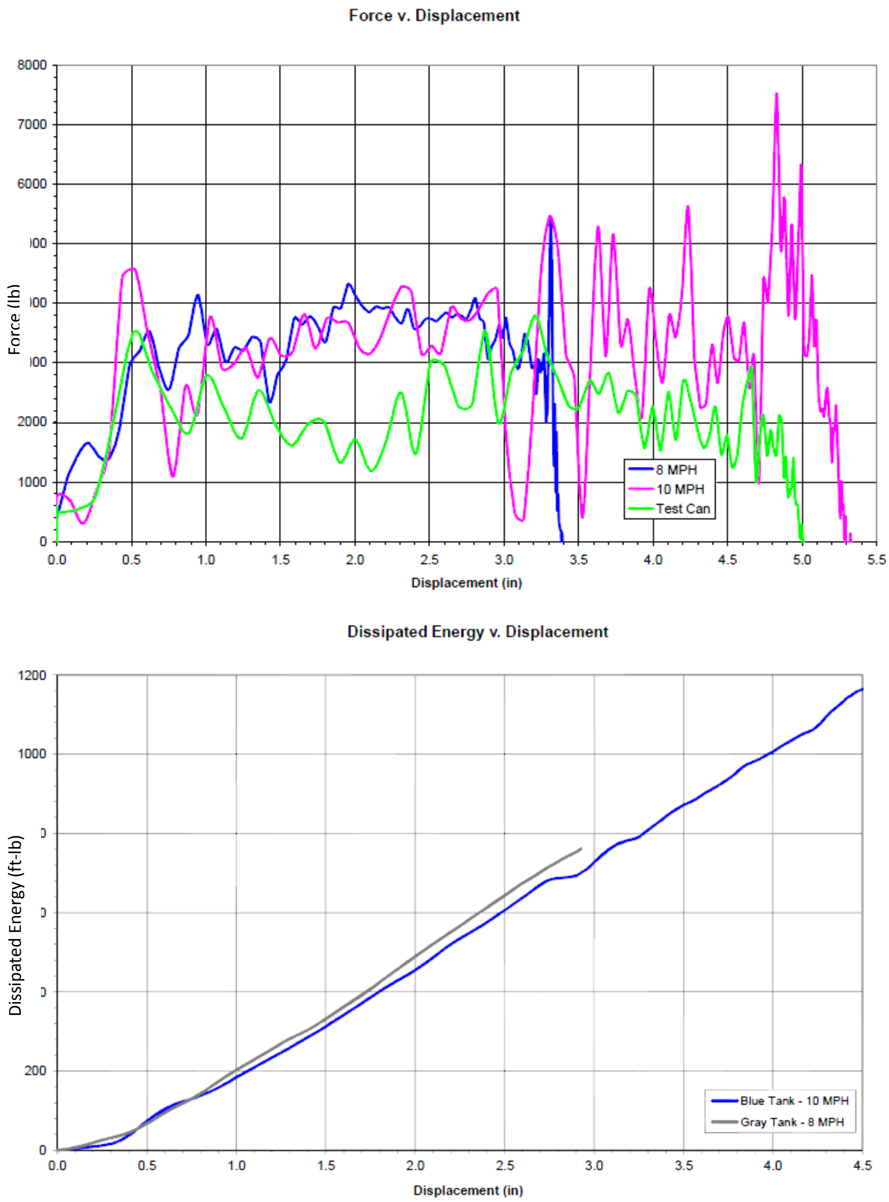

Figure 10. Component test force versus deflection and energy versus deflection graphs.

Example Calculation: Collision of Motorcycle and Panel

Consider a motorcycle crashing into an aluminum panel that is both broken and dented. Of the 0.1 m^3 volume damaged on the panel, 30% is broken and 70% is dented to within 50% of fracture. The motorcycle has a broken steel frame (volume of $5X10^{-6}$ m^3) and a dented steel gas tank (volume $2X10^{-5}$ m^3) which is estimated to be 65% to fracture. Modulus of toughness for aluminum is 60 MPa and for steel is 100 MPa. Table 2 shows the calculations.

Table 2. Energy (kN-m) and percent of total energy attributed to each damage in example.

Location	Volume (m^3)	Multiplier for Reduced Volume	Modulus of Toughness (MPa)	Energy (kN-m)	% Total
Truck Panel Broken	0.00012	0.3	60	2.16	15.6%
Truck Panel Deformed	0.00024	0.7(0.5)	60	5.40	39.0%
Broken Frame	0.00005	1	100	5.00	36.1%
Gas Tank Dent	0.00002	0.65	100	1.30	9.4%
			Total:	13.86	100.0%

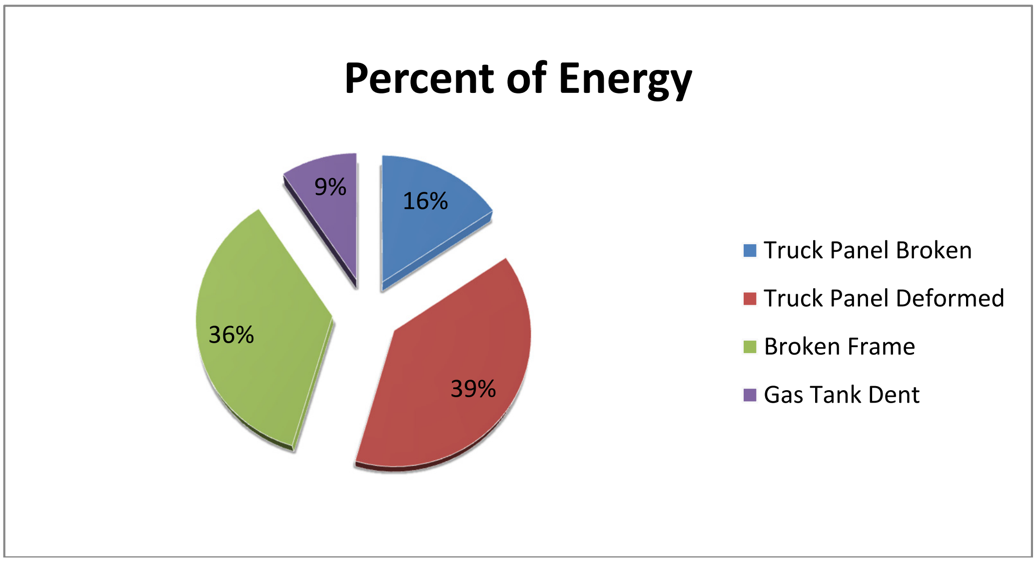

Figure 11. Percent of total energy attributed to each damage in example.

Field Analysis 1: Collision of Motorcycle and Semi-trailer Truck

The results of the approach are shown below for a field analysis. In this case, a spreadsheet was established that provided a range on the volumes associated with several damaged regions on the motorcycle and the large truck, a range of moduli of toughness were used for aluminum and steel, and the results were determined for 100 replications. The energy and percent of energy attributed to each damaged object are shown in Table 3 and Figure 12.

Table 3. Energy (kN-m) and percent of total energy attributed to each damage in field analysis 1.

Location	Energy (kN-m)	% Total
1. Right Fork upper Fracture	0.71	5.02%
2. Right Fork lower Fracture	0.25	1.79%
3. Right Front Wheel	1.94	13.75%
4. Brake Disc	1.07	7.58%
5. Right lower Frame	1.01	7.16%
6. Right upper Frame	0.41	2.92%
7. Left Front Wheel	3.29	23.29%
8. Left Fork Bend	0.95	6.69%
9. Gas Tank Dents	1.36	2.55%
10. Left Small Part	0.01	0.02%
11. Truck Foot	4.13	29.24%
Total:	14.14	100.00%

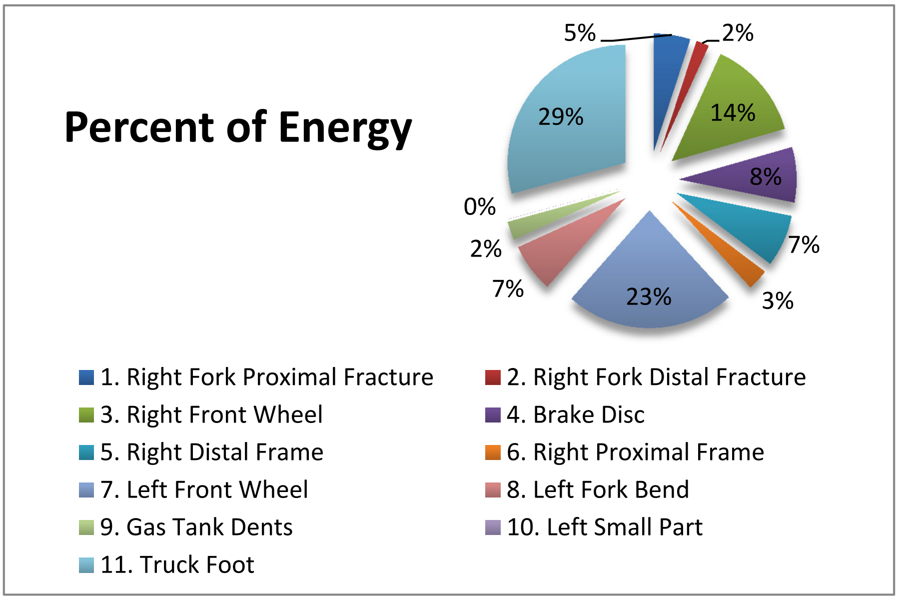

Figure 12. Percent of total energy attributed to each damage in field analysis 1.

For over 100 replications, the 95% confidence interval on the change in speed as a result of the impact was: 63-64 km/hr or 39-40 miles/hr.

Note, the analyst can evaluate when enough replications have been completed by examining a running average of the total energy and observing when this average stabilizes. This is shown in Figure 13.

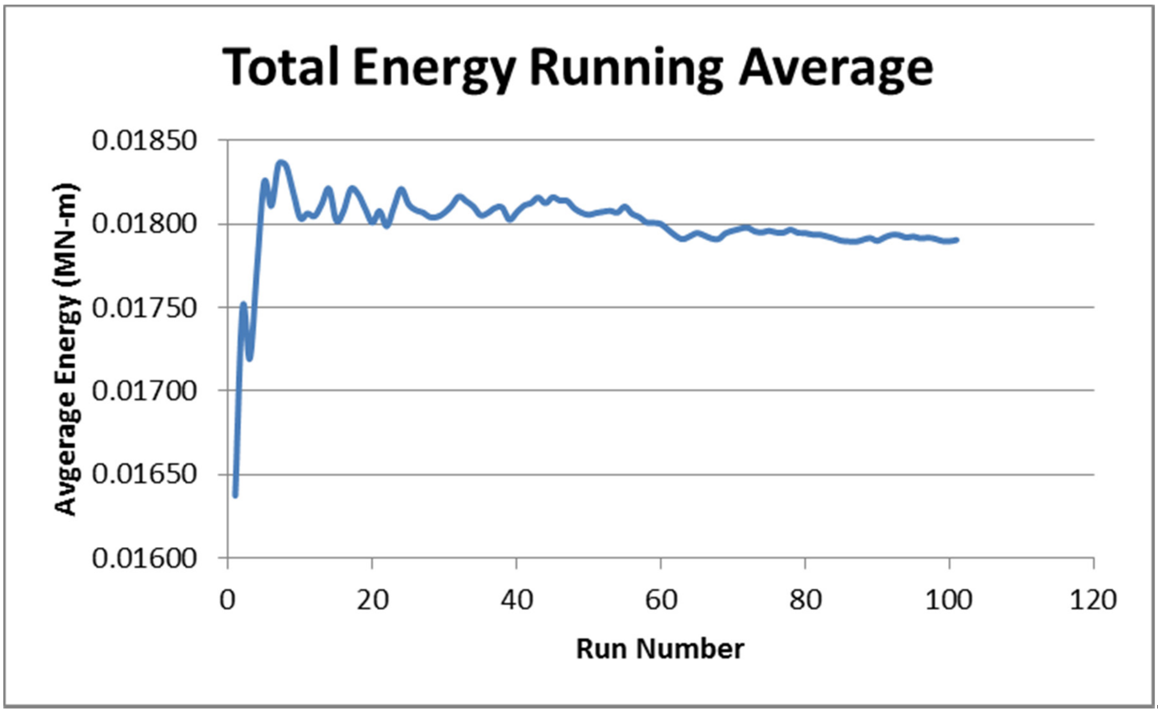

Figure 13. Running average of total energy (MN-m).

Note also that using the results of Wood et al. [2], for a motorcycle of this size, and damage similar to this, would result in an energy range of 11,350 N-m to 34,050 N-m. This analysis obtained 14,140 N-m (see "total" row in Table 4) which falls within Wood's range.

Field Analysis 2: Collision of motorcycle and Panel Vehicle

In this case like the previous, the primary damage to the motorcycle included more than a shortening of the wheelbase such as a broken frame and damaged gas tank so Wood et al's results could not be relied upon for the total energy absorbed by the motorcycle.

Table 4. *Energy (kN-m) and percent of total energy attributed to each damage in field analysis 2.*

Location	Low Energy (kN-m)	% Total	High Energy (kN-m)	% Total
Truck Panel	11.6	11.9%	23.3	11.6%
Truck Beam	8.5	8.7%	15.6	7.8%
Fork	9.8	10.1%	14.7	7.3%
Broken Frame	25	25.7%	100	49.9%
Gas Tank	36.7	37.7%	40.4	20.2%
Front Peg	0.7	0.7%	0.8	0.4%
Wheel Rim	5.1	5.2%	5.6	2.8%
Total:	97.4	100.0%	200.4	100.0%

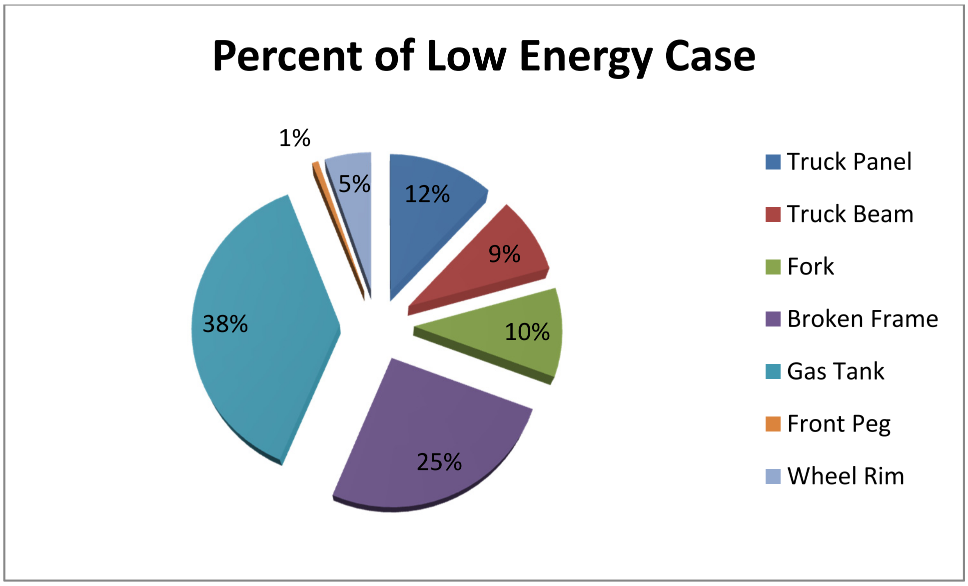

Figure 14. Percent of total energy attributed to each damage in field analysis 2 for low energy case in Table 4.

In this case, the speed change range resulting from the impact was 75-107 km/hr or 47-67 miles/hr.

Conclusion

As set forth herein, calculating energy dissipation resulting from impact damage can be evaluated by applying known strength of materials equations and/or testing. This energy can be related to a change in speed as a result of the impact. Combining the dissipated energy with pre-impact and post-impact dynamics analysis allows for the evaluation of speeds at earlier points in the event cycle. Careful application of this method is consistent with the testing evaluated as well as calculations obtained by other methods (energy related to motorcycle wheelbase shortening), such as those by Wood et al. [2].

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Appendices

Procedure for velocity determination from impact damage

The following is a general procedure for determining impact speed.

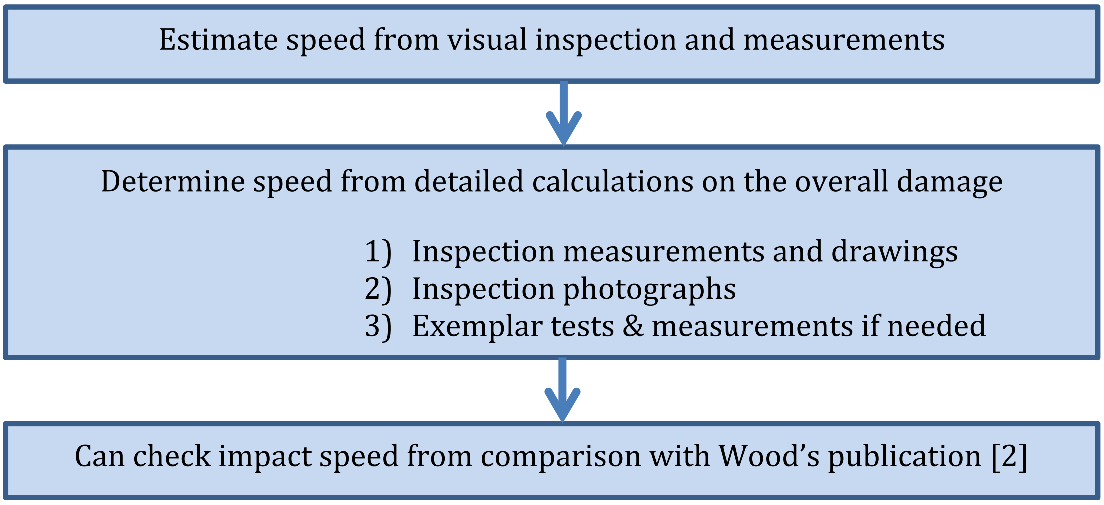

Figure A.1. General flow chart for determining speed.

Simple example for determining the modulus of toughness

Consider a sample of aluminum that has the simplified stress-strain data shown in Table A.1.

Table A.1. Simplified stress-strain data for an aluminum sample.

Strain (m/m)	Stress (MPa)
0.00	0
0.01	150
0.10	250
0.21	275
0.25	240

Using simple graphical integration as shown below with trapezoids one obtains a modulus of toughness of 58 MPa.

$$\begin{aligned}\text{Modulus of Toughness} = \; & \tfrac{1}{2}(0.01)(150 \text{ MPa}) + \tfrac{1}{2}(250 + 150)(0.10 - 0.01) \text{ MPa} \\ & + \tfrac{1}{2}(250 + 275)(0.21 - 0.10) \text{ MPa} \\ & + \tfrac{1}{2}(240 + 275)(0.25 - 0.21) \text{ MPa} = 58 \text{ MPa}\end{aligned}$$

Example determination of volume reduction factor for dent in metal that is approximately circular

Consider a dent that is reasonably circular with radius, R, is in a thin sheet having a thickness, t, and modulus of toughness, M_T. Further assume that the dent is sufficiently deep so that material at the center of the dent is just at the point of fracture and material at the extreme edge of the dent is just beginning to elastically deform. Material between these two extremes is modeled as following an r-squared distribution of deformation as a function of radius, r, from the center of the dent.

One way to calculate energy is through the product of the entire volume (nominal volume), the modulus of toughness, and the volume reduction factor. This energy is described by the following equation:

$$\text{Energy}_1 = (\text{Volume})(\text{Modulus of Toughness})(\text{Volume Reduction Factor}) = V(M_T)f \quad (A.1)$$

where,

V = nominal volume of the metal involved in the dent, $\pi R^2 t$ (m^3),
M_T = Modulus of Toughness of the material (N/m^2), and
F = multiplier for reduced volume (no units).

The energy can be more exactly calculated as an integral considering the distribution of the deformation throughout the dent:

$$\text{Energy}_2 = \int_0^R (2\pi r t)(M_T)\left(\frac{R-r}{R}\right)^2 dr, \text{ or} \quad (A.2)$$

$$\text{Energy}_2 = (2\pi t)(M_T)\int_0^R r\left(\frac{R-r}{R}\right)^2 dr. \quad (A.3)$$

After completing the integration this becomes:

$$\text{Energy}_2 = \left(\frac{1}{6}\pi R^2 t M_T\right). \quad (A.4)$$

Set the two energies equal to one another to obtain:

$$VM_T f = \left(\frac{1}{6}\pi R^2 t M_T\right). \quad (A.5)$$

The nominal volume of the material involved, V, is:

$$V = \pi R^2 t, \quad (A.6)$$

therefore, the volume reduction factor, f, is 1/6. Note, that this is an absolute minimum value as an r-squared distribution yields a low reduction factor and is approximately half of what would result from a linear distribution model.

Example determination of volume reduction factor for bent metal rod with circular cross section

Consider a component that is modeled as a metal rod with circular cross section having diameter, d_0, and length, *l*, and is made from a material having a modulus of toughness M_T. Further consider that the rod is bent but not fractured.

One way to calculate energy is through deflection formulas. Deflection of a cantilevered rod subjected to a load, W, at the endpoint, *l*, is [6]:

$$\delta = Wl^3/3EI, \quad \text{(A.7)}$$

where,

δ	= the deflection (m),
W	= load (N),
l	= length (m),
E	= modulus of elasticity (Young's Modulus) (N/m^2), and
I	= moment of inertia (m^4).

Solving for the force, W, one obtains:

$$W = 3EI\delta/l^3. \quad \text{(A.8)}$$

The energy associated with this deflection is given by the product of force and deflection, Wδ, thus:

$$Energy_3 = W\delta = 3EI\delta^2/l^3. \quad \text{(A.9)}$$

If an analyst desires to calculate the energies using the same approach for all of the different damaged components, the energies can be determined alternatively using the modulus of toughness approach. Energy is equivalent to the product of nominal volume involved, V, the modulus of toughness, M_T, and the volume reduction factor, f. Mathematically, this was given in equation (A.1). Note that volume for the cantilevered rod can be expressed as the product of the rod's cross-sectional area, A, and length of material involved, x:

$Energy_4$ = (Volume)(Modulus of Toughness)(Volume Reduction Factor)

$= V(M_T)f$

$= (Ax)(M_T)f.$ (A.10)

Equating $Energy_3$ and $Energy_4$, equations (A.9) and (A.10), respectively, and solving for the volume reduction factor, f, one obtains:

$$f = 3EI\delta^2/[(Ax)(M_T)l^3]. \quad \text{(A.11)}$$

As an example, consider a steel rod with the following dimensions and material properties and note that the cross-sectional area is $\pi/4(d_0)^2$ and the moment of inertia is $\pi/64(d_0)^4$ for a rod with circular cross section:

$$\text{Diameter } (d_0) = 3.81 \text{ cm } (1.5 \text{ in}), \quad \text{(A.12)}$$

$$\text{Deflection } (\delta) = 5.08 \text{ or } 6.35 \text{ cm } (2 \text{ or } 2.5 \text{ in}), \quad \text{(A.13)}$$

$$\text{Length } (l) = 45.7 \text{ cm } (18 \text{ in}), \quad \text{(A.14)}$$

$$\text{Modulus of Elasticity (E)} = 207 \text{ MPa } (30X10^6 \text{ lb}_f/\text{in}^2), \quad \text{(A.15)}$$

$$\text{Modulus of Toughness } (M_T) = 100 \text{ MPa } (14{,}500 \text{ lb}_f/\text{in}^2), \text{ and} \quad \text{(A.16)}$$

$$x = kl, \quad \text{(A.17)}$$

where,

k = fraction of the length associated with the damage, $0 \le k \le 1$.

Table A.2. Volume reduction factor, f, from equation (A.11) for example beam for various values of deflection, δ, and fraction of length, k, associated with damage.

		Fraction of Length Associated with Damage		
		0.06	0.08	0.10
δ (cm)	5.08	0.55	0.42	0.33
	6.35	0.87	0.65	0.53

Table A.2 illustrates for this example beam that there are bending conditions and choices of nominal volume that produce volume reduction factors between zero and one. Note that the reduction factor should always be between zero and one; thus, if equation (A.11) were to produce a result greater than one, then it simply indicates that the beam was at fracture point and the reduction factor should be one (in a case where the reduction factor is very close to one), or that too little nominal volume has been associated with the damage.

Analysis of the accident scenario of powered two-wheelers on the basis of real accidents

Analyse des Verkehrsunfallgeschehens motorisierter Zweiräder auf Basis von Realunfällen

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Abstract

For the first time since 20 years the German national statistics of traffic accidents revealed an increasing number of fatalities and seriously injured persons in 2011. This negative development was especially caused by increasing numbers in all groups of vulnerable road users (VRU). Furthermore, the comparison of fatality reduction rates between several categories of road users shows that persons on motorcycles show the worst performance over years. Although every second fatality in German traffic accidents is still a car occupant, users of PTW make up around 20% in the meantime. Assuming further improvements in the field of car occupant protection this trend will continue.

For that reason, a study on the basis of real-world accidents was conducted to describe the accident scenario involving motorcycles and to identify the reasons of the above-described fact. Approximately 1.800 motorcycle accidents out of GIDAS database were used for the analyses.

The first part of the study deals with the question how representative the GIDAS database is for the German motorcycle accident scenario. Afterwards, detailed descriptive statistics on motorcycle accidents were presented considering numerous parameters about the accident scene, environmental influences, vehicle information, individual characteristics, interview data, injury severity and injury causation. One important point is the identification of the most frequent critical situations that are typical for motorcycle accidents. Furthermore, a special focus was on accident causation. Finally, conspicuous facts out of the analysis are emphasized.

All in all, the study gives a comprehensive overview about the German motorcycle accident scenario. One the one hand, the use of weighted GIDAS data allows representative and robust statements on the basis of large case numbers; on the other hand highly detailed conclusions can be drawn. The results of the study help to understand the particularities of motorcycle accidents and provide approaches for further improvements in the field of PTW safety.

Analysis of the accident scenario of powered two-wheelers on the basis of real accidents

Motivation

In 2011 the positive trend of decreasing road fatalities in Germany was stopped for the first time since twenty years. This negative development was especially caused by increasing numbers of fatally injured pedestrians and users of powered two-wheelers (PTW). Motorcyclists showed the second highest increase rate of fatalities. On average, around two motorcyclists were killed in traffic in Germany every day. Current figures from 2013 reconfirm this trend. Users of PTW (motorbikes and mopeds) showed the smallest decrease of fatalities and strengthened their position as the second largest group of fatalities. Table 1 shows current figures of the German national traffic accident statistics from 2013.

Table 1. Type of fatally injured road users (Germany, 2010-2011, DESTATIS)

	Rank 2013	Fatalities 2012	Fatalities 2013	Proportion 2012	Proportion 2013
Car occupants	1	1.791	1.588	49,8%	47,6%
PTW users	***2***	***679***	***641***	***18,9%***	***19,2%***
Pedestrians	3	520	557	14,4%	16,7%
Cyclists	4	406	354	11,3%	10,6%
Truck occupants	5	152	147	4,2%	4,4%
(Others)		(52)	(52)	1,4%	1,6%
TOTAL		**3.600**	**3.339**		

Users of PTW represent the second largest group of fatally injured road users in Germany. Although nearly every second fatality in German traffic accidents is still a car occupant, users of PTW make up around 20% in the meantime. Assuming further improvements in the field of occupant protection this trend will continue and the proportion of motorcyclists will further increase (Figure 1).

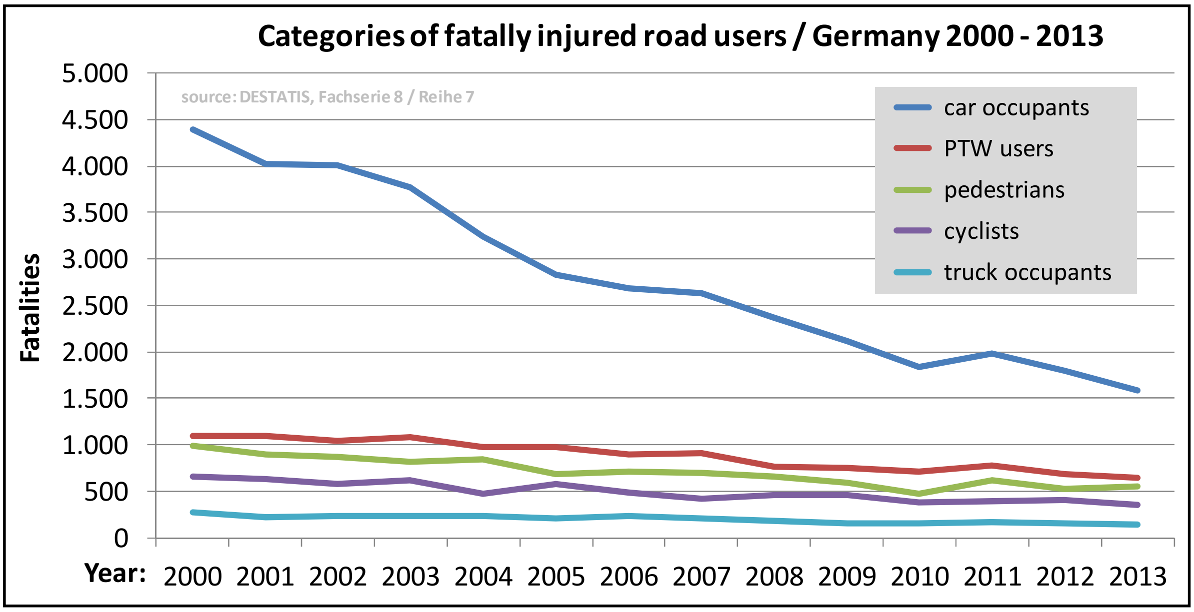


Figure 1. Type of fatally injured road users (Germany, 2000-2013)

The comparison of the fatality reduction rates between several categories of road users shows that motorcyclists show the worst performance over years (Figure 2).

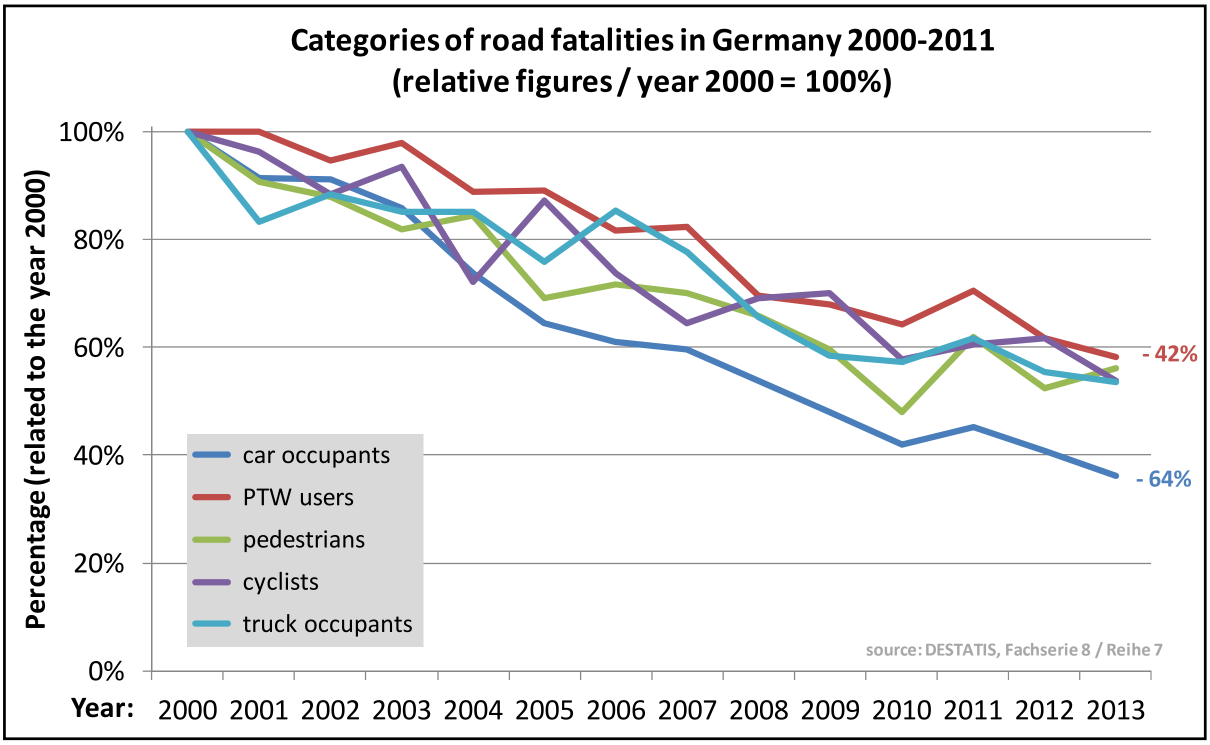


Figure 2. Development of road fatalities in Germany (relative)

Considering that the numbers of motorcycles is increasing over years it can be assumed that the relevance of accidents involving PTW will also increase in future.

In addition PTW users and the related accident scenario have some particularities that differ from other groups of road users.

This study was performed to learn more about the accident scenario of motorcycles and to understand the particularities of their accidents. A detailed descriptive statistics on the accidents and the involved vehicles and persons is done, followed by the generation of typical accident scenes.

Dataset

The entire study is based on real accident data out of the GIDAS project (German In-Depth Accident Study). GIDAS is the largest in-depth accident study in Germany and the collected data is very extensive. Due to a well-defined sampling plan, representativeness with respect to the federal statistics is also guaranteed. Since mid-1999, the GIDAS project has collected more than 20.000 on-scene accident cases in the areas of Hanover and Dresden. GIDAS collects data from accidents of all kinds.

Due to the on-scene investigation and the full reconstruction of each accident, it gives a comprehensive view on the individual accident sequences and the accident causation. The project is funded by the Federal Highway Research Institute (BASt) and the German Research Association for Automotive Technology (FAT), a department of the VDA (German Association of the Automotive Industry).

The used version of the GIDAS database contains nearly 20.000 reconstructed accidents.

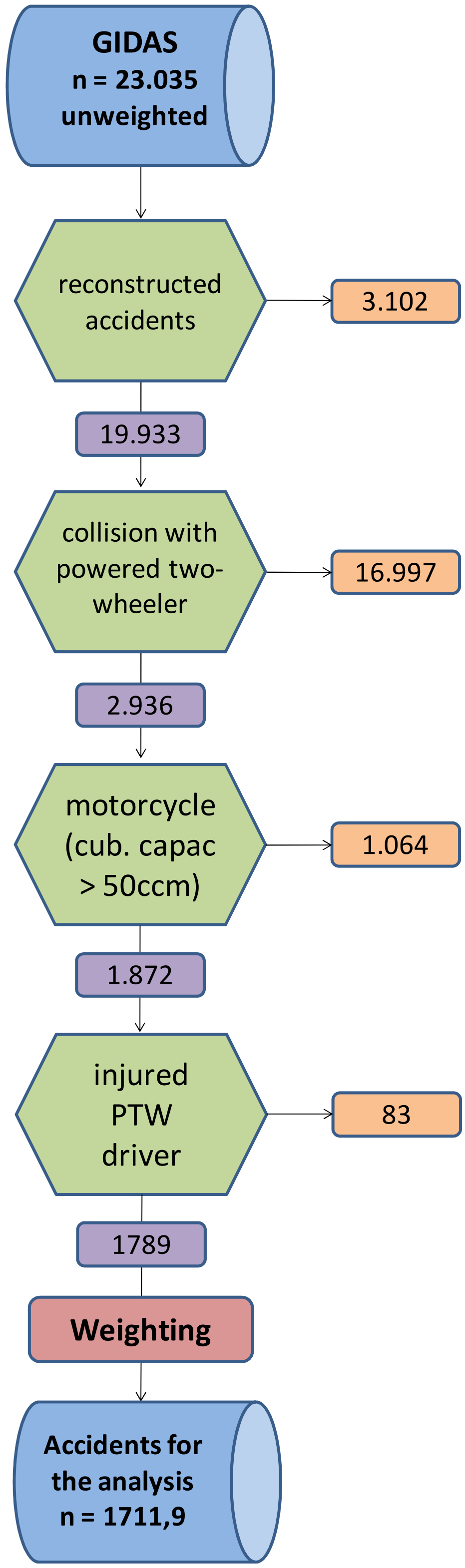
In about 3.000 of them a PTW was involved and had a collision (causers of accidents without collision were excluded from the study).

The next filter criterion for the creation of the master-dataset was the cubic capacity. For the study, only PTW were considered that are liable to registration. Thus, only motorcycles with a cubic capacity with more than 50 ccm have been chosen for the study. Mopeds have been excluded because it is assumed that these vehicles have a different accident scenario.

A total of 1.872 accidents could be identified that meet the filter criteria. At the end, only accidents with injured PTW drivers were considered. Due to the fact that nearly every collision or fall of a PTW leads to injuries the dataset I sonly reduced by some accidents.

Finally, 1.789 accidents out of the GIDAS database are considered for the study. To ensure representative results for the German accident scenario every accident is weighted to the German traffic accident statistics (DESTATIS, 2010). This process may lead to real numbers (1711,9 accidents).

Due to the fact that in some accidents more than one motorcycle is involved and more than one PTW driver is injured there are finally 1.734 persons resp. vehicles in the dataset.



Descriptive Statistics

The use of the GIDAS database and its large variety of encoded parameters enforces researches to do numerous analyses concerning the accident scenario of motorcycles. For the present study, a selection of important parameters was chosen to describe some particularities of motorcycle accidents in Germany.

First of all, the time of motorcycle accidents is analyzed. As expected, the majority of PTW drivers are involved in accidents in summer, spring and autumn (Figure 3). One main reason for this particularity is the weather (low temperatures, snow, and precipitation) during the winter period and the resulting poor road conditions. In Germany, many PTW only have seasonal license numbers.

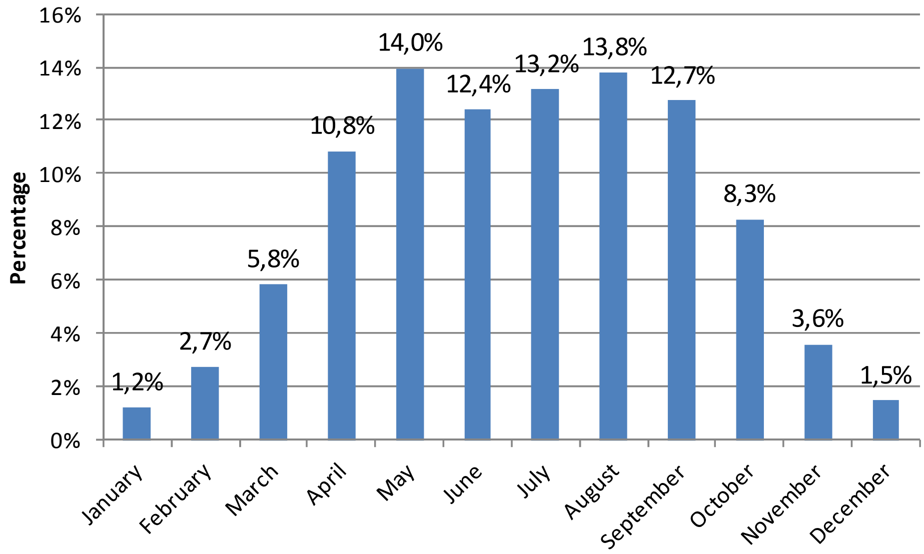


Figure 3. Accident time – Month

Besides some smaller proportions on Saturday (12,3%) and Sunday (12,8%), there are no substantial differences between the days of the week when the accident occurs (maximum on Thursday with 17,0%).

Four out of five accidents with injured motorcyclists occur during daytime (80,6%). Only 7,6% of the considered accidents occur during night.

Looking on the accident scene it can be stated that more than two thirds (68,6%) of motorcycle accidents with injured drivers occur on urban roads.

The kind of accident (Figure 4) shows that nearly one third of the considered accidents are collisions between vehicles that are turning into or crossing a road which is a typical urban situation. The second most frequent kind of accident are accidents of another kind which are mostly single falls on the road without leaving the carriageway.

Collisions with vehicles that are waiting / moving ahead or moving in the same direction are typical scenarios in longitudinal traffic and occur relatively frequent.

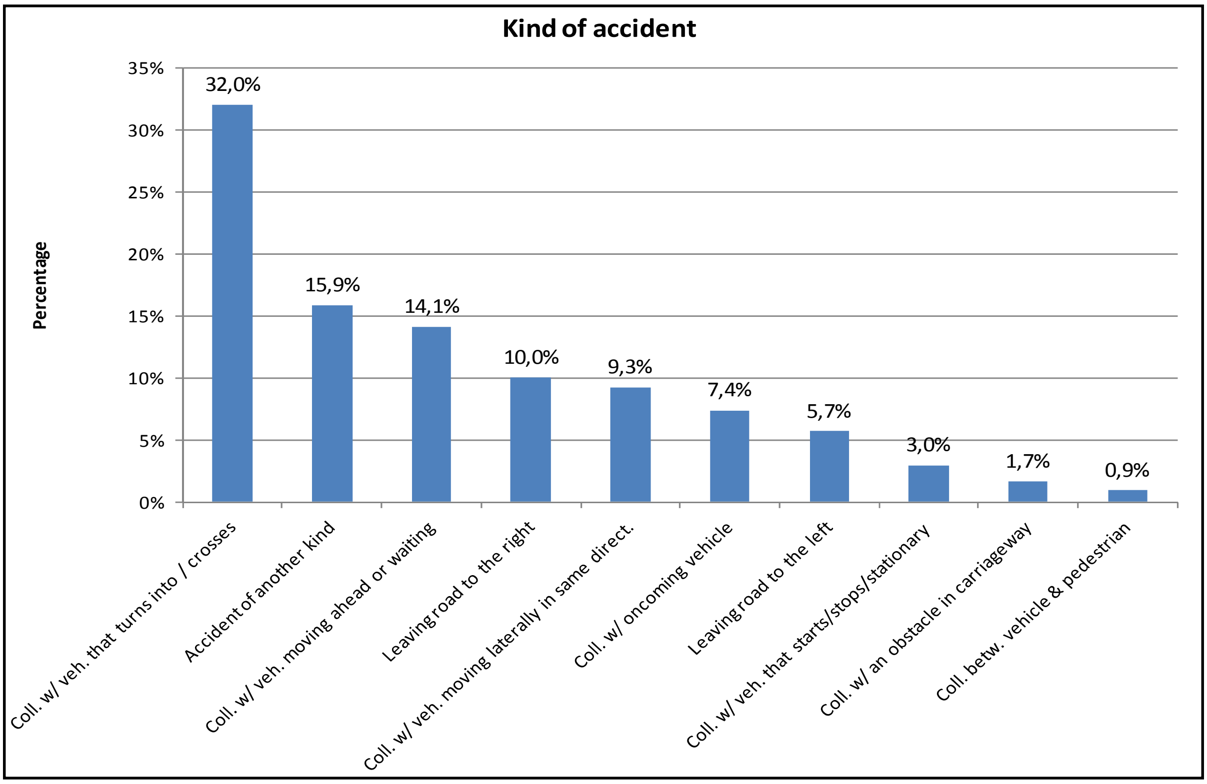


Figure 4. Kind of accident

It can also be seen that leaving the road to the right (10,0%) occurs nearly twice as often as leaving the road to the left side (5,7%). On the one hand the distance between the driving line and the edge of the road is smaller on the right (less space to correct mistakes) and on the other hand a collision with on oncoming vehicle is possible when leaving the own lane to the left (other kind of accident).

Nearly two thirds of the considered cases (64,5%) are accidents between the motorcycle and another participant (passenger car, truck, bus, tram, PTW, bicycle or pedestrian) which correlates with the above shown kind of accident. However, 29% of the cases are single accidents which are mostly loss of control situations.

Accidents with more than two participants are rather seldom (6,9%).

Together with the kind of accident the accident type is of special interest for the characterization of the accident scenario of PTW. The accident type describes the critical situation that caused the accident. Figure 5 shows the seven main categories of accident type for the 1712 analyzed accidents. It can be seen that every fourth accident of a PTW is a driving accident where loss of control played an important role. Turning into/crossing situations and conflicts in the longitudinal traffic each account for 21%. About 18% of the accidents occur during turning off the road.

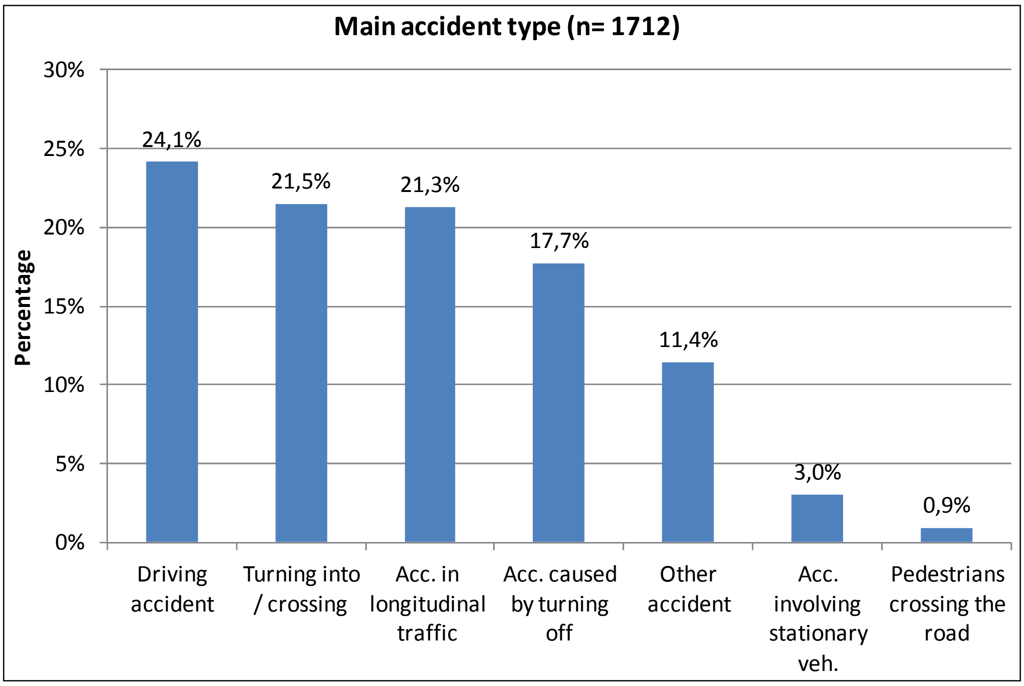


Figure 5. Accident type

To get a better understanding of typical conflicts between PTW and other road users the 10 most frequent single accident types and the role of the motorcycle (participant A = causer / participant B = non-causer / W = give right of way) is shown in Figure 6.

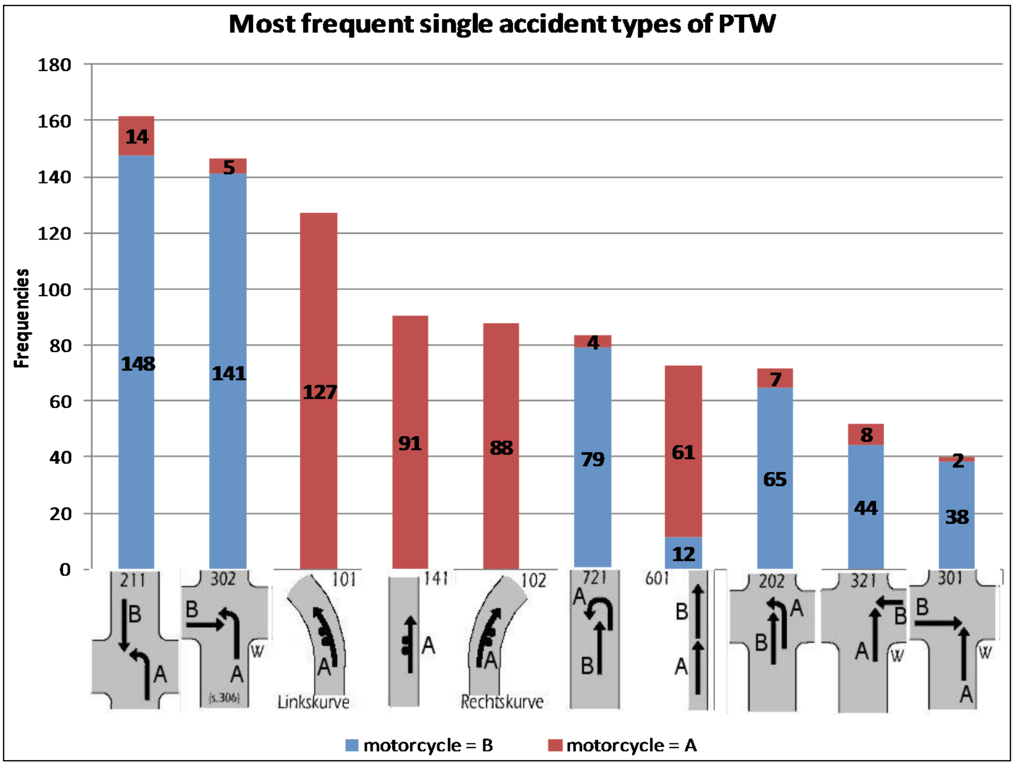


Figure 6. TOP10 single accident types and kind of PTW involvement

It can be seen that the accident type 211 is the most frequent initial situation in motorcycle accidents with injured drivers. It is very interesting that the PTW is nearly always the non-causing vehicle and is obviously overseen by another road user. The same fact can be derived from the accident types 302, 321, and 301 that represent 238 of the 1712 considered accidents (14%). In 94% of these situations there was a violation against the right of way of the PTW. Number 3, 4, and 5 of the ten most frequent accident types are loss of control accidents; the vast majority of these accidents are single accidents without involvement of other road users. Number 6 (721) and 8 (202) of the most frequent accident types are situations where the motorcycle is overtaking and another vehicle is turning on the road or turning into another road. These are particular situations that are often caused due to the fact that the PTW is overseen. Finally there is one frequent accident type in longitudinal traffic (601) where the vast majority is caused by the motorcycle due to appropriate safety distance.

In the next step the vehicle was analyzed. Numerous variables have been considered within the study. Some chosen results are given here:

- Nearly half of all considered PTW (47%) are younger than 5 years.
- Vehicles aged 20 years or more make up 3% in the dataset.
- Concerning engine power there are two obvious peaks within the distribution. The first one is the group up to 10kW (19%) and the second one is between 71 and 80 kW (16%). PTW with more than 100kW make up 6,5%.
- One third of the motorcycles have a cubic capacity between 501 and 750 ccm. Another 30% have more than 750 ccm and about one quarter (23,3%) have a cubic capacity between 81 and 125 ccm.
- The mileage of the most vehicles is below 20.000km (50%). PTW with a mileage of more than 50.000 make up 13% of the dataset.
- Only 5% of the vehicles in the dataset were equipped with ABS. One reason is the GIDAS dataset that contains accidents from 1999 to 2011 and thus, some older vehicles. However, even for newer motorcycles (registered in 2005 or later) the rate is only 17%.
- On 6,5% of the considered motorcycles a second person was on the vehicle.

Furthermore, some facts concerning the accident sequences, the driver behavior and the circumstances are presented:

- About three quarter (77,4%) of the vehicles had one collision and 19% collided two times. There are hardly three or more collisions.
- Every sixth motorcycle was skidding prior to the accident.

- In 84% of the accidents the road was dry. Accidents on damp or wet roads make up 9% resp. 7%. There was hardly any accident on snow/ice (0,2%).

Figure 7 shows the most frequent collision partners of motorcycles. As expected the most frequent collision partners are other vehicles and especially passenger cars which is correlating with the high proportion of accidents in urban areas. The road surface makes up about 30%. This group mostly contains single falls of the motorcyclists in loss of control accidents or accidents where the PTW rider braked too strong as reaction to a critical situation or another vehicle and fell on the road.

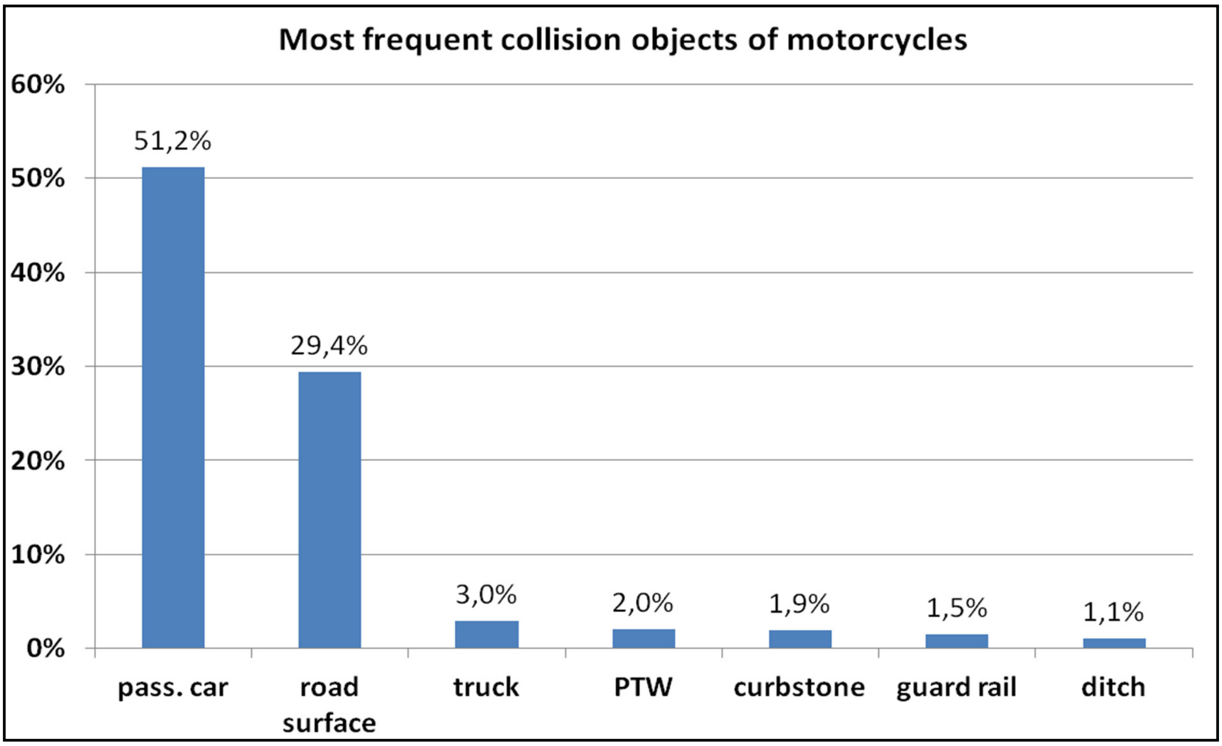


Figure 7. Most frequent collision objects of motorcycles

An important point in PTW accidents is the braking behavior. In general, the majority (72,8%) of motorcyclists is braking prior to the collision. About 40% are braking with more than 5 m/s^2 and less than 7,5 m/s^2 as reaction to the critical situation. Only 5% achieve a braking deceleration above 7,5 m/s^2.

Taking into account the maximum possible deceleration at the accident scene which is mostly determined by the type and condition of the road surface and the tire, the following distribution can be derived from the reconstruction data (Figure 8). It can be seen that only 30% of the drivers brake with more than 80% of the maximum possible deceleration. There seems to be a need of supporting the driver in braking situations. Possible measures for increased braking decelerations may be technical solutions (e.g. ABS) or training of the driver.

By analyzing the interview data of involved motorcyclists it could be stated that motorcyclists that already had a safety training showed slightly higher braking decelerations than riders without any training.

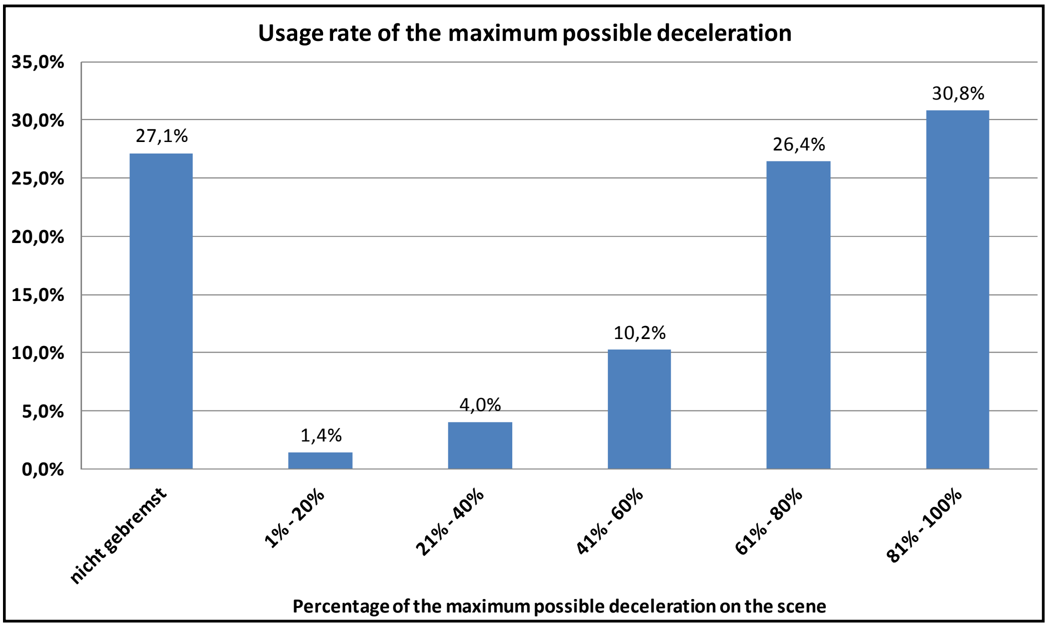


Figure 8. Mean braking deceleration of the motorcycle in PTW accidents

In the dataset the equipment rate of ABS is only 5% which is a result of the dataset (accidents from 1999 to 2011). In general, increasing numbers of vehicles with ABS can be found in GIDAS (although there may be a bias between the actual ABS equipment rate in the entire fleet and the ABS rate in accidents due to already avoided accidents by ABS). Figure 9 shows the ABS equipment rates per year of first registration in GIDAS. About 40% of modern motorcycles (registered since 2008 or later) are already equipped with ABS.

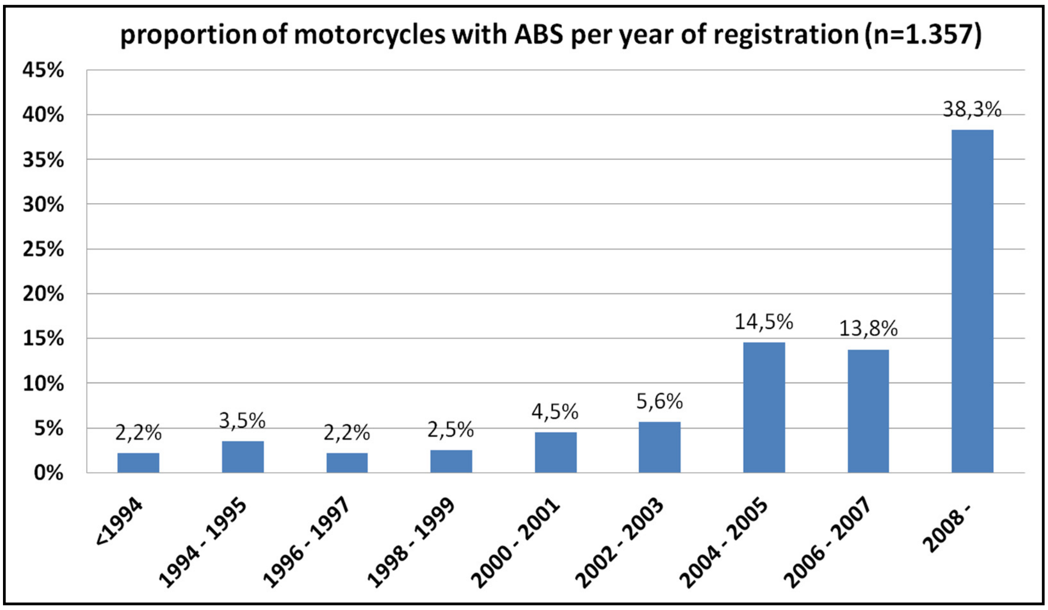


Figure 9. ABS equipment rate per year of first registration in GIDAS

The analyses on personal level showed that motorcyclists represent a very special group of road users. One particularity is the gender distribution. About 91% of the PTW riders in the dataset were male.

Looking on the age distribution it can be seen that – similar to drivers of passenger cars – especially young drivers are involved in accidents. This may correlate with a higher annual mileage of this group. Compared to passenger car drivers there are only few elderly riders involved in accidents which also may be caused by the decreased mileage or frequency of motorcycling in this age group Figure 10.

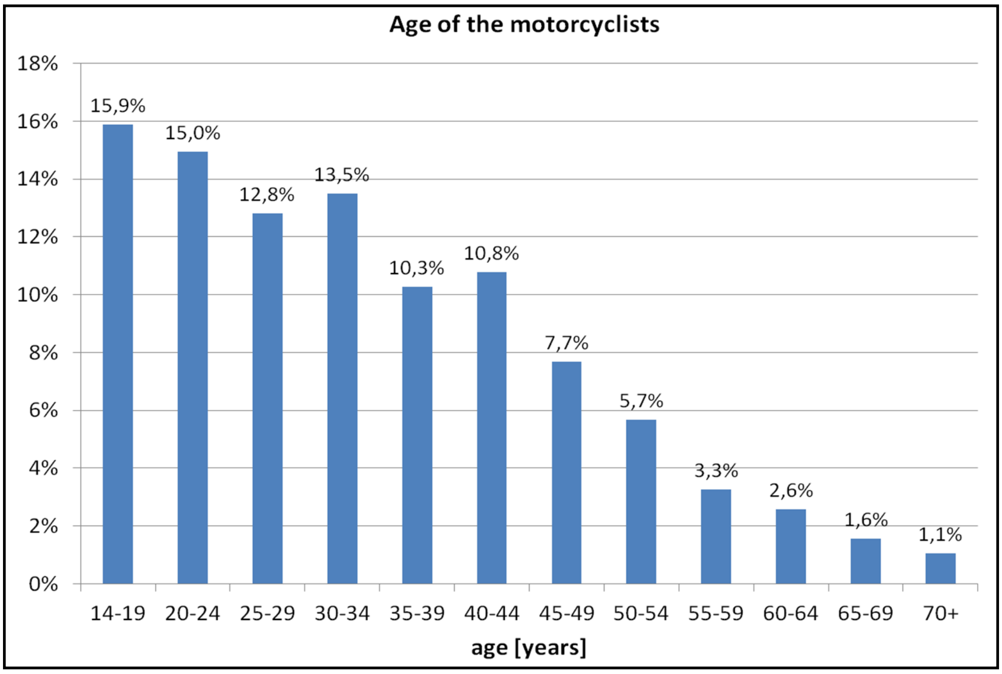


Figure 10. Age distribution of motorcyclists

Looking on the injury severity (official definition) it can be seen that more than two thirds (70,2%) of the motorcyclists were slightly injured (out-patient treatment). About 2% died in the considered accidents, 28% suffered severe injuries.

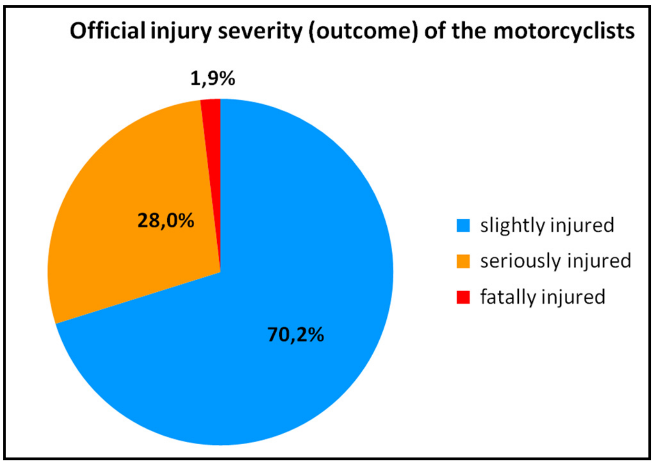


Figure 11. Injury severity according to the official definition

The analysis of the injury severity according to the MAIS gives similar results. For the study, the AIS definition of 1990 Update 1998 was used. About 60% of the riders were MAIS1 injured which correlates relatively well with the proportion of "slightly injured" persons. About 39% of the motorcyclists were MAIS2+ injured; a total of 12% suffered an MAIS3 or more. The proportion of MAIS5+ again correlates well with the fatally injured persons.

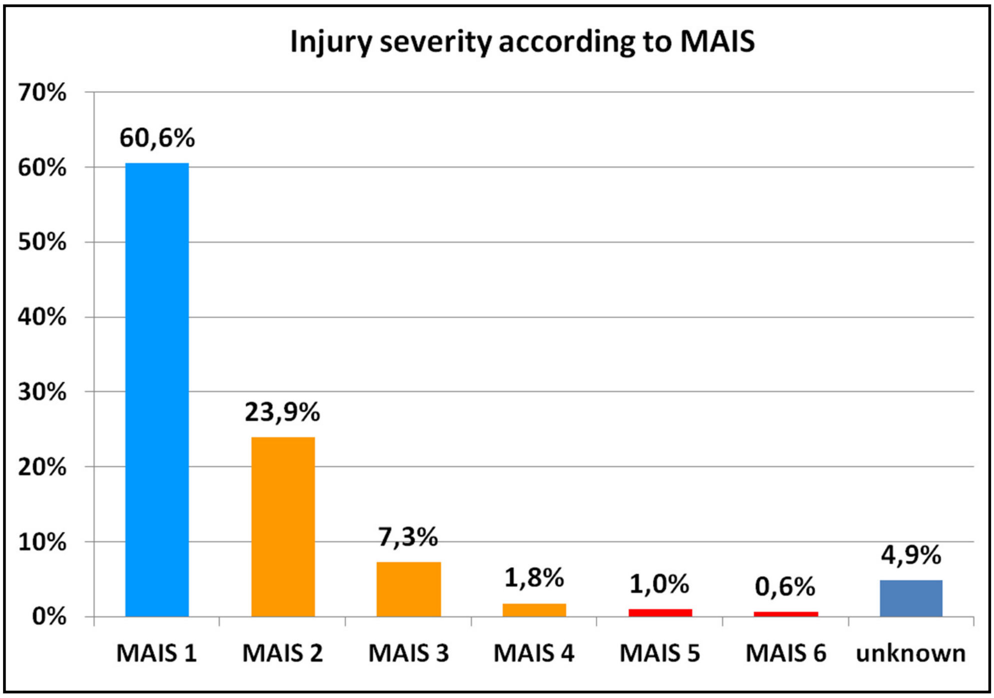


Figure 12: Injury severity according to the MAIS (AIS 1990 Update 1998)

Looking on the injured body regions of motorcyclists it can be derived from the data that most of the injuries occurred on lower and upper extremities. However, the most severe injuries occur on the head, the thorax, and the spine.

Finally the use of helmets was analysed. About 3% of the PTW riders in the dataset did not wear a helmet during the accident. This results in a very high fatality risk (Odds Ratio for sustaining fatal injuries approx. 17 times higher w/o helmet).

Summary and conclusion

Accident figures of many other countries show remarkable proportions of seriously and fatally injured motorcyclists. In Germany, nearly every fifth killed person in traffic accidents is a user of a PTW. Furthermore, this group of road users shows the worst performance over years, especially in comparison to car occupants, pedestrians and bicyclists.

To characterize the accident scenario of motorcycles, the VUFO did a comprehensive study on the basis of 1.800 real accidents out of GIDAS. Numerous parameters concerning the accident, the environment, the involved vehicles and injured persons were analyzed.

One main part of the study was the identification of typical situations and critical scenarios. It was found that motorcycles often collide with other vehicles on crossings or junctions and in the majority of these cases the PTW rider was not the main causer of the accident. On the other hand side the proportion of loss of control accidents (especially in rural areas) is remarkably high.

Motorcycles as road users show many particularities. The vast majority of riders are male; they mostly ride at certain times and for particular purpose (leisure).

The detailed analysis of accident initiation, accident causation and the most relevant accident types helps to identify some main problems of PTW. These are:

- poor perception / visibility; especially at junctions/crossings, leading to the violation against the right of way of the PTW
- loss of control accidents; mostly caused by speeding or inappropriate speed, leading to single accidents and – in case of collisions with objects – often to serious/fatal injuries
- insufficient braking; either as reaction to critical situations caused by other road users or in curves)

The main goal in motorcycle safety is the reduction of the numbers of slightly, seriously and especially fatally injured motorcyclists. Therefore, further improvements in different fields have to be made. To address the above mentioned problems, several measures seem to be effective, e.g.:

- prevention (safety training, education of both motorcyclists and others)
- technical solutions (e.g. active safety systems like ABS, (curve) braking systems etc.)
- increased perception (visibility)

The majority of measures or systems seem to be effective even for other countries with a varying motorcycle fleet and accident scenario.

Retrospective analysis of fatal motorcycle accidents and derivation of protective measures in complex braking maneuvers

Retrospektive Analyse tödlicher Motorradunfälle und Ableitung von Schutzmaßnahmen bei komplexen Bremsmanövern

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Abstract

Motorcycle riders have an up to 15 times higher risk for losing their life in an accident compared to car passengers. Since the year 2008 a decline is seen, but in comparison to the overall accident situation this decrease is unsatisfactory.

Therefore 48 fatal motorcycle crashes from the years 2004 to 2007 on Bavarian roads, in which the motorcycle rider was autopsied at the Institute for Legal Medicine of the LMU, were analysed.

These fatal accidents were reconstructed focusing on the braking maneuver, the speed of the motorcycle and the inclination angle, based on police reports as well as expert reports and photo documentation.

In Germany the lives of 100 – 200 motorcycle riders (12.5% -27%) per year could be saved, if every motorcycle was equipped with an antilock braking system.

45% of all fatal motorcyclist accidents on hand happened in bends. No one of the motorcycle riders drove with an inclination angle higher than 20 degrees, which is indicative for a deficit of riding skills. Almost every critical situation could have been avoided with only slightly increasing the inclination angle (up to 30 degrees).

Some riders (~ 30%) tried to escape this situation by braking. But the riders either locked the front wheel in an overreaction or could not compensate the upward roll movement of the bike and followed a path of leaving the lane and collided with oncoming traffic.

In the light of these results, the development of advanced antilock braking systems for motorcycles, being fully effective in bends, is to be addressed. Also, the training of the rider's inclination skills should be improved.

Kurzfassung

Das Risiko, als Motorradfahrer tödlich zu verunglücken, ist im Vergleich zu einem Pkw-Insassen deutlich höher. Auch wenn seit 2008 eine deutliche Reduktion zu erkennen ist, so kann der Rückgang der Getötetenzahlen im Motorradsektor im Kontext des Gesamtunfallgeschehens nicht als befriedigend angesehen werden.

Grundlage dieser Arbeit sind 48 tödliche Straßenverkehrsunfälle der Jahre 2004 bis 2007, bei denen der getötete Motorradfahrer im Institut für Rechtsmedizin der LMU obduziert wurde.

Die untersuchten Unfälle wurden anhand von Unfallberichten, Gutachten und Lichtbildern detailliert rekonstruiert. Hauptaugenmerk lag dabei auf der exakten Darstellung des Bremsmanövers, der Geschwindigkeit und der gefahrenen Schräglage des Motorradfahrers.

12,5% der untersuchten tödlichen Motorradunfälle wären mit einem konventionellen Antiblockiersystem vermeidbar gewesen, im Optimalfall sogar bis zu 27%. Das würde einer möglichen Reduktion von ca. 100 bis 200 getöteten Motorradfahrern pro Jahr im deutschen Straßenverkehr entsprechen.

45% der getöteten Motorradfahrer verunglückten in einer Kurve. Es konnte nachgewiesen werden, dass keiner der Fahrer einen Schräglagenwert von 20° überschritt. Daraus lassen sich Hinweise auf ein fahrerisches Defizit ableiten. Es wären annähernd alle kritischen Situationen ohne Reduzierung der Geschwindigkeit rein durch Vergrößerung der Schräglage (bis ca. 30°) vermeidbar gewesen. 30% der Fahrer versuchten zudem, ihre Kurvengeschwindigkeit durch ein Bremsmanöver zu verringern. Dabei erreichten sie entweder in einer Überreaktion die Blockiergrenze oder konnten das entstehende Aufstellmoment nicht kompensieren und wurden in den Gegenverkehr getragen.

Vor dem Hintergrund dieser Ergebnisse erscheint die Entwicklung eines voll kurventauglichen Antiblockiersystems zur weiteren Reduktion von Schwerstunfällen sinnvoll. Außerdem ist die Forderung nach verbesserten Aus-/ und Fortbildungsmaßnahmen zu stellen, um dem Schräglagendefizit der Motorradfahrer entgegenzuwirken.

Retrospektive Analyse tödlicher Motorradunfälle und Ableitung von Schutzmaßnahmen bei komplexen Bremsmanövern

Einleitung

In Deutschland ist das Risiko, als Motorradfahrer tödlich zu verunglücken, immer noch höher als für Pkw-Insassen. Die Getötetenzahlen im Motorradsektor sind zwar bis auf das Jahr 2011 kontinuierlich rückläufig, können aber im Kontext des Gesamtunfallgeschehens nicht als befriedigend angesehen werden. Im Jahr 2000 starben 945 Motorradfahrer auf deutschen Straßen, im Jahr 2007 immer noch 807. In den Jahren nach 2007 wurde ein deutlicherer Rückgang der Getötetenzahlen erreicht, im Jahr 2013 starben 568 Motorradfahrer [10].

Bezogen auf die Fahrleistung ist das Risiko, als Motorradfahrer tödlich zu verunglücken, über die vergangenen Jahre im Vergleich zu Pkw-Insassen jedoch sogar ansteigend. Die Gesamtjahresfahrleistung für Motorräder in Deutschland beträgt seit dem Jahr 2000 durchschnittlich 11 bis 13 Mrd. Kilometer, im Jahr 2012 waren es ca. 12 Mrd. Kilometer. Die Gesamtfahrleistung für Pkw steigt kontinuierlich an. Im Jahr 2000 waren es ca. 560 Mrd. Kilometer, im Jahr 2012 bereits 610 Mrd. Kilometer [2]. Kombiniert mit den stark rückläufigen Getötetenzahlen im Pkw-Sektor (im Jahr 2000 kamen 4396 Pkw-Insassen ums Leben, im Jahr 2012 nur noch 1791), ist das Risiko für Motorradfahrer, im Straßenverkehr ums Leben zu kommen, ungleich höher.

Im Jahr 2000 war das fahrleistungsbezogene Risiko, als Motorradfahrer tödlich zu verunglücken, 9-mal höher als für Pkw-Insassen. Im Laufe des vergangenen Jahrzehnts bis hin zum Jahr 2011 stieg dieser Faktor sogar auf 20 an.

Gründe für dieses erhöhte Risiko sind das komplexe Fahrverhalten von Motorrädern und die fehlenden Schutzzonen im Vergleich zu Pkws. Kommt es für den Motorradfahrer zu einer unvorhergesehenen Gefahrensituation, ist es für diesen je nach Erfahrung mitunter sehr schwierig, angemessen zu reagieren und sein Motorrad unter Kontrolle zu behalten. Ein Fahrzeug, das unvermittelt in eine Kreuzung einfährt oder eine falsch eingeschätzte und zu schnell angefahrene Kurve können sich sehr schnell zu lebensbedrohlichen Situationen entwickeln. Der Motorradfahrer muss innerhalb kürzester Zeit richtig reagieren, um einen drohenden Unfall und damit aufgrund der fehlenden Knautschzonen oft schwere Verletzungen zu vermeiden.

Motorradunfälle sind generell schwere Unfälle, der Motorradfahrer muss je nach Anprallkonstellation einen Großteil der auftretenden Energie direkt mit seinem Körper absorbieren; schwerste und tödliche Verletzungen sind oft die Folge.

Verglichen mit der Vielzahl von gut entwickelten Assistenzsystemen im Pkw-Sektor sind Assistenzsysteme für Motorräder weder in Anzahl noch Entwicklungsstand zufriedenstellend.

Das inzwischen am weitesten verbreitete und entwickelte System für Motorräder ist das Antiblockier-System. Dieses System unterstützt den Motorradfahrer bei harten Bremsmanövern und verhindert ein Blockieren der Räder. Somit bleibt die Fahrstabilität des Motorrads weiter erhalten: es kommt nicht zum plötzlichen Sturz aufgrund des Verlusts der stabilisierenden Kreiselkräfte. Ein konventionelles ABS kann sein volles Potential in kritischen Situationen vor allem auf geraden Strecken, z.B. bei Anfahrt auf Kreuzungen oder Einmündungen, entfalten.

Doch trotz solcher technischen Entwicklungen ist die korrekte und schnelle Reaktion sowie die sichere Beherrschung des Motorrads für Motorradfahrer in kritischen Situationen essentiell, um Unfälle vermeiden zu können.

Viele Motorradfahrer sind mit dem korrekten Durchfahren von Kurven und den physikalischen Zusammenhängen nicht vertraut. Das natürliche Schräglagenlimit von 20° ist für viele Motorradfahrer das subjektive Limit zum sicheren Durchfahren einer Kurve [9]. Das vom Reibwert (Straße und Reifen) abhängige Schräglagenlimit beträgt im Normalfall teils deutlich über 40°. Es galt deshalb auch im Rahmen dieser Studie, die Vermutung zu überprüfen, dass Motorradfahrer ein Defizit bei der Kurvenfahrt aufweisen und dieser Mangel an Erfahrung und Fahrzeugbeherrschung auch für einige tödliche Unfälle verantwortlich ist.

Da die Anzahl der schwersten und tödlichen Motorradunfälle in Deutschland nur langsam sinkt, werden im Rahmen dieser Studie mögliche Probleme und Lösungsansätze durch retrospektive Unfallanalyse erarbeitet. Es wird das Potential von ABS bei tödlichen Motorradunfällen durch detaillierte Einzelfallanalyse dargestellt. Zusätzlich wird das Defizit von Motorradfahrern beim Durchfahren von Kurven und das damit verbundene Schräglagendefizit betrachtet.

Material und Methoden

Grundlage dieser Arbeit sind 48 tödliche Straßenverkehrsunfälle der Jahre 2004 bis 2007, bei denen der getötete Motorradfahrer im Institut für Rechtsmedizin der Ludwig-Maximilians-Universität München (LMU) obduziert wurde. Das Einzugsgebiet umfasst Oberbayern, Niederbayern und Schwaben. Die erfassten Unfälle sind jeweils durch Polizeiberichte, unfallanalytische Gutachten, Lichtbilder und Obduktionsberichte dokumentiert. Zudem sind in Einzelfällen weitere ergänzende Unterlagen wie Blutalkoholbestimmungen, Drogenanalysen und Zeugenaussagen vorhanden.

Die verfügbaren Informationen wurden in einer Datenbank zusammengetragen; Hauptaugenmerk lag dabei auf den unfallrelevanten Daten wie Ausgangs-/Kollisionsgeschwindigkeiten, Brems- und Rutschspuren sowie Straßenverlauf und -zustand. Anhand dieser Daten wurden die unfallanalytischen Gutachten überprüft und der Unfall detailliert rekonstruiert. Hauptaugenmerk lag dabei auf der exakten Darstellung des Bremsmanövers, der Geschwindigkeiten, den Vermeidbarkeitsbetrachtungen und der gefahrenen Schräglage des Motorradfahrers.

Zur Darstellung des unfallvermeidenden Potentials eines konventionellen ABS wurden aus dem Fallkollektiv die genauer zu betrachtenden Fälle selektiert. Auswahlkriterium war eine dokumentierte Reaktion bzw. ein Bremsmanöver des Motorradfahrers im Unfallablauf.

Die relevanten Fälle wurden anschließend detailliert rekonstruiert. Es wurde die Ausgangsgeschwindigkeit des Motorradfahrers berechnet und die Entfernung zwischen Reaktions- und Kollisionspunkt ermittelt. Anschließend wurde unter der Annahme, das beteiligte Motorrad wäre mit einem ABS ausgerüstet gewesen, der theoretisch mögliche Anhalteweg berechnet und das dazu notwendige Bremsmanöver betrachtet. Der Straßenzustand und die Straßenoberfläche waren bei allen betrachteten Unfällen als gut bis sehr gut zu bewerten; die Unfälle geschahen alle auf trockenen Straßen. Somit wurde als durchschnittliche Bremsverzögerung ein Wert von 8,5 m/s^2 verwendet, was einer gut ausgeführten Vollbremsung unter guten äußeren Bedingungen entspricht. Auf Basis dieser Berechnungen wurde jeder einzelne Unfall (unter Annahme der Beibehaltung der Fahrstabilität) auf mögliche Vermeidbarkeit überprüft.

War der berechnete theoretisch mögliche Anhalteweg kürzer als die Distanz zwischen Reaktions- und Kollisionspunkt (der Unfall also räumlich vermeidbar), wurde das Potential eines ABS als „sehr hoch" eingestuft.

War der Anhalteweg länger als die Distanz zwischen Reaktions- und Kollisionspunkt, wurde überprüft, ob der Kollisionsgegner den Kollisionsbereich aufgrund der Zeitdifferenz bereits geräumt hätte, als der Motorradfahrer dort eintraf (zeitliche Vermeidbarkeit). Der Motorradfahrer erreicht den späteren Kollisionsbereich aufgrund des als optimal angenommenen Bremsmanövers und der deutlicher reduzierten Geschwindigkeit einen gewissen Zeitbetrag später, wodurch der Kollisionsgegner den späteren Kollisionsbereich möglicherweise bereits verlassen hat.

War der Unfall zeitlich vermeidbar, wurde das Potential des ABS als „hoch" eingestuft.

Bei den verbleibenden weder räumlich noch zeitlich vermeidbaren Unfällen wurde die Kollisionsgeschwindigkeit und die Kollisionsstellung bei optimalen Bremsmanöver neu bestimmt. Wurde eine im Vergleich zur ursprünglichen Kollisionsgeschwindigkeit deutliche Geschwindigkeitsreduktion bzw. eine als weniger kritisch anzusehende Kollisionsstellung erreicht (z.B. aufrechte Kollision mit der Motorhaube mit niedriger Geschwindigkeit statt rutschende Kollision mit dem Kopf voran gegen das Vorderrad), wurde das Potential des ABS als „mittel bis gering" eingestuft.

In allen verbleibenden Unfällen wurde das Potential des ABS als nicht vorhanden bewertet.

Zusätzlich wurde das Potential eines voll kurventauglichen ABS adressiert. Die Fälle, in denen der Motorradfahrer aufgrund eines dokumentiertem Bremsmanövers und einer Schräglage >15° aufgrund eines blockierenden Rades zu Sturz kam und verunfallte, wurde als (mit einem voll kurventauglichen ABS) potentiell vermeidbar eingestuft.

Zur Überprüfung des Schräglagendefizits der Motorradfahrer wurden die relevanten Fälle anhand des Kriteriums selektiert, dass der Unfall in einer deutlich wahrnehmbaren Kurve stattfand. Anschließend wurden für jeden relevanten Unfall der Kurvenradius sowie die Ausgangsgeschwindigkeit des Motorradfahrers ermittelt. Der Kurvenradius wurde, falls aus den vorliegenden Unterlagen nicht zu bestimmen, anhand von Bildern aus dem BayernAtlas [6] bestimmt. Dieser Dienst stellt sehr detailliertes und genaues Kartenmaterial zur Verfügung. Anhand der Ausgangsgeschwindigkeit, der Kollisionsgeschwindigkeit und des Kurvenradius wurde die Schräglage des Motorradfahrers zur jeweiligen Unfallphase berechnet. Zusätzlich wurde die erforderliche Schräglage berechnet, mit der der Motorradfahrer die Kurve mit der ermittelten Ausgangsgeschwindigkeit gefahrlos durchfahren hätte können.

Abschließend wurden die Ergebnisse der Berechnungen bezüglich des Potentials von ABS mit Hilfe eines Proportional Fitting Algorithmus (Randverteilungen Alter und Unfallmonat) auf die Gesamtzahl der in Deutschland getöteten Motorradfahrer hochgerechnet.

Ergebnisse

Potential ABS

Von den 48 zur Verfügung stehenden Unfällen wurden 21 als ABS-relevant bestimmt.

Die überwiegende Mehrheit dieser Unfälle geschah auf einer geraden Straße im Bereich einer Kreuzung oder Einmündung. 6 dieser 21 Unfälle hatten „sehr hohes“ Vermeidbarkeitspotential durch ein ABS. In weiteren 4 Fällen wurde das Vermeidbarkeitspotential als „hoch“ eingestuft. „Mittleres bis geringes“ Vermeidbarkeitspotential wurde in 3 Unfällen ermittelt.

Bezogen auf die Gesamtzahl aller untersuchten Unfälle lassen sich bezüglich der Wirksamkeit eines ABS demnach folgende Aussagen treffen:

- 12,5% der untersuchten Unfälle hatten „sehr hohes“ Vermeidbarkeitspotential
- 8,3% hatten „hohes“ Vermeidbarkeitspotential
- 6,3% hatten „mittleres bis geringes“ Vermeidbarkeitspotential

Im Optimalfall wären somit bis zu 27% aller untersuchten tödlichen Motorradunfälle mit einem konventionellen Antiblockiersystem vermeidbar gewesen. Das würde einer möglichen Reduktion von über 150 getöteten Motorradfahrern pro Jahr im deutschen Straßenverkehr entsprechen.

Mit einem voll kurventauglichen ABS hätten im Optimalfall weitere 8,3% aller Unfälle vermieden werden können.

Im vorliegenden Unfallkollektiv sind drei Unfälle vorhanden, in denen das verunfallte Motorrad mit einem ABS ausgestattet war, der Unfall aber nicht vermeidbar war. In diesen Fällen hatte der Motorradfahrer entweder keine Zeit zu reagieren oder geriet in einer Kurve ohne Reaktion auf die Gegenfahrbahn.

Defizit bei Kurvenfahrt

45% der getöteten Motorradfahrer verunglückten in einer Kurve; 70% davon in einer Rechtskurve, 30% in einer Linkskurve. Der Kurvenradius betrug dabei typischerweise weniger als 60 Meter. Der typische Unfallablauf kann dabei wie folgt beschrieben werden: Der Motorradfahrer verlässt aufgrund subjektiv zu hoher Geschwindigkeit und zu geringer Schräglage oder schlecht durchgeführter Bremsung seine Fahrspur tangential (meist im Bereich des Kurvenscheitels) und kollidiert entweder mit dem Gegenverkehr oder einem harten Gegenstand am Straßenrand (z.B. einem Baum oder Verkehrsschild).

30% der Motorradfahrer versuchten ihre subjektiv zu hohe Geschwindigkeit durch ein Bremsmanöver zu reduzieren. Dabei bremsten sie entweder schockartig bis über die Blockiergrenze und stürzten oder konnten das auftretende Aufstellmoment nicht kompensieren und verließen ihre Fahrspur.

Die restlichen 70% zeigten keine Reaktion vor Verlassen ihrer Fahrspur.

Es konnte nachgewiesen werden, dass keiner der Fahrer im gesamten Unfallablauf einen fahrstabilen Schräglagenwert von 20° überschritt.

Es wären alle kritischen Situationen ohne Reduzierung der Geschwindigkeit rein durch Vergrößerung der Schräglage (bis max. 35°) vermeidbar gewesen.

Die theoretisch mögliche Schräglage in jedem betrachteten Unfall betrug über 40°.

Eine Hochrechnung dieser Ergebnisse auf die gesamten Unfallzahlen in Deutschland erfolgte nicht.

Diskussion

Es wurde inzwischen in diversen Studien gezeigt, dass ein ABS im Motorrad ein relativ hohes Potential zur Unfallvermeidung hat. So ist in einer Studie des Allianz Zentrum für Technik (AZT) die Rede von 8-17% weniger Schwerstunfällen, falls die beteiligten Motorräder mit ABS ausgestattet gewesen wären [1]. Die Unfallforscher des ADAC gehen von einer möglichen Reduktion von bis zu 160 getöteten Motorradfahrern aus, falls ihre Maschinen mit ABS ausgerüstet gewesen wären [3]. Das IIHS hat eine mögliche Reduktion von 37% aller tödlichen Motorradfälle ermittelt [7]. Weitere Studien des Bundesamt für Straßenwesen [4] und der schwedischen Straßenbehörde Vägverket zeigen ebenfalls deutlich den Nutzen von ABS auf.

In der vorliegenden Studie konnte ebenfalls nachgewiesen werden, dass bis zu 27% aller untersuchten tödlichen Motorradunfälle durch ein konventionelles ABS vermeidbar gewesen wären. Durch die sehr gute Dokumentationsqualität aller vorliegenden Unfälle kann eine sehr hohe Qualität der Rekonstruktionen und weiterführenden Betrachtungen gewährleistet werden.

Die Anzahl der mit einem ABS ausgestatteten Motorräder stieg die vergangenen Jahre kontinuierlich an, ab 2016 ist ein serienmäßiges ABS für neue Fahrzeugtypen verpflichtend. Die Anzahl der tödlichen Unfälle zeigt dementsprechend eine zu erwartende Tendenz nach unten, die aber im Kontext des Gesamtunfallgeschehens als zu gering zu bewerten ist.

45% der untersuchten Unfälle geschahen in Kurven. Vor dem Hintergrund der Ergebnisse dieser Studie erscheint die Entwicklung und Verbreitung eines voll kurventauglichen Antiblockiersystems zur weiteren Reduktion von Schwerstunfällen sinnvoll, zumal seit kurzem ein solches voll kurventaugliches ABS [5] erhältlich ist.

Doch trotz erkennbarer Fortschritte im technischen Bereich erscheint es umso wichtiger, die Aus- und Fortbildung von Motorradfahrern, Fahrlehrern und Trainern zu verbessern. Alle untersuchten Unfälle in Kurven hätten sich rein durch vergrößern der Schräglage bis maximal 35° verhindern lassen können. Doch viele Motorradfahrer können weder ihre eigenen Fähigkeiten noch die Möglichkeiten und Grenzen ihres Motorrads einschätzen. So fällt in Fortbildungsveranstaltungen häufig auf, dass selbst langjährige Motorradfahrer weder ausreichend bremsen noch eine Schräglage von mehr als 20° erreichen können. Außerdem kennen viele Teilnehmer den Lenkimpuls nicht. Teilnehmer, die den Lenkimpuls kennen, haben diesen häufig nicht automatisiert. Das Abkommen von der Fahrbahn mit 20° Schräglage ist allein durch reflexmäßige Anwendung des Lenkimpulses um einen hohen Prozentwert reduzierbar [8].

Das Potential eines verbauten ABS wird erst gar nicht ausgereizt, falls der Motorradfahrer zu zögerlich oder mit zu geringer Handkraft bremst. Bei der Fahrprüfung wird nur eine Bremsung aus 50 km/h gefordert. Bei einer Bremsung aus 100 km/h oder mehr müsste bereits im Bereich der Fahrschulausbildung der Fokus noch mehr auf der richtigen Blicktechnik und Körperhaltung sowie Lösereflexen bei Stoppies oder einem blockierendem Vorderrad eingegangen werden. Eine Gefahrenbremsung aus 50 km/h lässt noch viele Fahrfehler zu, die bei höheren Geschwindigkeiten zu einem längeren Bremsweg oder sogar zum kurzzeitigen Lösen der Bremse führen können [8].

Viele Unfallsituationen in Kurven würden sich auch mit einer korrekten Kurventechnik bzw. rein durch Vergrößern der Schräglage vermeiden lassen, die natürliche Schräglagengrenze von 20° stellt hier einen annähernd unüberwindbaren Wert dar. Durch entsprechendes professionell angeleitetes Training lassen sich diese Defizite jedoch mit sehr geringem Aufwand verdeutlichen und überwinden.

Somit ist die Forderung nach verbesserten Ausbildungsmaßnahmen zu stellen, um das Bewusstsein der Motorradfahrer für sich, ihr Motorrad und möglichen kritischen Verkehrssituationen zu stärken. Vor allem die Vermittlung der korrekten Bremstechnik und der Beherrschung der Schräglage müssen in Zukunft optimiert werden. Es sollte ebenfalls die Empfehlung ausgesprochen werden, Motorradfahrer auch nach der Fahrschule für kontinuierliche Fahrertrainings zu motivieren.

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Motorcycle Stability Control – MSC
The next step into safety solutions for motorcycles

Motorcycle Stability Control – MSC
Der nächste Schritt zur Fahrsicherheit für Motorräder

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Abstract

Antilock Braking Systems ABS for motorcycles has already contributed significantly to the safety of powered two wheelers on public roads. Another step forward to the improvement of the controllability of PTW has been achieved with MSC by combining traction control and the essential sensors.

By taking account of all available vehicle information from brakes, power train and vehicle dynamics the distribution of brake and traction forces is controlled by an algorithm so that in unforeseeable situations the driver can still be supported. This ability can be implemented with reasonable effort by of means of extended software and additional inertial sensors.

These fundamentals generate the basis for more systems which contribute to the safety in public traffic in the future.

The presentation is divided in two parts. Bosch will describe the motivation for the system and the development of function and components. The benefits of system functions and the effects of MSC are presented in an understandable and figurative way. KTM will explain the implementation into the vehicle, the achievements in safety and the feedback of the market by taking the example of the KTM 1190 Adventure.

The presentation will be closed with an outlook of potential system fusions in the future.

Kurzfassung

Nachdem das Antiblockiersystem ABS für Motorräder bereits einen erfolgreichen Beitrag zur Sicherheit im Straßenverkehr mit Zweirädern leistet, ist durch die Verbindung von Traktionskontrolle und der dafür notwendigen Sensorik mit MSC ein weiterer Fortschritt zur Steigerung der Beherrschbarkeit des Zweirades gelungen.

Unter Nutzung aller verfügbaren Fahrzeuginformationen aus Bremse, Antrieb und Fahrdynamik wird mittels eines Algorithmus die Verteilung der Brems- und Antriebskräfte so geregelt, dass in unvorhersehbaren Situationen der/die Fahrzeugführer/in weiter unterstützt werden kann. Da dazu über die vorhandene Ausrüstung des Fahrzeuges eine erweiterte Software und Inertialsensorik notwendig ist, kann diese Fähigkeit mit vertretbarem Aufwand implementiert werden.

Diese Grundlagen bilden die Basis für zusätzliche Systeme in der Zukunft, mit denen ein wesentlicher Beitrag zur Sicherheit im Straßenverkehr geleistet werden kann.

Der Vortrag ist zweigeteilt. Es wird von Bosch die Motivation für das System, die Funktions- und Komponentenentwicklung von MSC und die Vorteile in der Verknüpfung der Systemfunktionen aufgezeigt und die Wirkungsweise allgemeinverständlich und bildlich dargestellt. Von KTM wird am Beispiel der KTM 1190 Adventure die Implementierung im Fahrzeug und der Sicherheitsgewinn durch MSC erklärt und mit Rückmeldungen aus dem Markt ergänzt.

Den Abschluss bildet ein Ausblick in die Zukunft möglicher Systemverknüpfungen.

Motorcycle Stability Control – MSC

Der nächste Schritt zur Fahrsicherheit für Motorräder

1 Marktentwicklung elektronischer Bremsregelsysteme

Wenn man die Einführung von Elektronik im Motorrad betrachtet so fällt auf, das diese Entwicklung deutlich später als beim PKW gestartet hat, und immer noch verzögert stattfindet.

Das erste serienmäßige ABS für Motorräder wurde erst 10 Jahre nach dem Serienstart bei Mercedes Benz 1978 bei BMW-Motorrad eingeführt.

Die Trennung der Betätigung der Bremse über Hand- und Fußhebel beim Motorrad hat auch zu Entwicklungen einer Kombination in der ABS Regelung geführt. Das erste Fahrzeug damit kam 1992 von Honda (Bild 1).

Motorcycle Stability Control (MSC)

The History of motorcycle ABS

Introduction	System supplier	Vehicle Manufacturer	Note
1988	FTE	BMW	1st Motorcycle ABS in a serial bike
1992	Nissin	Honda	Combination of ABS and hydraulic CBS function
1995	Bosch	Kawasaki	1. ABS from Bosch on the market
2001	FTE	BMW	1st system with electronic brake booster and full eCBS function
2006	Bosch	KTM	KTMs first motorcycle with ABS (990 Adventure)
2009	Nissin	Honda	1st Brake-By-Wire System. Very complex and heavy
2009	Bosch	BMW	1st motorcycle dedicated and worldwide smallest & lightest ABS with eCBS on the market
2010	Bosch	Kawasaki	1st motorcycle dedicated and worldwide smallest & lightest 2ch ABS on the market
2012	Bosch	KTM	1st ABS with integrated traction control (MTC)
2013	Bosch	KTM	MSC (Motorcycle Stability Control) 1st motorcycle ABS which uses lean angle information, and allows braking and traction control during cornering

Bild 1

Bosch hat sein erstes ABS 1995 in den Markt gebracht und 2006 zum ersten Mal in einer KTM, der 990 Adventure. Für sportliche Motorräder wurde bereits sehr früh erkannt, das Gewicht und Baugröße für die Integration ins Fahrzeug besonders wichtig sind.

Über verschiedene Entwicklungsstufen wurden diese Vorgaben erreicht und mit der Realisierung des MSC wurde die Besonderheit der Motorradfahrdynamik in der Kurve zum ersten Mal in Serie für ein Brems-und Antriebsregelsystem dargestellt.

Die Stückzahlentwicklung der ABS-Ausrüstung ist von erstem Einsatz 2006 bei KTM moderat mit der Marktsituation für die Modelle verlaufen (Bild 2).

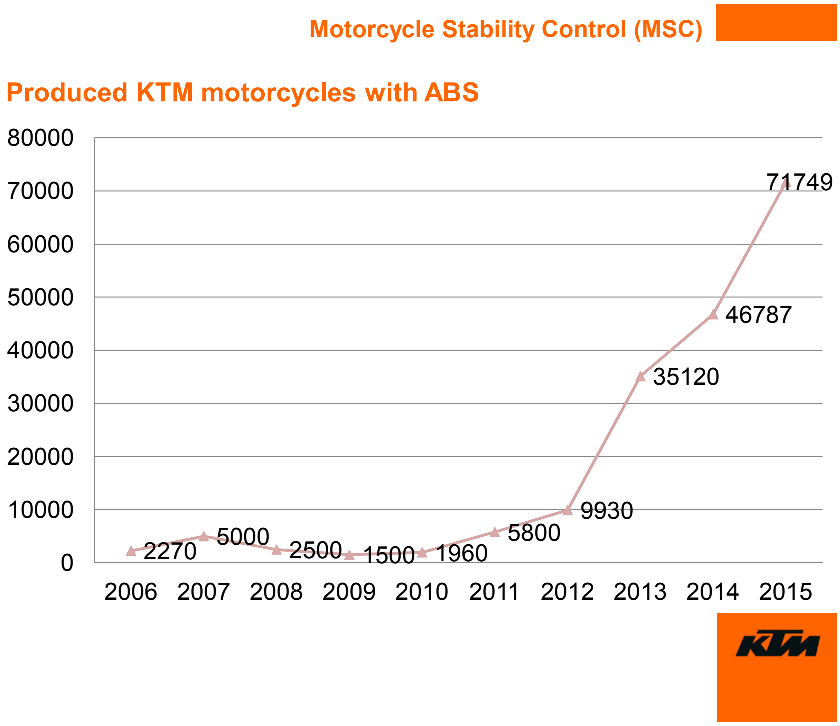

Bild 2

Mit der Ankündigung der verpflichtenden Ausrüstung für Motorräder in der Zukunft und der Nachfrage durch die Käufer der Fahrzeuge hat sich die Lage ab 2011 drastisch verändert. Die Steigerungen in den Folgejahren sind ein Resultat des Angebots in den verschiedenen Modellen von KTM und der großen Nachfragen nach sportlichen Fahrzeugen mit technischen Innovationen. Dazu gehört in erster Linie das ABS mit seinen erweiterten Funktionen Traktionskontrolle und Stability Control.

Die Zahlen der in Europa in Straßenverkehr getöteten motorisierten Zweiradfahrer ist eine starke Motivation durch technische Systeme eine Reduzierung zu erreichen. Ab 2007 bis zum Ende der Darstellung 2012 konnte eine Senkung um insgesamt 39% erreicht werden, wobei sich dieser Wert bei Motorrädern auf minus 23% und bei Mopeds auf minus 61% aufteilt (Bild 3).

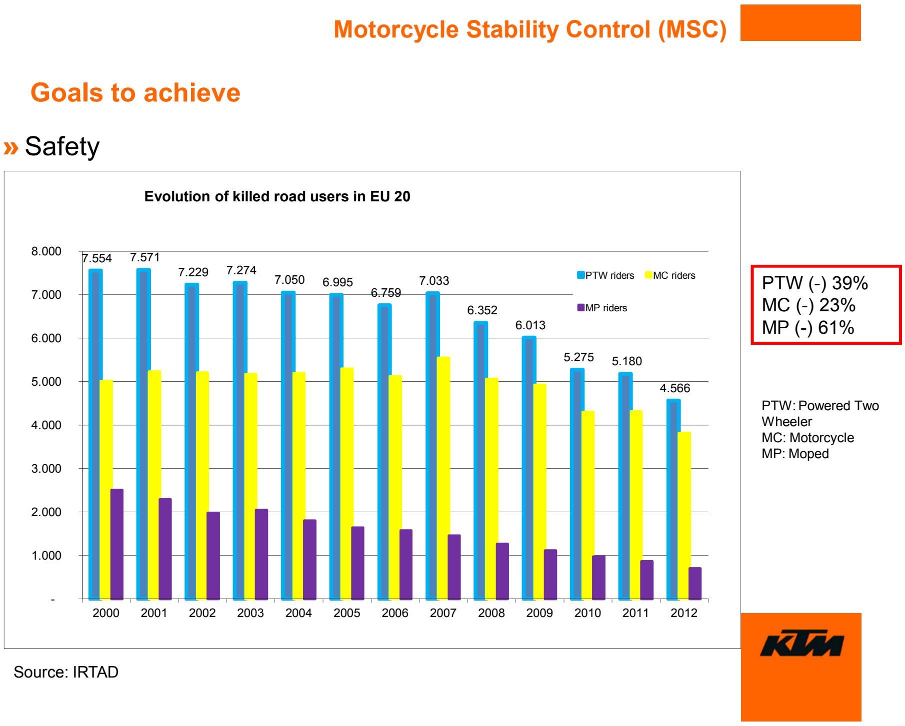

Bild 3

Die Reduzierung bei Motorrädern um 23% wird mit Recht der zunehmenden Verbreitung des ABS zugerechnet. Die deutlich geringeren Zahlen für Mopedfahrer sind auf die weitere Verbreitung der Helmtragepflicht zurückzuführen.

Das bedeutet, dass weitere Anstrengungen der Entwickler innovative Funktion in das Motorrad zu integrieren, für die Erhöhung der Sicherheit wichtig und sinnvoll sind.

Für den Fahrer kommen zusätzliche Schutzmaßnahmen wie z.B. eine Airbag-Weste gerade in die ersten Serienausrüstungen der Fahrzeuge.

Bei der Überlegung was alles technisch möglich sein könnte, müssen jedoch die Ziele der Fahrer unbedingt berücksichtigt werden. Die Fahrzeuge werden heute überwiegend in der Freizeit und für kurze Strecken im urbanen Umfeld genutzt. Die Befragungen der Fahrer nach der Wichtigkeit der Eigenschaften des Motorradfahrens zeigen eindeutige Schwerpunkte im Erleben von Freiheitsgefühlen und ganz besonders der Dynamik des Kurvenfahrens mit einer sportlichen Komponente (Bild 4).

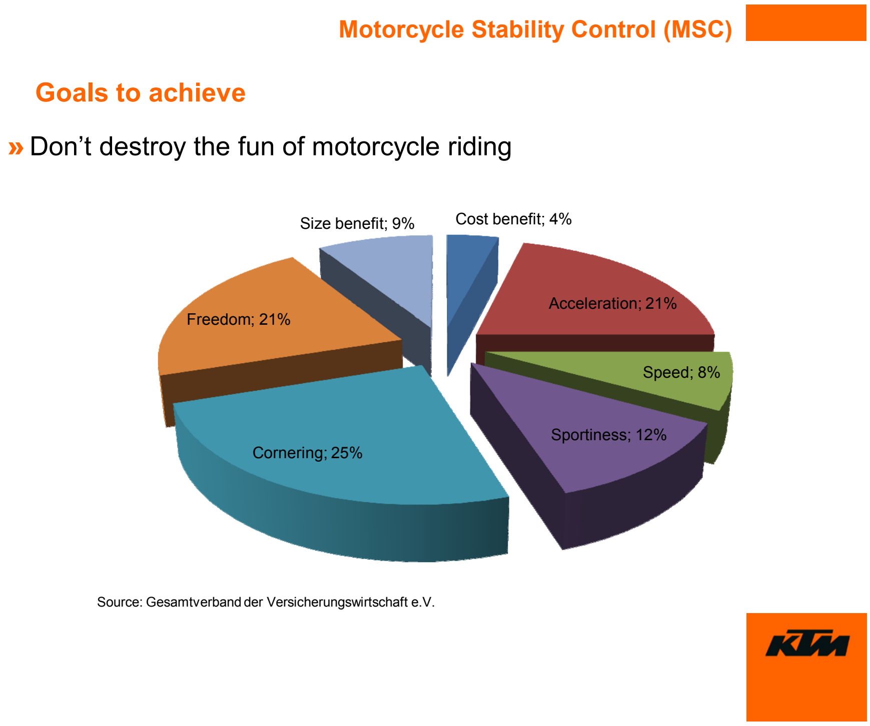

Bild 4

Die Bedeutung der absoluten Geschwindigkeit wird deutlich geringer als das Erleben von Beschleunigung bewertet. Damit sind die Ziele für die Entwicklung klar gezeichnet und müssen in der Auslegung und Applikation der Systeme für die verschiedenen Fahrzeugkategorien berücksichtigt werden.

Um die genannten Ziele nicht zu beeinträchtigen, wird als obere Vorgabe für die Entwicklung die Zurückhaltung der Systemfunktion in den Fahreigenschaften des Fahrzeuges festgelegt. Solange ein kontrollierter, stabiler Fahrzustand gegeben ist, soll der Fahrer von dem System im Hintergrund nichts wahrnehmen (Bild 5).

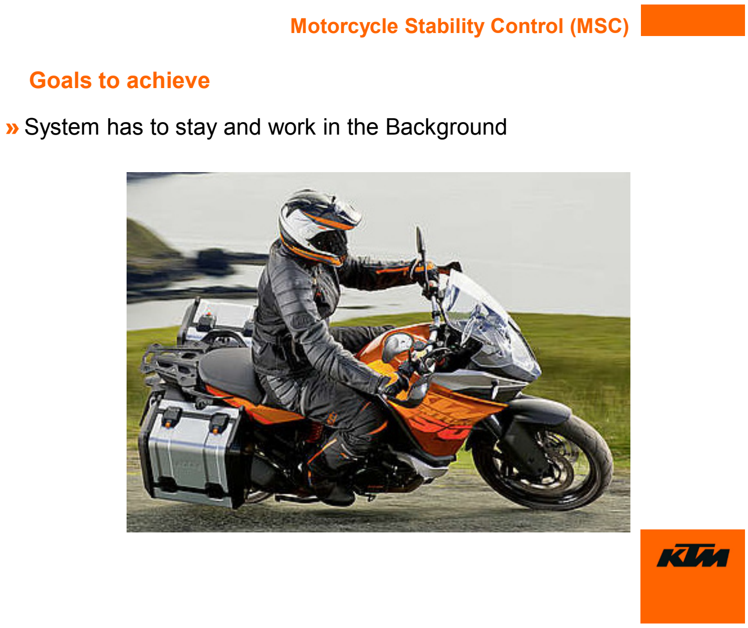

Bild 5

Wo eine Unterstützung sinnvoll wird, ist eine Auslegungssache bei der Applikation. Dabei werden insbesondere die verschiedenen Nutzungsbedingungen, Straße, Gelände oder Rennstrecke und die Umweltbedingungen, wie der Einsatz bei Regen oder trockener Fahrbahn, sorgfältig abgestimmt. Dem Fahrer werden dafür auch Wahlmöglichkeiten zur individuellen Auswahl angeboten. Ebenso ist die Berücksichtigung einer breiten Verteilung der Fahrfähigkeiten und Erwartungen an die Systemfunktionsgrenzen notwendig.

Für die KTM 1190 Adventure ist zum ersten Mal in Serie die Zusammenfassung von vier Systemfunktion unter der Gesamtfunktion Motorcycle Stability Control eingeführt worden (Bild6). Diese Funktionen bieten für die Straße, das Gelände und in Kurven eine optimale Unterstützung des Fahrers.

2 Systemaufbau Motorcycle Stability Control MSC

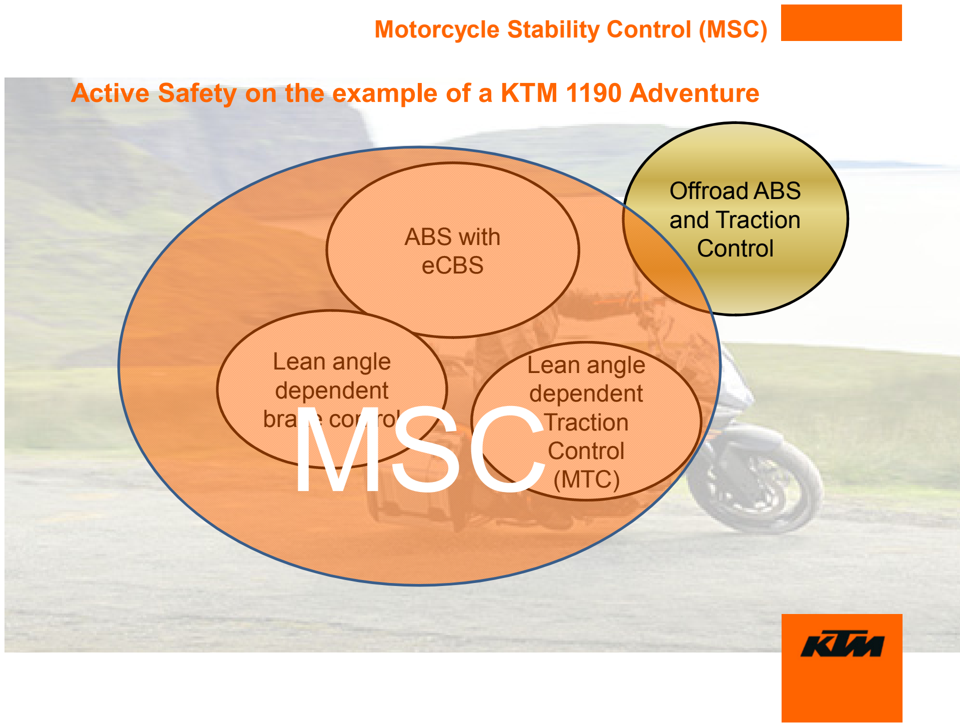

Bild 6

Die ABS-Funktion ist durch die elektronische Bremskraftverteilung eCBS ergänzt und ermöglich bei Betätigung des Handbremspedals eine gleichzeitige Aktivierung der Vorderrad- und Hinterradbremse. Damit werden die Bremskräfte entsprechend der Beladung, der Reibwertverhältnisse und der Fahrbahnbedingungen für eine beste Stabilität im Bremsfall geregelt. Wird die Hinterradbremse zusätzlich betätigt, wird diese in die Regelung für eine maximale Verzögerung mit einbezogen. Bei alleiniger Betätigung der Hinterradbremse, ist auch nur diese geregelt. Das Abheben des Hinterrades kann wirkungsvoll unterbunden werden.

Für das Fahren im Gelände z.B. auf geschotterten Nebenstraßen kann der Offroad-ABS Modus eingeschaltet werden. Das ermöglicht ein besonders dynamisches Fahren bei dem auch ein blockierendes Hinterrad in die Fahrzeugführung einbezogen werden kann. Der Regelalgorithmus für das Vorderrad ist auf diese Bedingungen ebenfalls angepasst. Das ermöglicht erfahrenen Geländefahrern die Ausnutzung der Fahrleistungen wie sie es gewohnt sind, bietet aber im Grenzfall die Absicherung über eine ABS Funktion um einen Sturz zu vermeiden.

Die Funktionen schräglageabhängige Bremskraftregelung und Traktionskontrolle bauen auf dem zusätzlichen Schräglagesensor auf. Da sich aus der Umfangsgeschwindigkeit der Räder in größeren Schräglagen die Schlupfdifferenz alleine nicht mehr berechnen lässt, wird der Schräglagewinkel als Information für die Regelung von Brems- und Antriebskräften mit einbezogen.

Motorcycle Stability Control verbindet die Regeleinheiten eines ABS 9ME mit der Motorsteuerung EFI ECU (Bild 7). Zusätzlich zu den bekannten Sensoren für die Raddrehzahl am Vorder- und Hinterrad wird eine Sensorbox MM5.10 verbaut. Diese Sensorbox enthält drei Beschleunigungssensoren für die drei Raumachsen und zwei Drehratesensoren. Die dritte Achse der Drehrate wird aus den anderen Signalen errechnet. Damit ist eine eindeutige Erfassung der Dynamik des Fahrzeuges im Raum möglich. Die Bremszylinder der Fuß- und Handhebel sind mit dem ABS-Hydraulikaggregat verbunden und von diesem werden die Bremszangen an Vorder- und Hinterrad mit Druck beaufschlagt. Die Zweikreisbremse bleibt dabei erhalten.

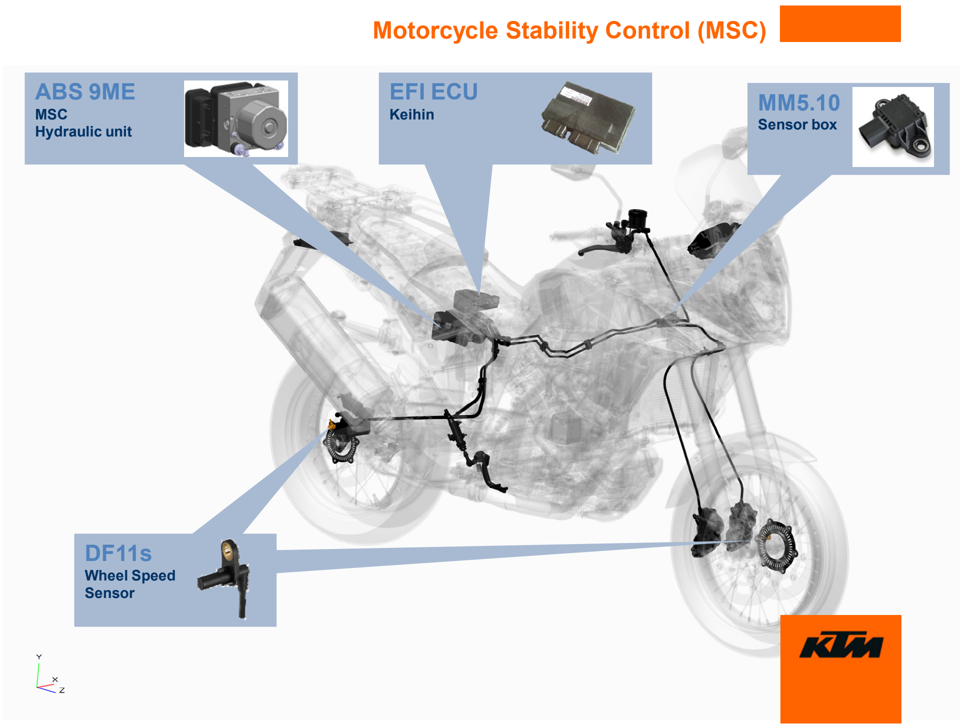

Bild 7

Für die Integration der Komponenten im Fahrzeug ist nur der Platzbedarf für den Schräglagesensor notwendig geworden. Dessen Baugrößenreduzierung gegenüber dem Vorgänger MM3.10 entspricht den Anforderungen des Motorraddesigns. Der Gewichtsunterschied zu einem Fahrzeug das nur mit ABS ausgestattet ist, sind wenige Gramm.

Während auf der Hardwareseite keine signifikanten Unterschiede erkennbar sind, findet auf der elektronischen Kommunikation zwischen den Systemen ein wesentlich erweiterter Informationsaustausch statt. In der Grundarchitektur sind die elektronischen Steuergeräte mit einem CAN-Bus verbunden (Bild 8).

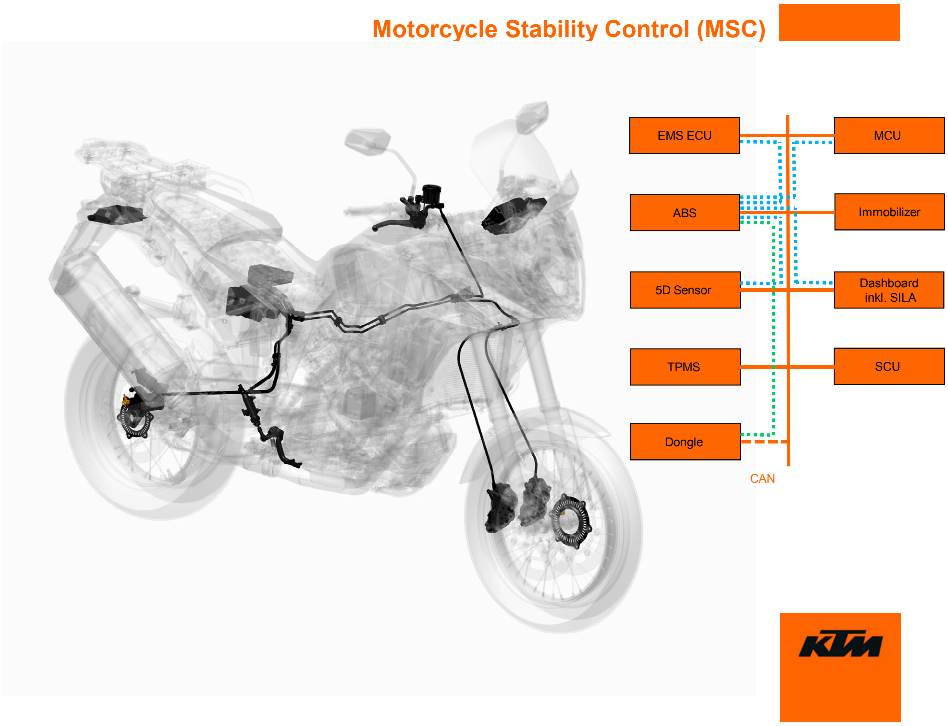

Bild 8

Das Motorsteuergerät EMS-ECU errechnet das aktuelle Antriebsmoment und liefert diese IST-Information an das ABS. Der Traktionsregelalgorithmus im ABS Steuergerät bestimmt aus den Schlupfwerten das SOLL-Moment und gibt diese Information an die EMS-ECU zurück. Diese regelt Einspritzung, Zündung und Drosselklappe auf diesen SOLL-Wert ein. Der 5D-Sensor liefert die Schräglageinformation an das ABS Steuergerät für die Traktionskontrolle und die Bremsregelung in Kurven. Das Management der Systeme übernimmt auch ein zentrales Steuergerät MCU und die Zustands- und Sicherheitsinformation SILA werden dem Dashboard übermittelt. Über eine Serviceschnittstelle kann mit geschützter Software auf die Systeme zugegriffen werden.

Zu dem CAN-Bus-Verbund gehören auch die Steuergeräte für die Reifendrucküberwachung TPMS und die elektronische Fahrwerkeinstellung SCU.

Das Gleichgewicht der übertragbaren Kräfte der Reifen auf die Straße lässt sich am besten mit dem „Kamm‘schen Kreis“ erklären (Bild 9).

3 Fahrdynamische Grundlagen für Brems- und Traktionsregelsysteme

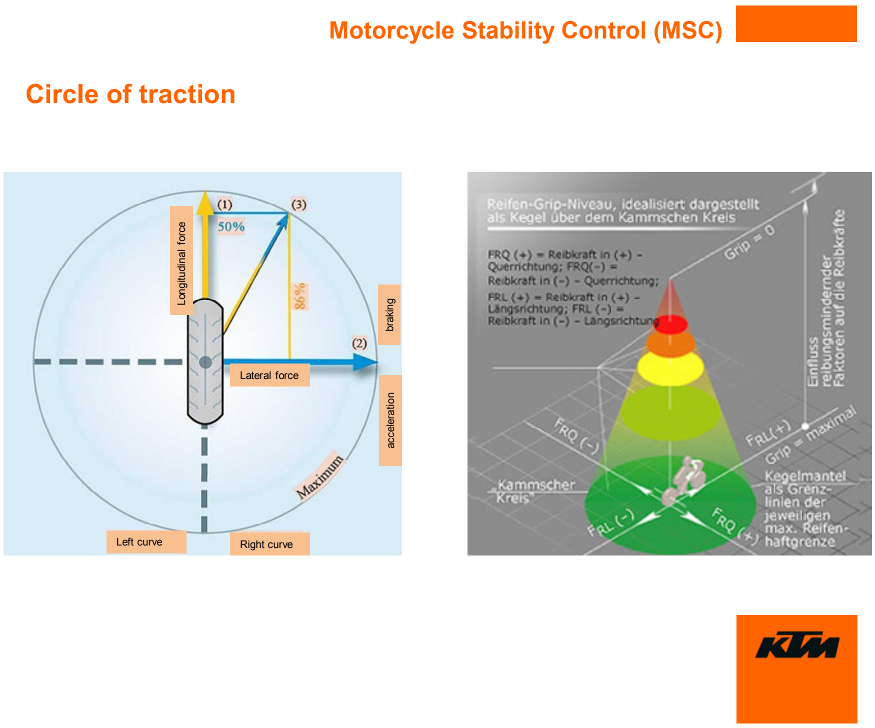

Bild 9

In dieser Darstellung wird die Änderung der Vektoren für Antriebs- und Bremskraft in Abhängigkeit von der Querkraft aufgezeigt. Die Seitenführungskraft entspricht der Querkraft die notwendig ist, um eine stabile Schräglage fahren zu können. Im Beispiel ist gezeigt, dass im Fall, dass 50 % der maximalen Querkraft benötigt werden, nur noch 86% der möglichen Bremskraft der Geradeausfahrt zur Verfügung stehen. Das heißt, dass ein längerer Bremsweg in der Kurvenfahrt daraus entsteht. Das gleiche gilt sinngemäß für die Beschleunigung. In der realen Welt hat dieser Kreis Formanteile einer Ellipse, was aber für die weiteren Betrachtungen nicht von Bedeutung ist.

Die dritte Dimension in dieser Darstellung ist der Durchmesser des Kegels. Dieser entspricht dem Reibwert oder „Grip". Ist der Wert sehr hoch, also auf rauem Asphalt und Trockenheit, dann ist der Durchmesser groß oder maximal. Wenn der Reibwert abnimmt, z.B. durch Nässe und einer Basaltoberfläche, wird der Durchmesser kleiner.

Im Extremfall geht dieser Wert zu Null, wie etwa bei einem Wasserfilm auf poliertem Eis. Dann ist ein Fahren mit einem Zweirad nicht mehr möglich.

Andere Faktoren sind natürlich die Gummimischung der Reifen und deren Temperatur, sowie Größe und Form der Aufstandsfläche, die eine Verzahnung mit der Oberfläche erzeugt. Bildet sich beim Bremsen vor dem Rad ein Keil aus, z.B. aus Schotter oder dreht das Hinterrad auf losem Untergrund mit einem Stollenreifen durch, gelten wiederum andere Bedingungen. Deshalb auch die Funktion Offroad-ABS in den KTM Motorrädern.

Für die Gesamtfunktion Motorcycle Stability Control greifen die einzelnen Systemfunktionen ineinander. Logischer Weise ist das für das Beschleunigen mehrheitlich die Momentenregelung des Motors, wohingegen beim Bremsen die Bremskräfte bestimmt werden. Dabei ist die Bremskraftverteilung in der Schräglage in die Betrachtung einzubeziehen, ebenso wie das Schleppmoment, das vom Motor aufgebracht wird.

Aus der Färbung des Kreises wird ersichtlich, dass es Grenzen der MSC-Funktion gibt (Bild 10).

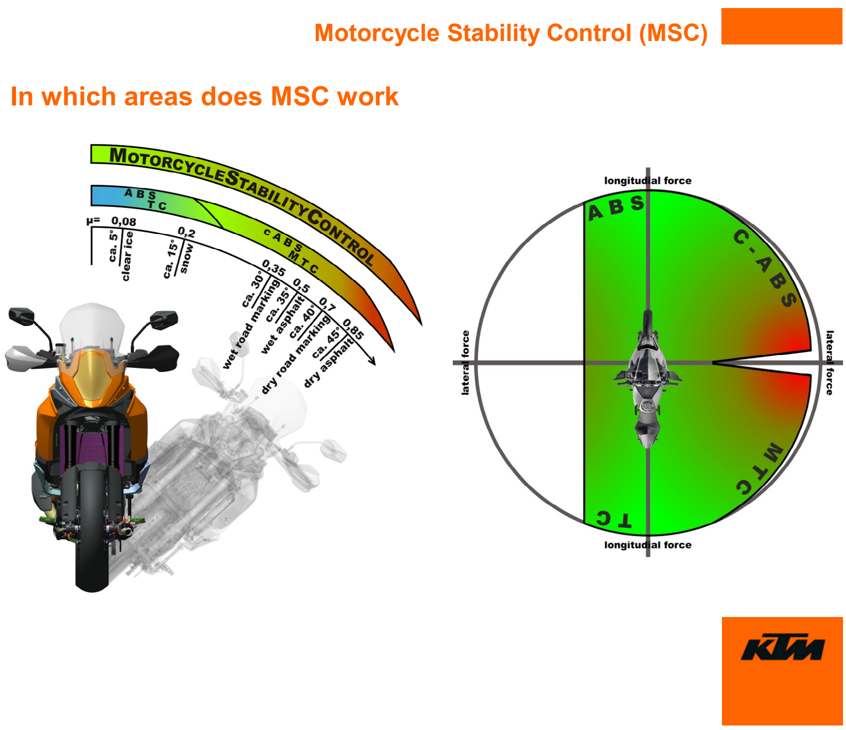

Bild 10

Einfach nachvollziehbar ist das bei extremen Schräglagen. An der absoluten Grenze reichen bereits geringe Unterschiede in der Verschiebung des Schwerpunktes durch den Fahrer aus, um die Haftgrenzen zu überschreiten.

Zusätzlich kommt hinzu, dass sich die Summenkräfte auf die Reifenaufstandsfläche in der Schräglage erhöhen, weil sich die Querkräfte zu der Normalkraft aus Fahrzeug und Fahrer geometrisch addieren.

Als Ausgangsbasis für die Betrachtungen zur Bremsdruckregelung in der Kurvenfahrt ist zuerst als Referenz eine Geradeausfahrt mit ABS Bremsung aus 100 km/h bis zum Stillstand dargestellt (Bild 11). Die gefilterten Radgeschwindigkeiten von Vorder- und Hinterrad sind in Bezug auf den Bremsdruck im Vorderradbremszylinder dargestellt. Am unteren Rand der Graphik ist die Schräglage gezeigt.

4 Messtechnische Ergebnisse und Systemgrenzen

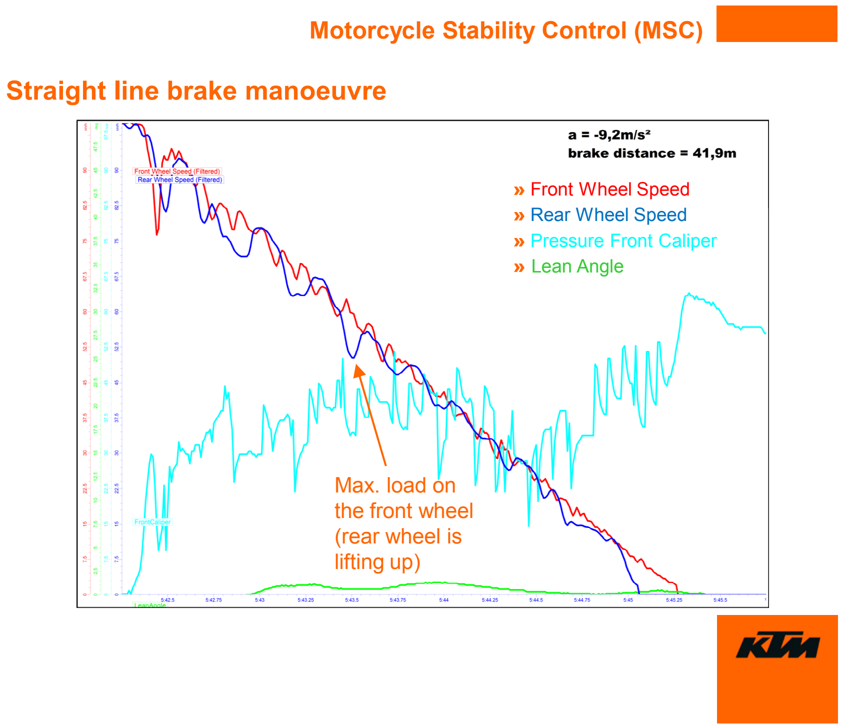

Bild 11

Das Regelprinzip der Radgeschwindigkeiten ist ein Stabilitätsregler. Dabei wird auf der Basis der Reibwert/Schlupfkurve der Druck in den Radbremszylindern so geregelt, dass das Maximum nur mit kleinen Abweichungen eingehalten werden kann. Das stellt sich in der Darstellung mit einer geringen Welligkeit der Radgeschwindigkeiten dar und bedeutet eine maximale Verzögerung und Stabilität des Fahrzeuges. Hebt das Hinterrad ab, wird zur Kompensation ein Impuls durch einen kurzer Druckabbau am Vorderrad erzeugt.

Ist das Rad wieder am Boden, kann es auch wieder beschleunigen und durch den Kontakt mit der Fahrbahn Seitenführungskräfte aufnehmen. Kurz vor Stillstand kommt es einmal zu einem beherrschbaren Hinterradabheber mit dem Vorteil eines kurzen Bremsweges.

Der resultierende Bremsweg ist 41,9m bei einer durchschnittlichen Verzögerung von 9,2 m/s².

Als Vergleich wir der Versuch unternommen, ebenfalls aus 100 km/h aber ohne MSC und ABS und in Schräglage einen möglichst kurzen Bremsweg zu erreichen (Bild 12).

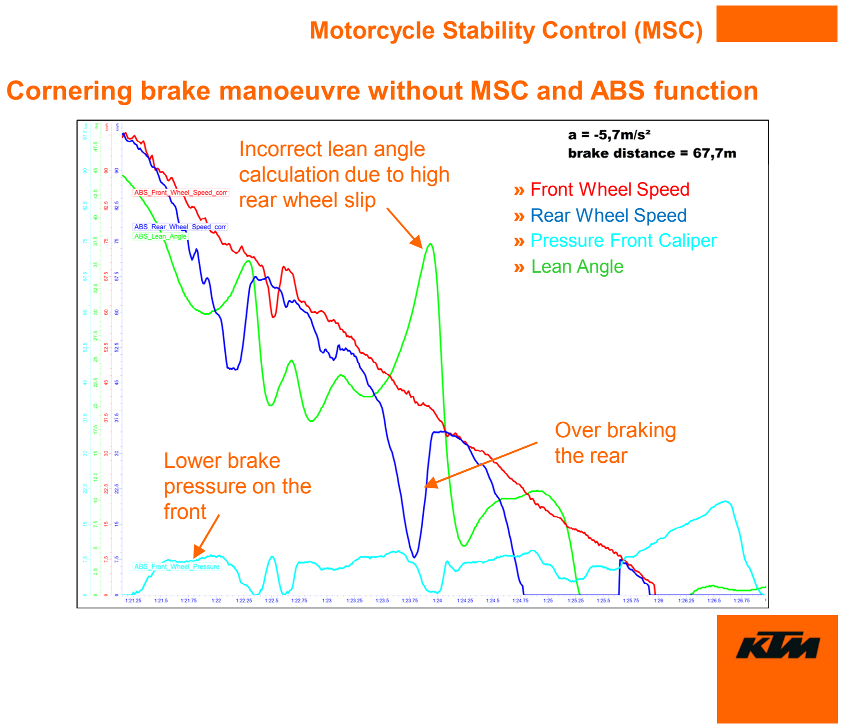

Bild 12

Die Anfangsschräglage beträgt 45° und reduziert sich, bedingt durch die Reduzierung der Geschwindigkeit auf 30°. Der sehr gut trainierte Fahrer wird aber durch einen hohen Schlupf am Hinterrad wieder in eine größere Schräglage gezwungen, die er dann durch aktives Fahren auszugleichen versucht. Die korrekte Schräglagenberechnung benötigt die Radgeschwindigkeiten. Ist, wie in diesem Fall für eine längere Zeit die Hinterradgeschwindigkeit sehr viel geringer als die Fahrzeuggeschwindigkeit kommt es zu einer Fehlberechnung. Diese wir sofort korrigiert, wenn das Rad wieder beschleunigt und mit dem Vorderrad übereinstimmt. Am Ende der Fahrt ist das Hinterrad für eine längere Zeit in der Luft und der Fahrer versucht durch Reduzierung der Bremskraft am Vorderrad einen Überschlag zu verhindern.

Die durchschnittliche Verzögerung beträgt 5,7 m/s² beim Anhalteweg von 67,7 m.

Wenn das Manöver mit der MSC Funktion durchfahren wird, fallen in der Darstellung sofort zwei wesentliche Unterschiede auf (Bild 13).

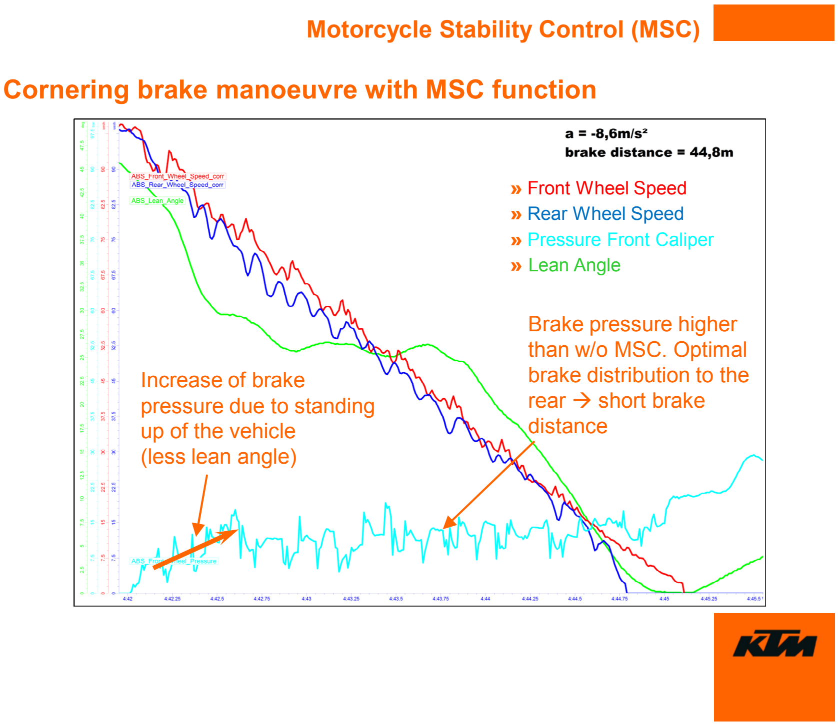

Bild 13

Ersten ist der Bremsdruck am Vorderrad im Mittel deutlich höher und die Schräglage hat einen kontinuierlichen Verlauf. Durch die optimierte Verteilung der Bremskraft auf Vorder- Hinterrad kann ein sehr kurzer Bremsweg erreicht werden. Ein Bremsweg von 44,8m im Vergleich zu 41,8 m in der Geradeausfahrt, mit einer erreichbaren durchschnittlichen Verzögerung von 8,6m/s², können ohne ein Regelsystem auch von einem sehr guten Fahrer nicht erzielt werden.

Das Hinterrad bleibt kontrolliert am Boden und kann Seitenführungskräfte aufnehmen. Die Änderung der Schräglage ist gleichmäßig. Nach dem Stillstand muss der Fahrer das Fahrzeug abstützen.

Entscheidend für die Sicherheit oder den theoretischen Schaden ist die Restgeschwindigkeit eines Motorrades ohne MSC-Regelsystem an der Stelle, an der das Vergleichsfahrzeug mit MSC-Regelung bereits zum Stillstand gekommen ist (Bild 14).

Comparison of a MSC and a "normal" brake manoeuvre

	Straight line	Cornering with MSC	Cornering w/o MSC
deceleration	9,2 m/s²	8,6 m/s²	5,7 m/s²
Brake distance	41,9 m	44,8 m	67,7 m
Speed after brake distance with MSC			58,2 kph

*Speed at the beginning of the brake manoeuvre 100 kph, and lean angle 45°

Bild 14

58 km/h ist für die dann noch resultierende Energie ein Wert, der für den Fahrer und Beifahrer ein erhebliches Verletzungsrisiko darstellen kann.

Das der Bremsweg in der Kurve etwas länger ist als bei Geradeausfahrt, ist durch die Erklärungen zum „Kamm´schen Kreis" physikalisch nachweisbar.

In dem Vergleich der Messungen ist eine wesentliche Grundlage die Fahrzeugbeherrschung durch den Fahrer. Die Schräglage von 45° wird bei 100 km/h bei einer Kreisfahrt mit einem Radius von 80m erreicht (Bild 15).

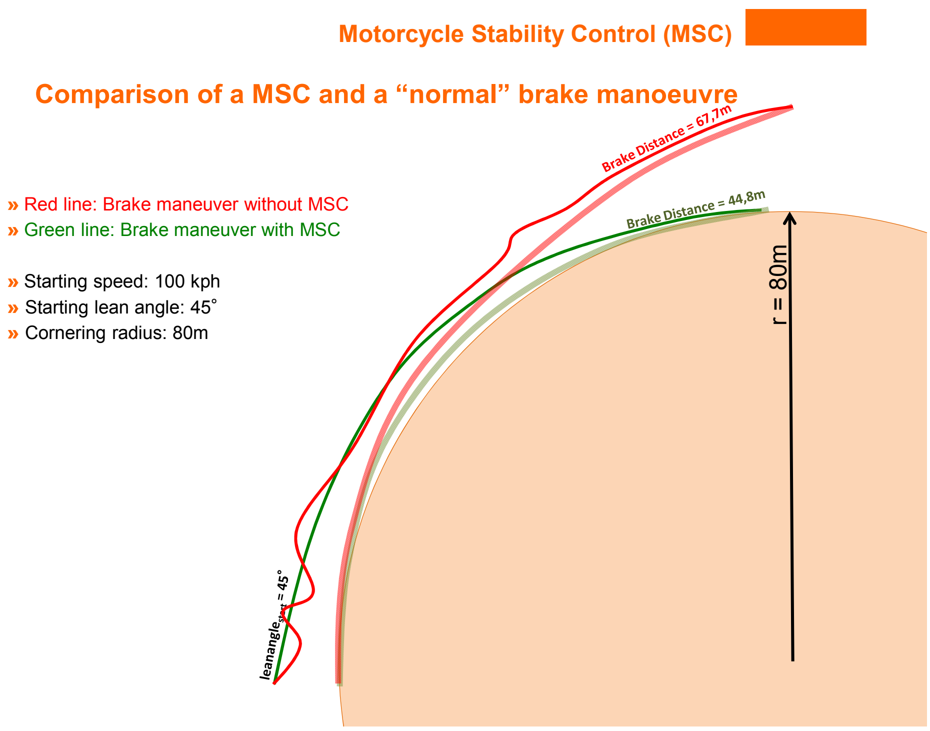

Bild 15

Während das Fahrzeug mit MSC während der Bremsung fast ideal dieser Kreisbahn folgen kann, benötigt das Fahrzeug ohne MSC deutlich mehr Raum, also Platz auf der Straße. Dieser Platzbedarf ist in vielen Verkehrssituationen von entscheidender Bedeutung, vor allem im Hinblick auf die Gefahren durch andere Verkehrsteilnehmer.

Die Kontrolle der Schräglage zusätzlich dazu dargestellt zeigt, den hohen Anspruch an den Fahrer für diese Manöver. Es kann davon ausgegangen werden, dass ein Sturz ohne MSC nicht unwahrscheinlich ist.

Welche Situationen bereits mit einem ABS beherrscht werden können, ist in dieser Tabelle für verschieden Fahr- und Straßenbedingungen dargestellt (Bild 16). Dabei wird in beherrschbar, gerade noch beherrschbar, nicht beherrschbar und physikalisch nicht möglich unterschieden.

Motorcycle Stability Control (MSC)

Which System works in which situation

ABS					
	dry asphalt µ 1,0 – 0,8	wet asphalt µ 0,7 – 0,6	wet basalt µ 0,4 – 0,3	µ jump high --> low	µ jump low --> high
straight line					
low lean angle cornering lower that 20°					
medium lean angle cornering between 20° and 30°			Situation not possible		
high lean angle cornering higher than 30°			Situation not possible		Situation not possible

Speed at the beginning of the brake manoeuvre 100 kph

Bild 16

Bis zu einer Schräglage von ca. 20° ist auf trockenem Asphalt eine ABS Bremsung beherrschbar. Das gilt auch für den schnellen Wechsel von niedrigem auf hohen Reibwert.

Alle anderen Situationen sind nicht beherrschbar oder unmöglich zu erreichen.

Diese physikalischen Grenzen bleiben natürlich auch mit MSC bestehen.

Für alle anderen Fälle ändert sich das mit MSC gravierend (Bild 17).

Motorcycle Stability Control (MSC)

Which System works in which situation

MSC					
	dry asphalt µ 1,0 – 0,8	wet asphalt µ 0,7 – 0,6	wet basalt µ 0,4 – 0,3	µ jump high --> low	µ jump low --> high
straight line					
low lean angle cornering lower that 20°					
medium lean angle cornering between 20° and 30°			Situation not possible		
high lean angle cornering higher than 30°			Situation not possible		Situation not possible

Speed at the beginning of the brake manoeuvre 100 kph

Bild 18

An der Grenze befindet sich der Fahrer mit dem Fahrzeug bei großen Schräglagen auf nassem Asphalt oder Basalt und bei einem Wechsel von hohem Reibwert auf einen niedrigen. Für den umgekehrten Fall des Reibwertsprungs verschiebt sich das Fenster zu größeren Schräglagen.

Der Übergang von hohem Reibwert auf niedrigen in größeren Schräglagen kann bereits ohne Bremsung nicht mehr beherrschbar sein. Die Erklärung dazu liefert ebenfalls der „Kamm´sche Kreis“, das Vorderrad kann die Seitenführungskräfte nicht mehr aufnehmen.

Die Funktion des MSC kann durch verschiedene Faktoren beeinflusst werden (Bild 18).

Bild 18

Dazu gehören die Abstimmung der Feder/Dämpfercharakteristik, die Zuladung und deren Verteilung, die einen Einfluss auf den Schwerpunkt nimmt, die Bremsbeläge und Bremsscheiben mit ihrer Materialpaarung und vor allem die Reifen und die Fahrbahnoberfläche.

Diese vielfältigen Faktoren und ihre Kombination verschieben die Grenzen der MSC- Wirksamkeit, wobei immer mehr Sicherheit für eine stabile Bremsung erhalten bleibt, als ohne MSC oder natürlich ohne ABS.

Das wird aus verschiedenen Berichten von Fahrversuchen bestätigt.

5 Weiterentwicklungen in der Motoradsicherheit

Der Fortschritt der mit der MSC-Entwicklung erreicht wurde, lässt sich in der Zukunft noch weiter ausbauen. Die Sicherheit von Motorradfahrern kann durch die Technik im Fahrzeug, Maßnahmen für den Fahrer selbst und die Infrastruktur gesteigert werden.

Die Unfallvermeidung steht im Vordergrund, aber eine Erweiterung des Schutzes und eine schnelle Rettung im Falle erheblicher Verletzungen sind in diese Strategie mit einzubeziehen (Bild 19).

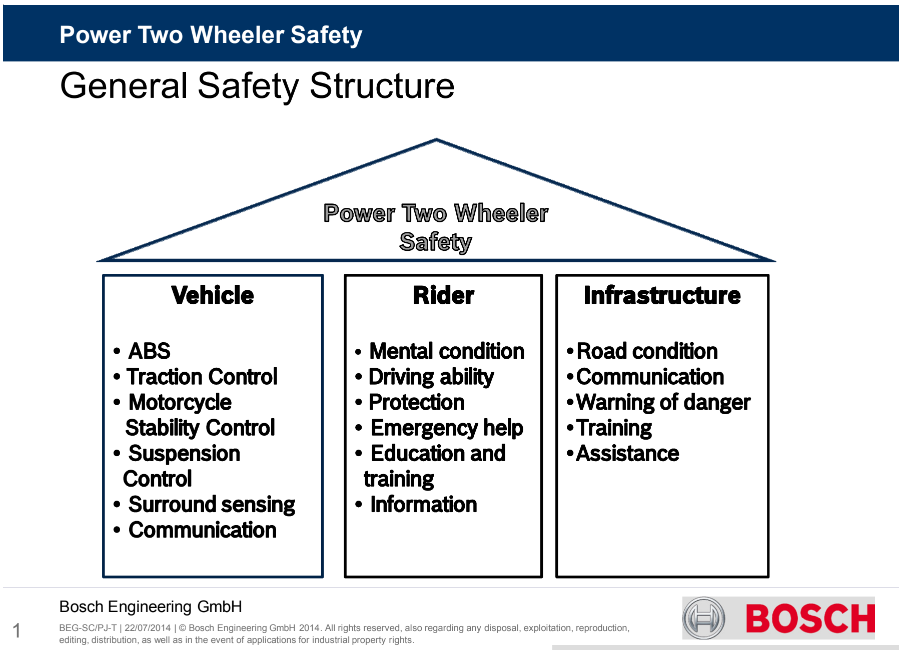

Bild 19

Die Fahrzeugtechnik hat die größten Schritte in den letzten Jahren gemacht. Die Einführung von ABS bis zur MSC Funktion in Kurven kann zukünftig noch erweitert werden. Die nächste technische Komponente stellt die Fahrwerksregelung dar. Für die Unterstützung der Wahrnehmung der Umgebung und des Verkehrs sind Entwicklungen wie „blind spot detection" bis zur B2X-Kommunikation wiederum als Ableitung der großen Aktivitäten für den PKW naheliegend. Allerdings müssen für die Kommunikation mit dem Fahrer motorradspezifische Wege erforscht und untersucht werden. Der Bereich der Wahrnehmung von Informationen ist durch den wesentlich aktiveren Einsatz des Fahrers in die Erhaltung der Fahrstabilität stark eingeschränkt.

Diese körperliche und mentale Einbindung des Fahrers in die Fahrzeugführung kann durch Ermüdung und/oder mangelndes Training erheblich beeinträchtigt werden. Dazu können ihm in der Zukunft dienliche Hinweise gegeben werden. Im Falle eines Sturzes bietet die Verbesserung der Kleidung und insbesondere die Wirkung eines Airbags am Körper eine große Chance, die Unfallzahlen mit Todesfolge deutlich zu reduzieren. Ein weiteres Potential liegt in der Erweiterung der Vorausschau durch Hinweise auf Gefahren die noch nicht ersichtlich sind.

Das setzt voraus, dass die Infrastruktur dafür zur Verfügung steht. Eine „Fahrzeug zu Fahrzeug-Kommunikation" kann sowohl dem Motorradfahrer einen Hinweis geben, als auch dem anderen Verkehrsteilnehmer die Möglichkeit, sich auf die Besonderheit der Situation einzustellen. Das erweitert das Training und leistet eine Assistenzfunktion in unübersichtlichen Verkehrsverhältnissen.

An dem Beispiel der Einstellmöglichkeiten am Fahrwerk moderner Motorräder ist die Komplexität der der technischen Möglichkeiten ersichtlich. Die Fahrzeuge werden mit vielfältigen Einstellmöglichen der

Federung und Dämpfung ausgestattet, aber nur ein sehr kleiner Kreis von Experten ist in der Lage diese optimal zu nutzen (Bild 20).

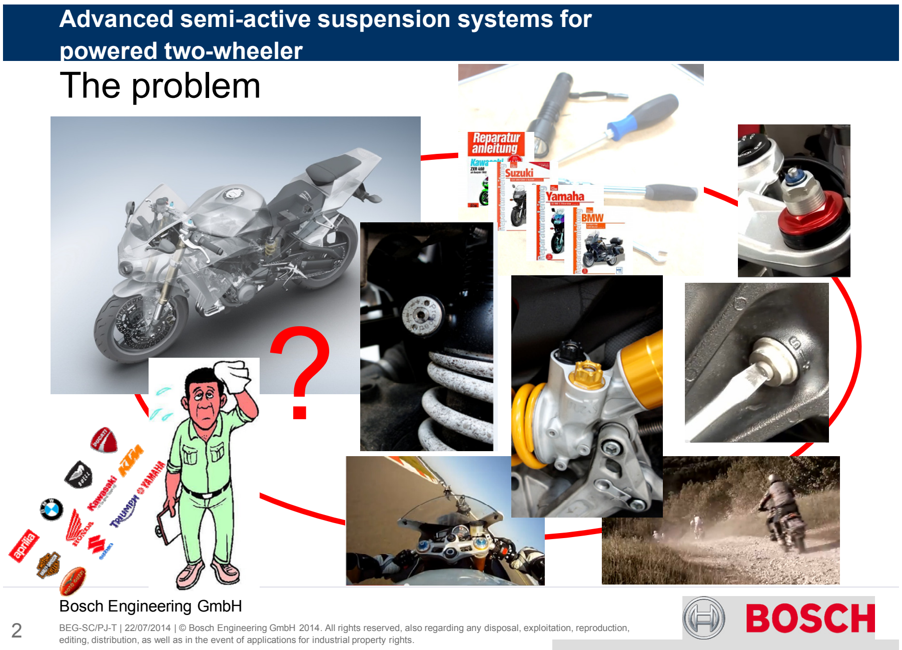

Bild 20

Das bezieht sich nicht nur auf die Grundeinstellungen im Stillstand sondern auch auf die Veränderungen während der Fahrt. Wir die Fahrt auf gut ausgebauten Straßen begonnen, so können doch im Laufe eines Tages veränderte Bedingungen, wie leichte Geländeabschnitte, zu bewältigen sein. Dafür jeweils eine passende Fahrwerkabstimmung zu haben bietet die semi-aktive Fahrwerksregelung.

Diese, im ersten Anschein, Komfortfunktion bietet auch ein erhebliches Potential zu Verbesserung der Fahrsicherheit. Welche Wechselwirkungen sich ergeben können ist in Bild 21 und Bild 22 dargestellt.

Advanced semi-active suspension systems for powered two-wheeler

Semi active suspension – main contribution #1

Braking - ABS
Improvement of braking stability by increasing compression ratio in the initial phase of an emergency braking. Decrease of rebound setting to keep tyre in close contact to road. Reduction of braking distance.

Driving – drive by wire
Modifying compression and rebound value depending on speed and road surface roughness.

Acceleration – TCS Traction control
Depending on the acceleration and deceleration level the pitch angle is reduced to achieve better control of the bike.

Cornering – MSC Motorcycle stability control
During the high deceleration phase in corners compression and rebound adjustment is optimized for bike stability and braking distance.

3 Bosch Engineering GmbH

BOSCH

Bild 21

Advanced semi-active suspension systems for powered two-wheeler

Semi active suspension – main contribution #2

Additional load – Load adjust
Depending on load e.g. fuel tank, luggage, passenger and individual body weight (two users) the setting is optimized in correspondence to the ride level adjustment as well.

Weather conditions – Rain sensor
With manual setting of rain mode or by reading a rain sensor the suspension is modified to a softer set up to maintain best contact of tyres to the road.

4 Bosch Engineering GmbH

BOSCH

Bild 22

Die Steigerung der Beherrschbarkeit des Fahrzeuges reduziert den Anspruch an den Fahrer zur Fahrzeugführung und eröffnet Raum für die Verkehrsbeobachtung. Mit dem gesteigerten Vertrauen in die eigenen Fähigkeiten werden die Anspannung und die Stressfaktoren geringer.

Für die Fahrzeuge bietet die installierte Sensorik eine gute Möglichkeit den Fahrzustand und die Dynamik zu erfassen. Um das auch für den Fahrer möglich zu machen, ist eine zusätzliche Sensorik notwendig. Dafür eignet sich in besonders der Helm, weil es eine Tragepflicht gibt und ein enger Kontakt mit dem Kopf zwingend für die Schutzwirkung ist. Dadurch hat eine Sensorik Zugang zu den Vitalitätsdaten des Fahrers. Eine Inertialsensorik im Helm zeigt die Bewegungsabläufe.

Aus der Kombination der verschiedenen Information können wichtige Rückschlüsse über das Befinden gezogen werden. Informationen der Herztätigkeit in Verbindung mit der Atemfrequenz deuten auf den Stressfaktor hin. Die Temperatur und die Hautfeuchtigkeit über die Zeit in Verbindung mit der Pulsfrequenz, können ein Maß für die Belastung darstellen und aus den Bewegungsinformationen ist ein Rückschluss auf einen Sturz oder eine Bewegungsunfähigkeit möglich. Bringt man diese Informationen in Verbindung mit Daten aus dem Fahrzeug, so lassen sich Aussagen über die Häufigkeit von Fahrfehlern treffen und das bietet dem Fahrer die Möglichkeit durch Selbstbeobachtung zu lernen. Die Wirksamkeit von Training sowohl in körperlicher Hinsicht, als auch auf die Fähigkeit zur Fahrzeugbeherrschung, wird persönlich dokumentierbar (Bild 23).

Bild 23

Durch die enge Kopplung des Kopfes und dem eingeschränkten Sichtfeld ist ein Rückschluss auf die Blickrichtung gegeben. Damit lassen sich Beobachtungen der Aufmerksamkeit für Verkehrssituationen, Warnhinweise und Fehler in der Blickführung gut ableiten. Gerade bei Regen wird sehr häufig der Blick zu dicht vor das Fahrzeug gerichtet. Damit verliert der Fahrer Möglichkeiten sich an den Streckenverlauf anzupassen. Unter der Randbedingung, dass eine B2X Kommunikation vorhanden ist, können zusätzliche Warnhinweise auf die Fälle beschränkt werden, bei denen davon auszugehen ist, dass der Fahrer nicht die entsprechende Aufmerksamkeit gezeigt hat. Aber auch bereits eine Nichtbeachtung einer Vorfahrtsregelung in Verbindung mit einem GPS an einer Kreuzung ist mit einfachen Mitteln vorstellbar.

Sollte es trotz aller Vorsichtmaßnahmen zu einem Sturz kommen, bietet die Körperdynamik eine Erweiterung der Auslösealgorithmen einer Airbag-Schutzweste.

Die Informationen über den Ablauf der Instabilität bei einem Sturz enthalten wertvolle Daten für die Beurteilung der Schwere eines Unfalls. Die Geschwindigkeit zum Zeitpunkt der Trennung von Fahrer und Fahrzeug und die Zeit bis zum Stillstand, ist ein Maß für die Energie die auf dem Körper gewirkt hat. Diese Daten können zur Beurteilung der Lage, im Fall das ein eCall ausgelöst worden ist, eine wesentliche Erweiterung darstellen. Eine Sprachverbindung mit einer Notrufzentrale kann nicht sichergestellt werden.

Die Algorithmen die hinter der Erfassung von Stabilitätskriterien der Fahrdynamik stehen, mit Abwandlungen für alle gezeigten Anwendungen nutzbar. Die Ausrüstung des Fahrers mit Sensoren, deren Informationen drahtlos an das Fahrzeug gesendet werden, ist mehrfach und individuell nutzbar. Die Entscheidung über diese Nutzung kann der Fahrer treffen und auch durch Software auf verschiedenen Medien gestalten.

Die Realisierung von Sicherheitsmaßnamen am Fahrzeug, Fahrer und in der gesamten Infrastruktur biete als ganzheitliche Lösung nochmals eine deutliche Reduzierung von Verletzungen und Todesfällen bei Motorradfahrern.

6 Zusammenfassung – Summary

Der Systemaufbau des Motorcycle Stability Control MSC wurde am Beispiel der KTM 1190 Adventure gezeigt. Die Kundenerwartungen sind die Entwicklung des Systems einbezogen. Die Grundlagen der Kräfteverhältnisse am Reifen werden für die verschiedenen Reibwerte in der Kurven- und Geradeausfahrt mit dem Kamm'schen Kreis in ihrer MSC-Systembedeutung erklärt. Die graphische Darstellung der Bremsdrücke, Radgeschwindigkeiten und der Schräglage ermöglicht ein Verständnis über Unterschiede einer Bremsung mit und ohne MSC-Unterstützung.

An dem Beispiel der semi-aktiven Fahrwerksregelung und ersten Überlegungen zu Unterstützung des Fahrers selbst, kann das Potential zu Verbesserung der Motorradsicherheit dargestellt werden. Diese Maßnahmen sind als ganzheitlicher Ansatz aufgebaut.

The system design of motorcycle stability control MSC is shown with example of the KTM 1190 Adventure. Customer expectations are considered during the development of the system. The basic forces acting on the tire for MSC are explained for different friction coefficients during cornering and straight driving by the "Kamm'schen Kreis". Through graphs of brake pressure, wheel speed and lean angle differences between braking with and without MSC is made understandable.

With the example of semi-active suspension, initial concepts are shown to support riders and to increase motorcycle safety. These ideas will be covered in the future comprehensively.

Improved Safety for Motorcycles, Scooters and Mopeds – Summary and Conclusions of the ITF/OECD Working Group

Verbesserte Sicherheit für Motorräder, Roller und Mopeds – Zusammenfassung und Ergebnisse der ITF/OECD-Arbeitsgruppe

Véronique Feypell de la Beaumelle

International Transport Forum, The Organisation for Economic Co-operation and Development (OECD)

IMPROVED SAFETY FOR MOTORCYCLES, SCOOTERS AND MOPEDS

SUMMARY AND CONCLUSIONS OF THE ITF/OECD WORKING GROUP

FINAL DRAFT

SEPTEMBER 2014

KEY MESSAGES

1. **Powered two-wheeler (PTW) numbers are growing and PTWs play a significant role in mobility**

   The powered two-wheeler population (which includes motorcycles, scooters and mopeds) has been constantly increasing and PTWs play a significant role in mobility in many countries, particularly in many of the world's large cities. Some riders use PTWs as their primary form of transport, others for recreation. For many it is the only affordable or practical means of individual motorized mobility.

2. **It is essential to consider PTWs needs in transport policy.**

   PTWs are becoming an important component of the transport system, which in many countries has given the priority to 4 wheel vehicles. PTWs now need to be properly integrated into mobility plans.

3. **PTW riders are at far more risk than car drivers**

   PTW riders are at far more risk than car drivers per km ridden in terms of fatalities and severe injuries entailing long-term disability. Moreover, they have not benefited at the same pace as car occupants from safety improvements over the recent decades. In OECD countries, they represent 17% of total fatalities on average, while PTWs account for about 8% of the motorized vehicle fleet. PTW fatalities often comprise a much higher proportion of total fatalities in low- or middle-income countries. In addition to human lost and associated pains, the economic costs associated with PTW crashes are significant. Investing in PTW safety can therefore bring important societal and economic benefits.

4. **Failures of perception and control are frequently implicated in PTW crashes**

   The most frequent PTW fatal crashes are: collisions at intersections, commonly involving problems of perception and appraisal by both the driver and the rider, and single-vehicle crashes, due to PTWs being more sensitive to external perturbations (for example road surface or weather conditions). Speeding (which encompasses excessive and inappropriate speed) and consumption of alcohol and drugs are critical factors in the occurrence and severity of PTW crashes, as for other road users.

5. **A safe system approach is required to improve the safety of PTWs**

   Growing PTW traffic makes it imperative to adopt safety interventions targeting this mode of transport, while integrating it into a safe system approach. The safe system approach recognises that road users can make mistakes or take inappropriate decisions. The role of the system is both to minimize the production of these errors and to protect road users from death and serious injuries when errors occur. While a safe system approach concern all countries, a tailored approach is required to take into account the local specificities when addressing powered two-wheeler safety.

6. **Improving PTW safety is a shared responsibility of all stakeholders**

   Improving the safety of PTWs should be a shared responsibility. All relevant stakeholders, including civil society organisations, need to be actively involved in the process of drawing up and implementing a shared road safety strategy which includes safer behaviour of all road users, safer infrastructure and vehicles with enhanced safety features. PTW safety is not only the responsibility of governments, administrations, and manufacturers, but also PTW associations, insurance companies, the media, etc.

7. A toolbox of measures is required to improve the safety of PTW riders

A toolbox of measures is required to improve the safety of PTW riders within the traffic system. These measures must take into account the specific challenges associated with PTW mobility and also consider the variety of PTW users, insofar as some segments may be addressed with particular measures. A strategic approach should consider the most effective combination of measures according to the specific needs of individual jurisdictions.

8. Promoting appropriate behaviours of road users is a prerequisite

Licensing, training and education are essential tools for improving riding safety. Access to PTWs should be gradual, with a licensing system aiming to manage novice rider risks while riders are gaining experience and maturity.

Training for riders and drivers is an important to promote safer behaviours. In particular, novice riders of every kind of PTW should be trained. Training should not only focus on basic manoeuvring skills and mastering traffic situations, but also address attitudes towards safety, putting a special emphasis on hazard perception and defensive riding. Training should be designed to promote safe behaviours; performance focused training has not proven effective in increasing safety.

Other road users should also be made aware of the specific risks associated with the vulnerability and crash patterns of PTWs.

Enforcement of traffic rules is an indispensable ally of other safety measures. PTW operators, as with other operators of motorized vehicles, must comply with traffic rules. Enforcement activities to control speeding, drink driving, and non-respect of traffic rules apply equally to all motorized vehicle drivers.

Communication campaigns addressing required behaviour changes should be targeted at key groups of drivers and riders.

9. Helmets provide the most important protection against severe injuries and death

A helmet dramatically reduces the risk of being killed or severely injured and should be worn by riders and passengers of motorcycle and moped riders. All countries should have and enforce a helmet law. A 100% wearing rate is the only acceptable objective. In addition, the wearing of protective clothing with adequate safety standards – adapted to regional conditions - is essential to reduce the severity of injuries and should be promoted.

10. Vehicles with enhanced safety features can save lives

The car and motorcycle industries are continuously developing safety devices to both avoid crashes and mitigate their consequences. The prevention of crashes (also called active safety) is crucial for the safety of motorcyclists. Enhanced safety features in PTWs should be adopted, notably with the general introduction of advanced braking systems. Crash avoidance systems on board other vehicles may also contribute to reducing collisions with PTWs.

11. **Self-explaining and forgiving roads contribute to lower crash risk**

Infrastructure should be improved with the development of self-explaining roads – to guide drivers and riders to adopt appropriate behaviours speeds –, traffic calming measures and PTW-friendly infrastructure (forgiving roads).

The consequences of crashes are particularly exacerbated for PTWs by the aggressiveness of obstacles. Infrastructure measures, including the design of junctions (for example round-abouts) and the choice of barriers and road surfaces, require an integrated impact assessment taking into account all roads users and local conditions.

Engineers, road designers and providers, local authorities, road safety auditors and inspectors should be trained to consider PTWs in the design, construction, maintenance and operation of roads, and be provided with the necessary risk assessment tools to make the right decisions.

12. **It is essential to extend our knowledge of PTW mobility and crash mechanisms**

Additional research is needed to better understand current challenges related to PTW mobility and safety. There is a great need to develop and apply relevant methods, tools and indicators to measure PTWs in traffic flows and analyse their mobility and behaviour. In particular, exposure data are needed to better understand the specific crash characteristics of PTWs. More in-depth investigations will allow a better understanding of fatal and serious injury crash patterns and causes. Lack of conspicuity and other perception problems deserve further study in order to identify key contributing factors and effective countermeasures.

Operational research and development is needed to achieve a traffic system which better integrates and protects PTWs in a cost efficient manner. Intelligent Transport Systems (ITS) require more research and development on its capacity to prevent and mitigate PTW crashes. Further investigation is required regarding the content and effectiveness of training, including post-licence training, with the aim of improving the behaviour of both drivers and riders.

SUMMARY AND CONCLUSIONS

1. The role of PTWs in mobility

The powered two-wheeler population increases and plays a significant role in mobility.

The powered two-wheeler population (which includes motorcycles, scooters and mopeds) has been constantly increasing and plays a significant role in mobility in many countries, particularly in many of the world's large cities.

Worldwide the current production of PTW is around 50 million units per annum to be compared with around 65 million units for passenger cars. In the various OECD countries, PTWs account for between 2 to 31% of the motorized fleet; the highest percentage generally being found in countries with a mild climate. PTWs can be the dominant motorized transport mode in some developing and emerging countries, comprising up to 85% of motorized vehicles. In most OECD countries, the motorcycle fleet increased much faster than the passenger car fleet from 2001 to 2010. In France for example, the PTW fleet increased by 48% in the last decade, and the car fleet increased by only 11%.

In many cities, PTWs have become a real alternative to passenger cars given the level of traffic congestion. PTWs indeed present a number of advantages including flexibility, reliability of travel time, and lower cost of use compared to a private car. As a consequence, the PTW fleet has expanded very rapidly in some cities. As an example, in 2013 Rome was the European city with the largest PTW fleet, with about 700 000 PTWs (compared to 1.9 million passenger cars).

Some riders use PTWs as their primary form of transport, others more for recreation. For many it is the only affordable or practical means of individual motorized mobility. In Europe, PTWs are commonly used for commuting, but this is less common in the United States, Canada or Australia, where the primary purpose of PTW use is often recreational riding. In some low and middle income countries, PTWs are the main mode of individual motorized transport and considered to be the family vehicle.

The PTW rider population is composed mostly of males, but the trend is changing with more and more females also riding. In many OECD countries, there is an increasing number of "returning" riders, i.e. typically males in the 40-50 year age group, who stopped riding a PTW for a period of more than 5 years, who usually return to riding on powerful motorcycles.

It is essential to take into consideration PTWs needs in transport policy.

PTWs are becoming an important component of the transport system and in some cities represent up to 30% of the motor vehicle fleet. They present both assets for mobility, and also challenges in terms of traffic management and safety. However, only a few countries have in place a national transport strategy for PTWs; though several measures have been taken at local level.

Traditionally, the transport system in many countries has primarily focused on the traffic of four wheeled vehicles. There would be many benefits, in terms of mobility and traffic management as well as traffic safety, in a better integration of PTWs into mobility plans and in the development of national and local transport strategies.

2. Safety issues for PTWs

PTW riders are at far more risk than car drivers

In OECD countries, PTWs represent on average 8% of the motorized vehicles but 17% of total fatalities. This share is much higher in low and middle income countries, where PTWs can represent up to 70% of road fatalities. They have not benefited at the same pace as car occupants from safety improvements over the recent decades. While, on average, OECD countries have seen a reduction of about 36% in the number of persons killed in traffic crashes in 2000-2010, the number of motorcyclists killed has decreased by only 13%. The discrepancy is particularly obvious in the United States, where the number of motorcyclists killed increased by 44% between 2001 and 2011, while the number of passenger car occupant fatalities decreased by 29%.

Per kilometre driven, PTW riders have a much higher risk of being killed than car occupants. For a motorcyclist the risk is, depending on the country, between 9 and 30 times higher; the increased risk is slightly lower for moped riders. PTW riders are also more likely to be very seriously injured in a road crash with long term disabilities than other motorized road users. As the large majority of motorcyclists are younger than other motorized road users, this translates in many years lost or with lost capacities.

Addressing the safety issues of powered two-wheelers should be seen as a priority in all countries to improve overall road safety. It is one of the main challenges in the context of the UN Decade of Action for Road Safety.

In addition to the human tragedy associated with PTW crashes, their economic consequences are significant; therefore investing in PTW safety can bring important societal and economic benefits.

Poor perception and control are frequent failures that lead to PTW crashes

Poor perception and control are frequent failures that lead to PTW crashes. The most common PTW fatal crashes occur at intersections with other traffic, often involving a problem of perception and appraisal by the driver and/or the rider. The other most frequent crash type are single-vehicle crashes, notably due to intrinsic difficulties of riding a PTW (e.g. necessity to keep the balance) and to the higher sensitivity of riders to external perturbations (e.g. wind or poor pavement condition). The consequences of crashes are particularly aggravated for PTWs by the aggressiveness of roadside obstacles.

The problem of perception is complex and involves a variety of parameters: the visual characteristics of PTWs, the sensory capabilities of the human perceptual system, the atypical behaviour of PTWs and the familiarity with PTWs in traffic.

As for other road users, speeding (i.e. driving above the speed limit or with an inappropriate speed) and consumption of alcohol and drugs are critical factors in the occurrence and severity of crashes. Operating a PTW requires more co-ordination, balance and alertness than operating a car, which explains that impaired riding is even more problematic for PTW riders.

A more frequent combination of road crash contributory factors is found in PTW crashes, compared to other road users crashes, which results in the multiplication of the relative risk of PTWs.

Human behaviours and conditions are the most frequently represented contributing factors in PTW crashes. However this does not mean that solutions to improve the safety of PTWs must only focus on behaviours. A safe system approach is required; it can be more efficient to change crash and injury outcomes by implementing a range of interventions, including road users, the infrastructure, the vehicle and the system as a whole.

3. PTW safety in the context of a safe system

A safe system approach is required to improve the safety of PTWs

The safe system approach recognises the fact that road users can make mistakes, or take inappropriate decisions; the role of the system is first to minimize the production of these errors and secondly to prevent road users from death and serious injuries when errors occur.

Effective strategies have been shown to be based on specific absolute targets. They should be supported by regular evaluation of progress against outcome measures relevant to each intervention. The results of the evaluation allow adjustments to plans to ensure ongoing effectiveness of the strategy and continuous improvement in implementation.

Inclusion of PTW users into the Safe System yields two challenges. The first is the technical challenge of providing protection from physical harm at the speeds at which collisions with other vehicles or fixed objects are likely. While this could be solved by ensuring travel speeds of, and in the vicinity of, PTWs are much lower, this then amplifies the second challenge, which is to ensure that any measures taken to improve PTW safety are supported both by the broader community and by PTW riders in particular.

This leads to consideration of whether the conventional Safe System approach should be modified by recognising that, in the short to medium term, PTW riding will remain an inherently risky activity and that measures should be taken to reduce risk. This may result in, for example, strategies that focus more on avoiding crashes, rather than mitigating their effects.

Improving PTW safety is a shared responsibility between all stakeholders. A safe system also calls for a shared responsibility on the road and to be accountable for one’s own actions. Improving the safety of PTWs requires all relevant stakeholders to be actively involved in the process of drawing up and implementing a shared road safety strategy which includes safer behaviour of all road users, safer infrastructure and vehicles with enhanced safety features. This shared responsibility should also extend to the planning for road safety and the implementation of road safety management systems. PTW safety is not only the responsibility of governments, administrations and manufacturers, but also PTW associations, insurance companies, the media, etc.

While a Safe system approach is adapted to all countries, whatever their level of development and safety performance, it must acknowledge that the usage of PTWs greatly varies in various parts of the world. A tailored approach is required to adequately take into account the local specificities.

A toolbox of measures is required to improve the safety of PTW riders

A toolbox of measures is required to improve the safety of PTW riders within the traffic system. These measures must take into account the specific challenges of PTW traffic, and also consider the variety of PTW users, insofar as some segments may be addressed with particular measures. A strategic approach should consider the most effective combination of measures according to the specific needs of individual jurisdictions. The measures are developed in the points below. Developing countries often lack basis standards for roads and road safety. In these cases priority should be given to securing basic infrastructure and an inclusive approach towards motorcycling in transport policies, including training and education of riders, helmet law, etc.

4. Countermeasures

Promoting appropriate behaviours of road users:

The Safe System approach assumes that road users will enter the system competent and will take measures to ensure that they remain compliant and alert. Licensing, training, education, and enforcement campaigns are essential tools for improving riding safety.

Licensing, training and education

Access to PTWs should be gradual, with a licensing system aiming to manage novice rider risks while riders are gaining experience and maturity. The licensing system should also ensure that mature novice riders directly accessing high-powered motorcycles possess the skills, knowledge and correct attitude to safely drive these vehicles.

Several countries have adopted graduated licensing schemes. These schemes are designed to provide new riders with driving experience and skills that can be developed gradually over time in low-risk environments. The rider obtains a licence by passing through a number of stages; restricted, provisional or probationary and full licence.

In Europe, Member States of the European Union have a harmonized licensing system. The 3rd Driving Licence Directive came into force in January 2013 and mandates a strict graduated approach towards heavier machines. The Directive requires a minimum age of 24 to ride the A category (> 35 kW). However, the subsidiarity principle applies and countries can adapt the Directive.

Training for riders and drivers is an important measure to promote safer behaviours with the objective that they acquire a good appreciation of the road environment and its danger. Even more than for driving a car, riding a PTW requires technical skills. Novice riders of every kind of PTW should be trained. Training should not only focus on basic manoeuvring skills and mastering traffic situations, but also address attitudes towards safety, putting a special emphasis on hazard perception and defensive riding. As an attitude, defensive riding enables the rider to systematically foresee what the riskiest scenario may be at any given moment. Defensive riding allows the PTW rider to avoid, or cope with, these riskiest situations, should they occur. Training should be conceived to promote safe behaviours; performance focused training has not proved to be effective in to increasing safety.

The training challenges for PTW safety do not only address PTW riders. The *curricula* for training and education of drivers in all other vehicle categories should also focus on risk awareness when dealing with PTWs, their vulnerability, and crash patterns.

Enforcement

Enforcement of traffic rules is an indispensable ally of other safety measures. PTW operators, as other operators of motorized vehicles, must comply with traffic rules and typical enforcement activities to control speeding, drink and driving, non respect of traffic rules. Intensive, visible enforcement accompanied by other measures, such as communication and publicity has proven to have a strong deterrent effect by increasing the perceived likelihood of detection. In addition, the progressive adoption of automated speed enforcement has also proven its effectiveness in reducing speed. In this respect motorcyclist associations can also play an important role in making enforcement understood and accepted as an effective safety measure.

Communication campaigns

Communication campaigns addressing required behaviour change should be targeted at key groups of drivers, riders and other road users. Every road user should be made aware of the specific risks associated with PTWs vulnerability and crash patterns. Facilitating a safety dialogue among the motorcycling community has proven to be an effective tool to convey safety messages.

The helmet is the most important source of protection against severe injuries and death

The helmet is clearly the most important source of protection against injury for both motorcyclists and moped riders. It contributes to reduce dramatically the risk of being killed or severely injured. Helmets can prevent damage to the brain, which may result in very severe physical and psychological handicaps.

All countries should have and enforce a helmet law. A 100% wearing rate is the only acceptable objective. Still, not all OECD countries have a national helmet law. Enforcement and communication campaigns should not only focus on wearing but also on *proper* wearing of a helmet (i.e. with fastened chin strap) and on fighting, especially in low and middle income countries, against the proliferation of fake helmets.

Other protective equipment include airbag jackets and protective clothing (gloves, jackets and boots). The Working Group recommends promoting the use of this equipment with adequate safety standards. Airbag jackets appear as a promising technology to minimise injury to the rider in case of a crash and further research is needed to evaluate their effectiveness.

Regarding high visibility clothing, research shows different results regarding their effectiveness in reducing conspicuity related crashes, depending on time and location. The contrast with the road environment is the most important element: in short, when riding through highly dense traffic, a rider should wear bright clothing. When riding mostly in open-space (cruising) a rider is better off wearing darker clothing. At night reflective clothing is more effective.

Vehicles with enhanced safety features

There are a number of developments within the motorcycle industry for technologies to assist in the prevention of a crash (active safety) and to protect occupants and riders during a crash (passive safety). Some are already available and proposed as an option when purchasing the bike, while others are still at the development stage.

Anti-lock Braking System (ABS) and Combined Braking System (CBS) are well proven technologies which can significantly improve the safety of PTWs in specific traffic situations involving emergency braking. While ABS is currently offered as an option on new bikes of major PTW manufacturers, with a slow penetration rate in most OECD countries, the Working Group considers that it can certainly benefit all PTWs and should become a standard. Cost is however an issue, and industry and government should work together to facilitate a quicker penetration of these technologies, which will become mandatory in some regions in the coming years (expected in the European Union for the year 2016). While this technology is mature for OECD countries, there might be other priorities in low and middle income countries especially for the light motorcycles, as the implementation of existing lighting regulation, or in other fields the generalised use of helmets.

Advances in car technology can also bring positive safety benefits to PTW users. There are a number of new technologies, such as forward collision warning, blind spot information and vulnerable road user protection systems, which can prevent collisions, including those with PTW riders, pedestrians and cyclists.

There is a consensus that there has been little advancement of intelligent transportation systems research dedicated to motorcycle safety. ITS developed for motorcycles offer opportunities to improve the safety of the rider as well. There is, however, a number of constraints specific to PTWs that need to be carefully addressed, including the specificities of the vehicles and the riding task and the challenges posed by the Human Machine Interface requirements, costs, and the required support from the motorcyclist community.

Self-explaining and forgiving roads contribute to lower crash risk

The road environment has a significant influence on the risk of crashes involving PTWs. Contributing factors include: road surface defects (such as roughness, potholes or debris on the road); presence of slippery material (water, oil) on the road; broad line markings or use of raised pavement markers; poor road alignment; presence of obstacles, roadside hazards and safety barriers, and interactions with other road users (including heavy vehicles, cars, cyclists, pedestrians and other PTWs).

PTW-friendly road design, maintenance and infrastructure generally benefit all road users. The aim is to ensure that the safety of PTW riders is considered in the design and maintenance of roads and the implementation of traffic management plans. The design of junctions (for example roundabouts), the choice of barriers and road surfaces, require an integrated impact assessment taking into account all roads users and local conditions

A consistent road and road environment invite road users to adopt the appropriate behaviours for safe riding and driving. A self-explaining road allows road users to anticipate changes in the local road context. Infrastructure can be improved to guide drivers and riders to adopt appropriate behaviour, to prevent the occurrence of crashes and mitigate their consequences (forgiving roads).

Engineers, road designers and providers, local authorities, road safety auditors and inspectors should be trained to consider PTWs in the design, construction, maintenance and operation of roads, and be provided with the necessary risk assessment tools to make the right decisions based on an overall impact assessment.

5. Need for further research

Extending the knowledge on PTW mobility and crash mechanisms

Additional research is needed to better understand current challenges related to PTW mobility and safety problems. This involves a need to develop and apply relevant methods, tools and indicators to measure PTWs in traffic flows and analyse their mobility and behaviour (exposure data). More in-depth investigations will allow a better understanding of fatal and serious injury crash patterns and causes. Conspicuity and other perception problems deserve further study in order to identify key contributing factors and effective countermeasures.

Operational research and development is needed

Operational research and development is needed to achieve a traffic system which better integrates and protects PTWs in a cost efficient manner. A co-ordinated and concerted cooperation between a variety of disciplines (e.g. civil and mechanical engineers, economists, educationalists, psychologists, transport planners, lawyers etc.) is key to the development of a consistent set of measures to address real issues regarding the safety of PTW riders.

While Intelligent Transport Systems offer opportunities to improve the safety of drivers and rider as well, they require more R&D on their capacity to prevent PTW crashes, as ITS applications for cars are not directly transferable to PTWs. . Any ITS application which removes or interferes with the longitudinal or lateral control of the vehicle could have adverse effects. Further research is therefore needed on the challenges posed by the Human Machine Interface requirements, the impact on human behaviours and adequate training for the riders.

Further investigation is required dealing with the content and effectiveness of training, including post-licence training, with the aim of improving the behaviour and safety of both drivers and riders.

Further research and development into protective clothing and equipment with lower weight and improved ventilation are needed and should be encouraged.

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The Shared Road to Safety – A Global Approach for Safer Motorcycling

Der gemeinsame Weg zur Sicherheit – ein globaler Ansatz für sicheres Motorradfahren

Edwin Bastiaensen

International Motorcycle Manufacturers Association (IMMA)

The Shared Road to Safety
A Global Approach for Safer Motorcycling

IMMA INTERNATIONAL MOTORCYCLE MANUFACTURERS ASSOCIATION

May 2014

The Shared Road to Safety
A Global Approach for Safer Motorcycling

IMMA INTERNATIONAL MOTORCYCLE MANUFACTURERS ASSOCIATION

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Content

Preface

At worldwide level there is an increased use of Powered Two Wheelers[1] in both developing and developed countries. As a result of urbanisation, associated congestion and the shift in economic balance, there is an increased need for mobility in developing nations. More and more people choose PTWs as a result of the benefits they provide. At the same time there is a global challenge to ensure sustainability from a road safety perspective.

In many situations, PTWs have not been adequately addressed in local, national and regional policy plans. This needs to change by introducing inclusive policy plans – which means a positive consideration of PTWs in transport plans, in an integrated perspective.

The safety of PTW riders is a high priority of the global motorcycle industry as represented by IMMA. Safer motorcycling leads to more sustainable motorcycling and the realisation of the key benefits that motorcycles can bring to transport and the economy.

As road safety policy and practice evolves in a global sense, it is becoming increasingly clear that there is a role for the global institutions in supporting countries and regions in their efforts to reduce the social and economic toll of road casualties. The UN Decade of Action on Road Safety is a welcome initiative towards this end.

However, equally clear is the fact that the global institutions need to take a holistic approach to road safety issues, particularly in developing countries. The mere 'imprinting' of developed nation road safety policies and strategies on developing countries could otherwise have unintended economic and social effects on such countries.

Road safety strategy should be focused on a progressive improvement of both road safety policy and practice standards of road safety and not on immediate implementation of advanced safety policies in countries and regions which will require time to develop institutions, economics and infrastructure to enable them to move towards the highest standards. As illustrated in this document, still too many countries lack even basic standards for roads and IMMA strongly believes that the path to enhanced road safety comes primarily from first securing basic infrastructure and through the establishment of sustainable and respected traffic and transport policy making processes.

Both in developing and in more developed countries, the sharing of best practices is key, like the sharing of proven techniques in social and safety policy designed to support safer roads. A number of examples are illustrated in this document as they relate to motorcycles.

IMMA believes that the most sustainable route to safer motorcycling lies within taking a comprehensive approach to safety policy and practice, based on a 'shared responsibility' approach.

In order to realise this and ensure that safety is managed with an even hand and on a level playing field, the first and most important step is to recognise motorcycling's place within society and overall transport strategies. Indeed, the OECD firmly stated this key point in their primary recommendations from the 2008 Lillehammer safety conference.

Such an approach will open up the ability to integrate PTW safety as part of broader transport planning. This will result in not only fewer PTW casualties, but also the important role that motorcycling plays in social, business and emergency transport.

1 The term "Powered Two-Wheeler" (PTW) covers a wide diversity of vehicles. The products are divided into different segments such as moped, scooter, street, classic, super-sport, touring, custom, supermoto and off-road motorcycles. In international regulatory environment, PTWs fit under the term vehicles of category L. IMMA represents mopeds, motorcycles and three-wheelers. Therefore, IMMA refers to PTWs as Powered Two and Three wheeled Vehicles.

Cycling is a worldwide important mode of transport which shares many common issues with motorcycling when it comes to safety, infrastructure policy and issues arising from other road users. Like cycling, motorcycling is not in itself dangerous. But riders of both modes are subject to certain vulnerabilities on the world's roads. By recognising the socially positive attributes of cycling, much has been done to improve cycle safety and improve visibility within traffic. The same approach is now needed for motorcycling.

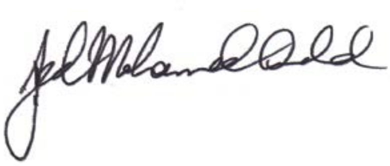
This document 'A Global Approach to Safer Motorcycling' updates and replaces the IMMA motorcycle safety document 'HHRT – Headlight, Helmet, Road Surface and Training' published in 2010. The key principles in HHRT still apply, but the new document includes a selection of global best practices for policy makers' consideration and implies a wider perspective on sustainable road safety – the position of the Powered Two Wheeler (PTW) in society, its economic contribution, how PTWs are used and how infrastructure can be developed to support rider safety. This document emphasises the importance to consider local, national and regional differences of motorcycling in the context of policy making.

IMMA is delighted to have recently become a member of the UN Road Safety Collaboration and looks forward to assisting discussions on key matters of road and motorcycle safety.

IMMA recommends this document for the use by the global institutions, safety managers and policy makers world-wide, as a valuable resource for developing holistic motorcycle safety and transport policies.

Shungo Akizuki,
Chairman,
IMMA Road Safety Working Group 2013-2014

Dato' Syed Mohamad Aidid
Sponsor, IMMA President 2010 - 2012



The purpose of this document

This document has the intention of:

- Engaging policy makers, safety experts, road users, and all related stakeholders in supporting and enhancing safer motorcycling at global, regional and national level.
- Providing recommendations for attention to key aspects of overall transport policy and planning, in addition to motorcycling focussed safety policy.
- Identifying PTWs' characteristics compared to other vehicles. It highlights the different styles and uses of PTWs, and the regional distinctions between attitudes and usage patterns, traffic and infrastructure environments.
- Revealing the importance of an integrated approach towards PTW safety for achieving real, efficient and sustainable results.
- Providing an overview of the safety activities that the motorcycle industry has already undertaken at the global and regional level.
- Promoting a set of successful best practices that have been implemented across the world by governments, industry and other important stakeholders for consideration in a fully holistic global motorcycle safety and transport policy.

"Improving the safety of PTWs must consider all the actors and elements at play.

It is not enough to pay attention to PTW riders, one must also monitor their interactions with all other road users, the environment, the vehicles and the social, cultural and political dimensions that shape and supervise their use.

Moreover, action should not be restricted to the most obvious parameters but must also take into account the background behind the problems".

(*OECD - ITF* Joint Transport Research Centre draft Report "Safety of Powered Two Wheelers", 2014)

Executive Summary

This document calls upon governments across the globe to take a more strategic approach to motorcycle safety, incorporating the active involvement of all relevant stakeholders.

This approach is not necessarily a globally prescriptive one, as there is no one single type of motorcycle rider and no one single motorcycle riding environment dominating in the different regions of the word.

In this document IMMA promotes the sharing of best practices from around the world. The objective is to stimulate national road safety authorities to consider what may be the best approach for their citizens in relation to motorcycle safety and transport policy.

IMMA members believe that the following approach should be taken by all road safety stakeholders: Policy, Infrastructure, Training and Technology.

In order to successfully implement the four stage safety strategy any action must involve all relevant stakeholders. Actions must have an understanding and appreciation of the traffic situation specific to the country in question and using accurate, standardised data to inform and support any policy decisions.

Four Stage Strategy

1 – Public Policy Considerations

It is important for officials and policy makers to recognise that PTWs are a key mode of transport which fulfils a number of important and diverse roles – in many cases particularly important to local economies and citizen mobility. As such, they should be integrated into policies and initiatives aimed at creating a safer environment for users and addressing vulnerabilities that all users of two wheeled transport sometimes face (cyclists and motorcyclists).

The promotion of PTW usage in transport policy can have a considerable and positive impact on reducing traffic density in heavily congested cities and can bring economic gains through access to jobs, social mobility and even healthcare in developing nations where other transport modes are unavailable, impractical or too expensive.

2 – Infrastructure suited to Safer Motorcycling

In many developing countries, uneven, damaged road surfaces are a large contributing factor to poor motorcycle safety. However, even in high income, developed countries, safety issues caused by poor infrastructure persist. Examples include badly positioned or unnecessary street furniture, visibility at junctions, poor quality or 'potholed' roads, dangerous crash barriers and raised divides on roundabouts.

3 – Training for riders and awareness raising among other road users

The Human Factor has been shown to be the most critical in PTW accidents. IMMA supports both pre- and post-license training for motorcycle riders. It is furthermore crucial that other road users have an appreciation of the dangers of misjudging the speed or behaviour of a PTW rider – including the common error of failing to see an approaching PTW.

IMMA supports an integrated approach to a better understanding among other road users. This is why training for all types of license holders should include awareness of the characteristics and behaviours of other vehicles and other vehicle users. This would include the common causes of accidents, such as perception failures or misjudgements of capabilities, understanding of vehicle blind spots, or the differences in stopping distances.

4 – Technology advances

The industry is fully committed to on-going research into and development of safer on-vehicle PTW technologies, safety devices, via individual manufacturers' as wall as pan-industry projects.

Work by industry, governments and other stakeholders has resulted in a quite significant improvement in PTW fatalities per 10.000 vehicles in most countries/regions (2011 vs 2005). This relative reduction of PTWs fatalities must be seen against a background of a large increase of the PTW circulating park during the same period.

In other words, the actual risk of an individual having an accident on a PTW has fallen despite fatality records not having improved as fast as is desired. It should also be noted that significant disparities exist between the safety performances of different road users' and PTW riders' safety performance. These differences can be largely explained by differences in traffic mix by regions.

In order to provide a significant progress on PTW's safety (particularly in reducing the PTW proportion of overall traffic fatalities), policy and practice needs to move beyond isolated responses. Policies should include a wider and more holistic consideration of how PTW safety can be further improved through the recognition of motorcycling in overall transport strategies and PTW inclusion in mainstream transport policies that seek to improve the roads environment for users..

A Supported Safety Strategy

The four strategic tiers are supported by 3 fundamental requirements for success:

1. An Integrated Stakeholder Approach

Whilst recognising that many improvements have been made to vehicle safety, with further developments likely to follow as motorcycles evolve, a true solution to safer riding requires the involvement of all road traffic stakeholders. This includes the driving communities, riders themselves, public authorities and governments, research institutions, national road infrastructure designers and local town planners - among others.

2. Accurate and Harmonised Data Collection

An essential step in identifying the true extent of the different causes of PTW accidents is the systematic collation of accident data and the details of crashes involving PTWs. This is essential in order to identify and set up realistic goals, targets and eventually measures. Cross-border comparisons and analyses of real value cannot be made today due to insufficient comparable data, in particular usage data and accidents per km/mile travelled. Common themes of accident causation will enable the proper identification of solutions and the sharing of correct best practice solutions among regions.

3. A Tailored Approach to Local Situations

Any strategies, campaigns or activities aimed at safer riding will be most effective if they have public and rider acceptance. This can be best achieved if there is a proper consideration given to tailoring measures to the local traffic needs. This includes specific national, regional or local constraints, such as: numbers of PTWs in circulation, the types of PTW usage, e.g. majority leisure, commuting or utility, distance travelled by the PTW fleets, weather conditions, etc.

IMMA, the manufacturers and related businesses that IMMA represents, are committed to working together with other stakeholders to play a part in the much needed development of an integrated approach to analysing, developing and promoting the uptake of safety solutions. This is an area where much work remains to be done by the global institutions.

Chapter 1:
Introduction of the International Motorcycle Manufacturers Association (IMMA) & Industry's Commitment to Safer Riding

IMMA is the association which represents the manufacturing industry of powered two wheelers (PTWs) at the global level.

Today, IMMA represents the major part of the worldwide manufacturing of PTWs, with membership as follows:

Regional association members

The Motorcycle industry in Europe (ACEM): representative of the industry in Europe with members from Austria, Belgium, Czech Republic, France, Germany, Greece, Italy, Ireland, the Netherlands, Poland, Romania, Spain, Sweden, Turkey and United Kingdom.

The Federation of Asian Motorcycle Industries (FAMI): representative of the industry in Indonesia, Japan, Malaysia, the Philippines, Republic of China (Taiwan) and Thailand.

National manufacturing members

The Society of Indian Automobile Manufacturers (SIAM)

The United States Motorcycle Manufacturers Association (USMMA)

Associated members

The Federal Chamber of the Automobile Industries (FCAI), representative of the industry in Australia

The Motorcycle and Moped Industry Council (MMIC), representative of the industry in Canada

acem The Motorcycle industry in Europe	United States Motorcycle Manufacturers Association, Inc.	FAMI Federation of Asian Motorcycle Industries
FCAI Federal Chamber of Automotive Industries	MMIC CIMC The Motorcycle & Moped Industry Council Le Conseil de l'industrie de la motocyclette et du cyclomoteur	SIAM Society of Indian Automobile Manufacrurers

From its inception, IMMA has been a member driven organization, providing the necessary services to the industry via its expert committees, dealing with environmental issues, road safety and the harmonization of technical rules.

For more than 50 years, IMMA has been a strong contributor to the work of the UNECE, in particular the World Forum for the Harmonization of Vehicle Regulations (WP.29) and the Road Safety Forum (WP.1).The World Forum has incorporated into its regulatory framework the technological innovations of vehicles to make them safer and more environmentally sound.

Following the consideration that motorcycle safety requires attention beyond local and regional level also at the global level, IMMA established its Road Safety Task Force in 2008. In 2010, IMMA published "HHRT Motorcycle Safety - IMMA contribution to the Decade of Action" - the precursor of the current publication. HHRT identified the priority instruments for improving motorcycling safety that should be considered in safety policies and recommended the Headlight, Helmet, Road surface and Training approach. Following this publication, IMMA recognised a further need for promoting 'inclusive' policies integrating motorcycling in local, national and regional transport and mobility policies and the need for exchange of experience through best practices. Consequently Road Safety activities in IMMA expanded and were brought under a new permanent high level working group to allow acceleration of its road safety activities.

Aside of the activities of the IMMA members in their respective regions and countries, IMMA has made key contributions to road safety networks, such as the International Traffic Safety Data and Analysis Group (IRTAD), the International Transport Forum (ITF). Since 2013, IMMA has been contributing to the United Nations Road Safety Collaboration (UNRSC).

◢ IMMA's Main Objectives for Promoting Safer Motorcycling:

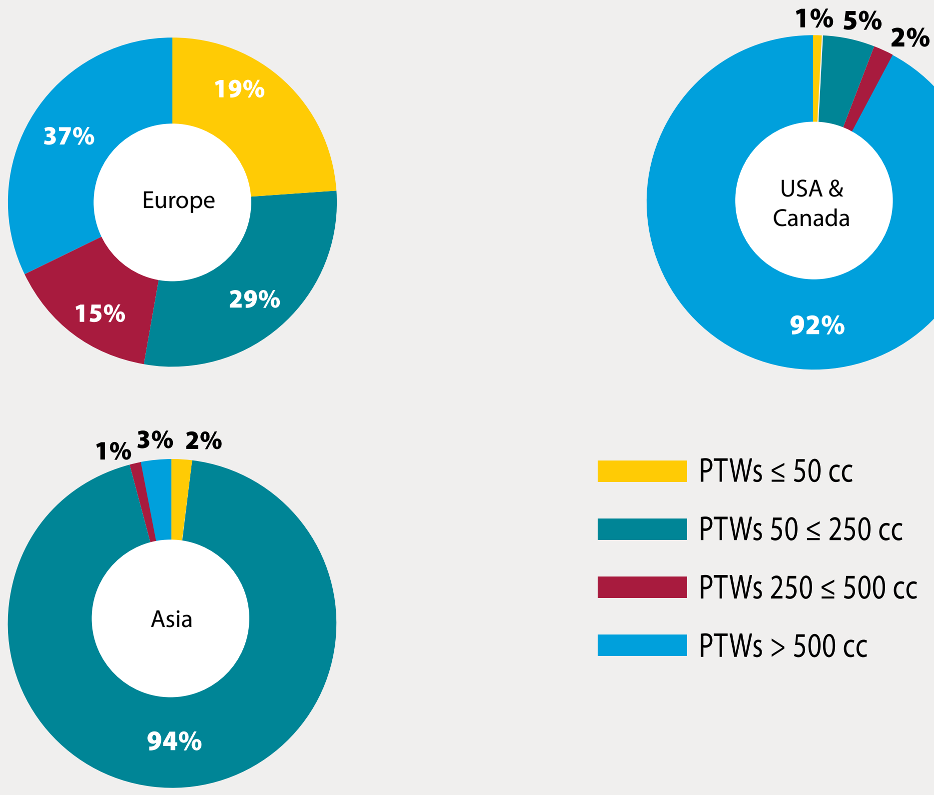
1. To demonstrate to policy makers that an integrated approach, involving multiple stakeholders, is an important factor in improving PTW safety.
2. To promote key tools and instruments that should be in place in a PTW safety policy.
3. To prompt national and regional policy makers to adequately consider PTWs in traffic policies.
4. To promote the safe use of PTWs and to improve the skills of riders.
5. To support and contribute to the process of updating International and Global Agreements in the frame of UNECE WP.29 (harmonisation of vehicle regulations) and UNECE WP.1 (road safety).
6. To foster a healthy competitive environment across the global PTW industry and to promote the development and use of state of the art technologies.
7. To support forums establishing standards and methodologies e.g. on accident data collection and analysis.
8. To support and contribute, through all of the above, to the UN Decade of Action.

Chapter 2:
The role of Powered Two Wheelers (PTWs) in Society: Changing Perceptions

Diversity of products

The term "Powered Two wheelers" (PTWs) includes products from small 50cc step-through vehicles, up to motorcycles of 1000cc and over. These products are divided into different segments, such as moped, scooter, street, classic, performance or super-sport, touring, custom, supermoto and off-road motorcycles and tricycles.

PTWs production displacement mix



Source of data: IMMA, 2012, Production data

Road safety policy towards motorcycles needs to integrate with local patterns of usage and be sensitive to the role that PTWs play in local societies.

Many people consider 'motorcyclists' to be a homogeneous group of people and as such, road safety solutions and public policy decisions are often aimed at this 'group'. Sometimes, PTW safety policy is poorly differentiated from car safety policies, with PTW statistics in transport indicators 'lumped in' with car statistics. Safety policy often considers the motorcycle safety 'problem' as a standalone issue, without considering how PTWs are used, or their contribution to the overall traffic and transport 'mix'. Often, **little regard is given to how PTW safety issues can be transformed into safety and transportation 'opportunities'.**

However, the reality of the situation in all countries is that PTW riders within the same country represent a wide variety of people who use vast numbers of different vehicle types, with different characteristics, designed for myriad different terrains and used for numerous distinct purposes. These differences can be even starker across a global comparison, where the terrain, cost of living, infrastructure and climatic conditions vary so greatly.

It is this diversity that means policy approaches cannot work to a one-size-fits-all approach designed to improve "motorcycle safety globally". Safety policy needs to be tailored to differing local environments and take account of the PTWs position in society and the economy in a given country – plus the social, mobility and economic opportunities that safer motorcycling can bring to such societies. IMMA strongly supports the sharing of best practice, which can be applied or adapted where appropriate to the local situation of traffic and usage patterns.

◢ PTW characteristics

PTWs excel in providing convenient, low cost personal mobility, which offers riders shorter journey times, while generating fewer emissions, and using less fuel. Thanks to their smaller and lighter profile, PTWs occupy less space and cause reduced wear and tear on road infrastructure compared to other forms of transport. **For these reasons and many more, PTWs support the lifestyle and mobility needs of a growing number of people around the world. In many developing countries they are important to local economies and businesses.**

It is important that policy makers recall the many benefits PTWs bring to their riders and to wider society, instead of considering these vehicles solely as a policy problem.

Convenient Mobility
PTWs enable greater freedom of movement in crowded urban environments and their relatively small size offers advantages for reducing congestion and decreasing the need for large amounts of parking infrastructure compared to cars. PTW usage also reduces wear and tear on road surfaces. Where other means of public transportation either do not exist, or they are inadequate or inconvenient, PTWs can provide an important source of personal mobility. Reduced commuting times allow riders to spend more time with family and friends.

Energy savings
PTWs are engineered for efficient fuel economy and help conserve energy. PTWs, being of lower mass than automobiles, require less energy to manufacture and recycle.

Economy of use
PTWs deliver efficient transport for individuals in terms of reduced time on given journeys, especially in an urban environment. PTWs also often offer a low purchase cost. That, combined with a good fuel economy and low maintenance costs, delivers riders an economical means of greater mobility. This is one reason why PTW fleets are the natural choice in many countries, with many national PTW fleets numbering in the millions.

Unique personal experience
PTW use for sport and leisure has attracted many around the world for the personal benefits they can bring: stress reduction, social interaction with others, the personal and economic perspective of PTW tourism and the pleasure of riding as an end in itself.

Diversity of owners, usage and patterns around the world

In large parts of the world, PTWs are used by the majority of riders on a daily basis. In some regions, PTWs are also used by specific groups for leisure activities. However, in all regions, PTWs are increasingly used by commuters to provide an answer to traffic congestion.

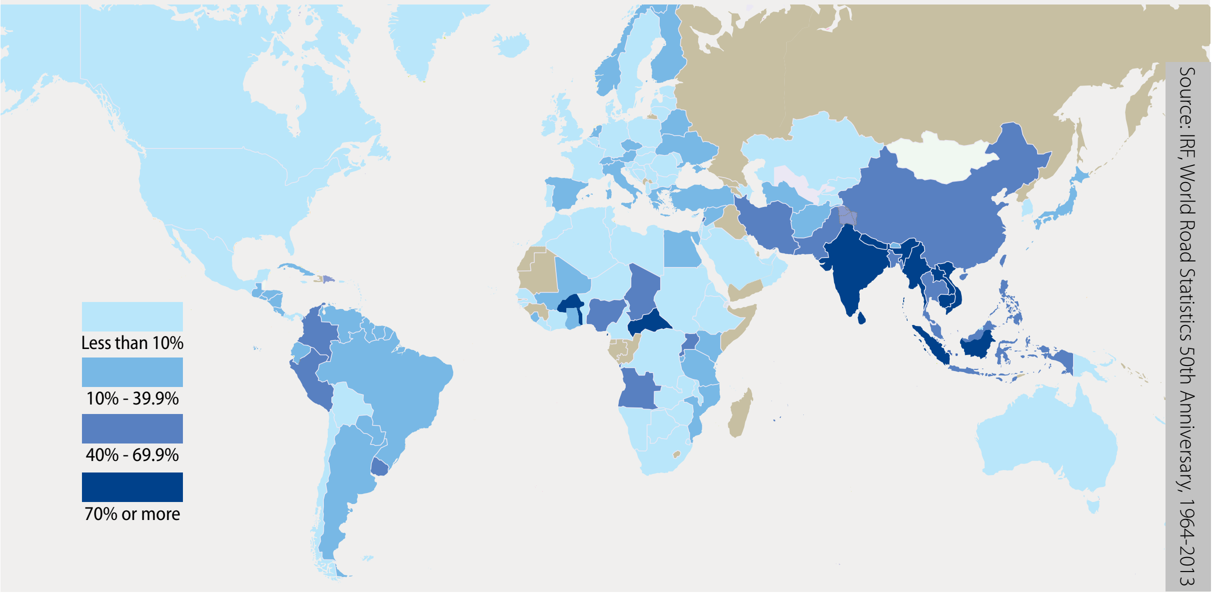
In many countries and in regions like Europe, leisure machines offer a 'cross over' function, also being used for commuting. In the UK for example, the Government estimates that over 60% of PTW distance travelled is for commuting, utility or socially practical purposes.

A toolbox of measures is required to improve the safety of PTW riders within the traffic system. These measures must take into account the specific challenges of PTW traffic, and also consider the variety of PTW users, insofar as some segments may be addressed with particular measures. A strategic approach should consider the most effective combination or measures according to the specific needs of individual jurisdictions.

(OECD - ITF Joint Transport Research Centre draft Report "Safety of Powered Two Wheelers", 2014)

Increasing PTWs' presence in the world

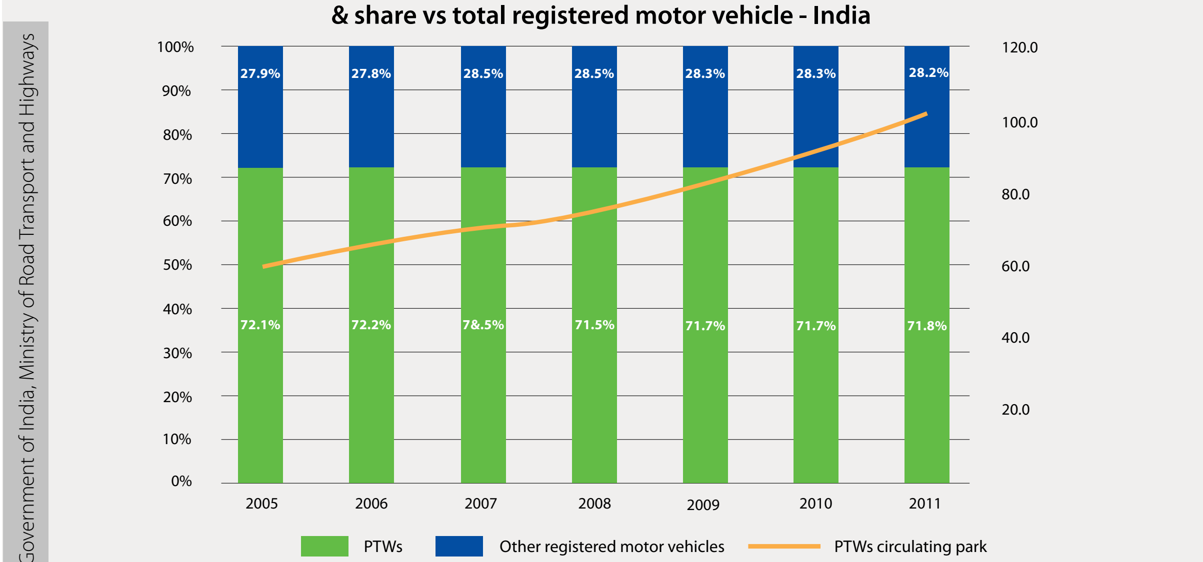
Percentage of PTWs in total motor vehicles by country
Variation of the PTW presence in transport mix around the globe



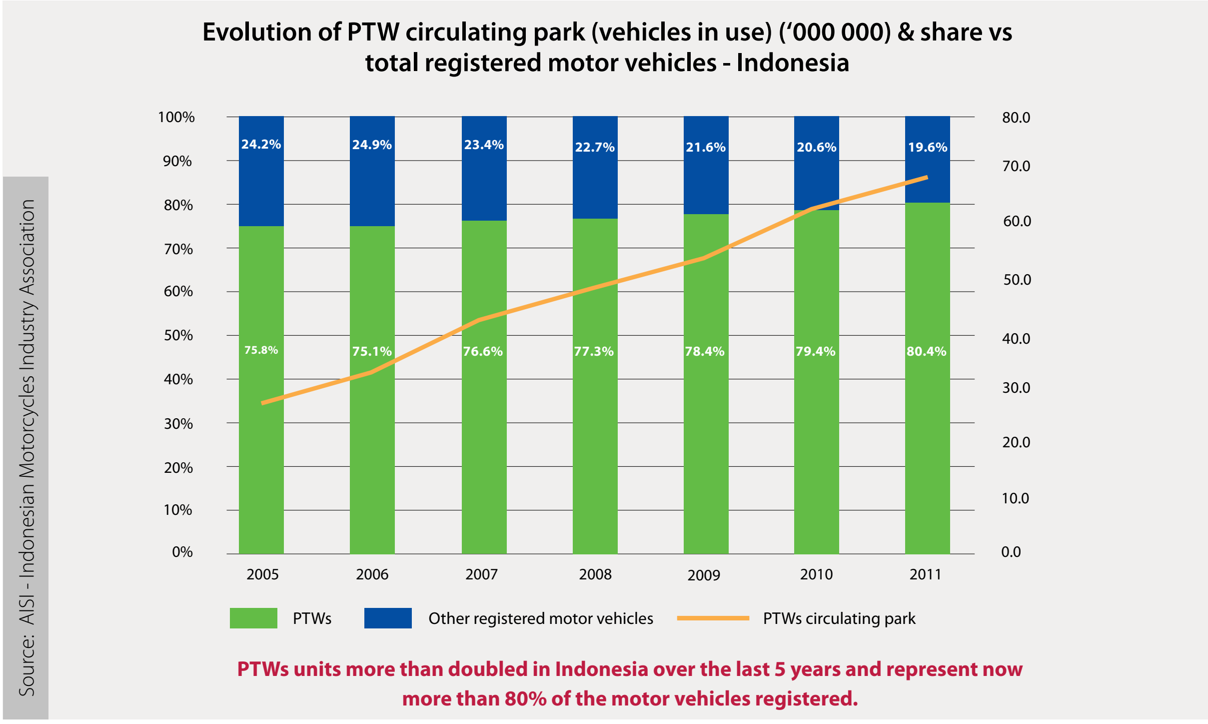
PTWs are the most common type of motor vehicles in many countries around the world - in Asia and Africa in particular. In some regions, PTWs are crucial to national economies. This is because a very high proportion of such economies are organized around this means of transportation: commuting, post, delivery, police, fire fighters, rescue teams, humanitarian workers and volunteers, etc

The share of PTWs on the road compared to other types of vehicle is also extremely high in India (72%) and Indonesia (80%). These trends are also seen in other rapidly developing countries in South-East Asia, Africa and South America.

Evolution of PTW circulating park (vehicles in use) ('000 000)
& share vs total registered motor vehicle - India

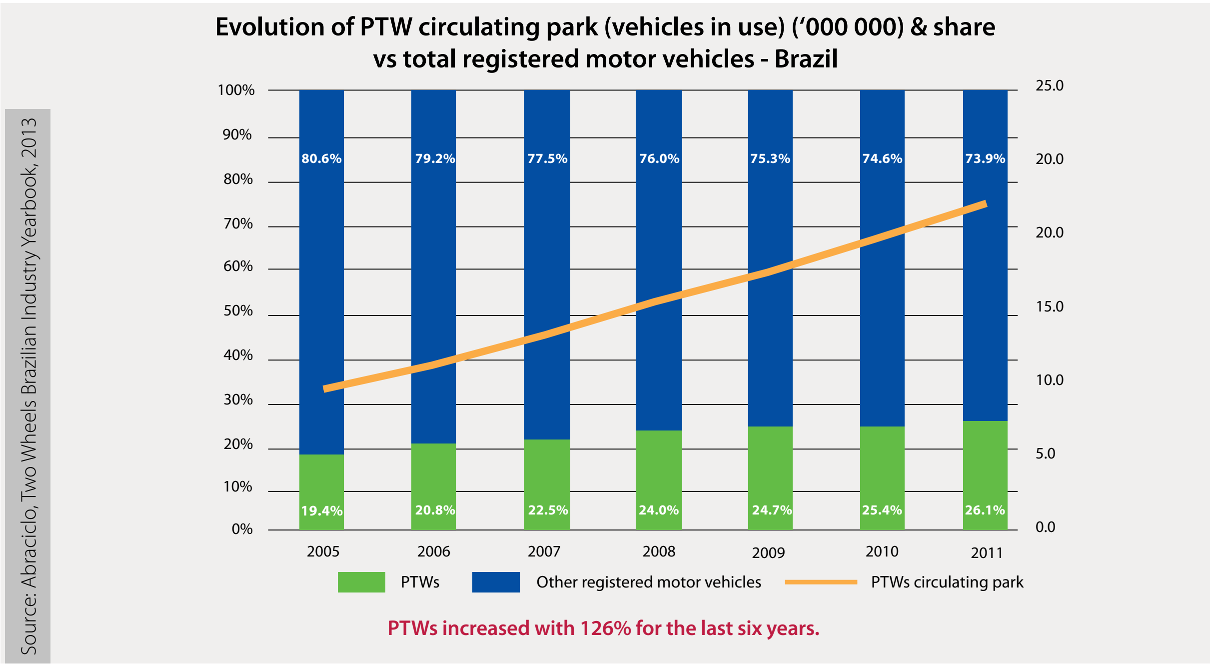


Despite the high increase of PTW units over the last years in India, the PTW's share in the total registered motor vehicles remains stable, slightly above 70%.

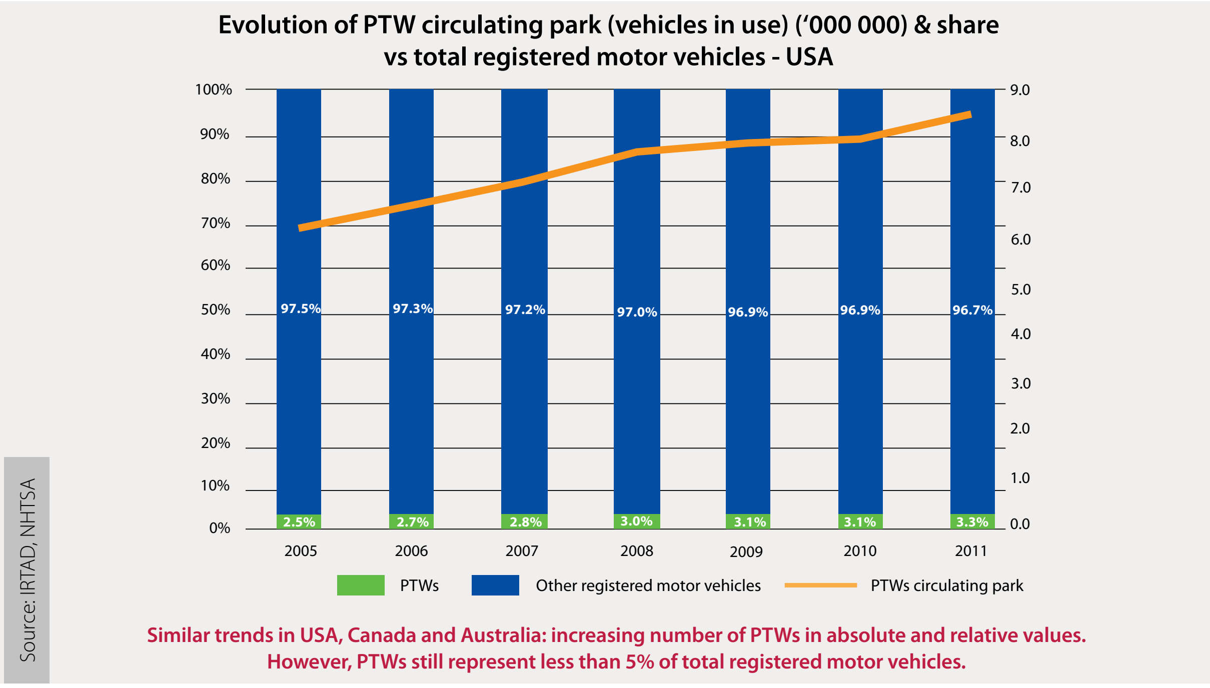


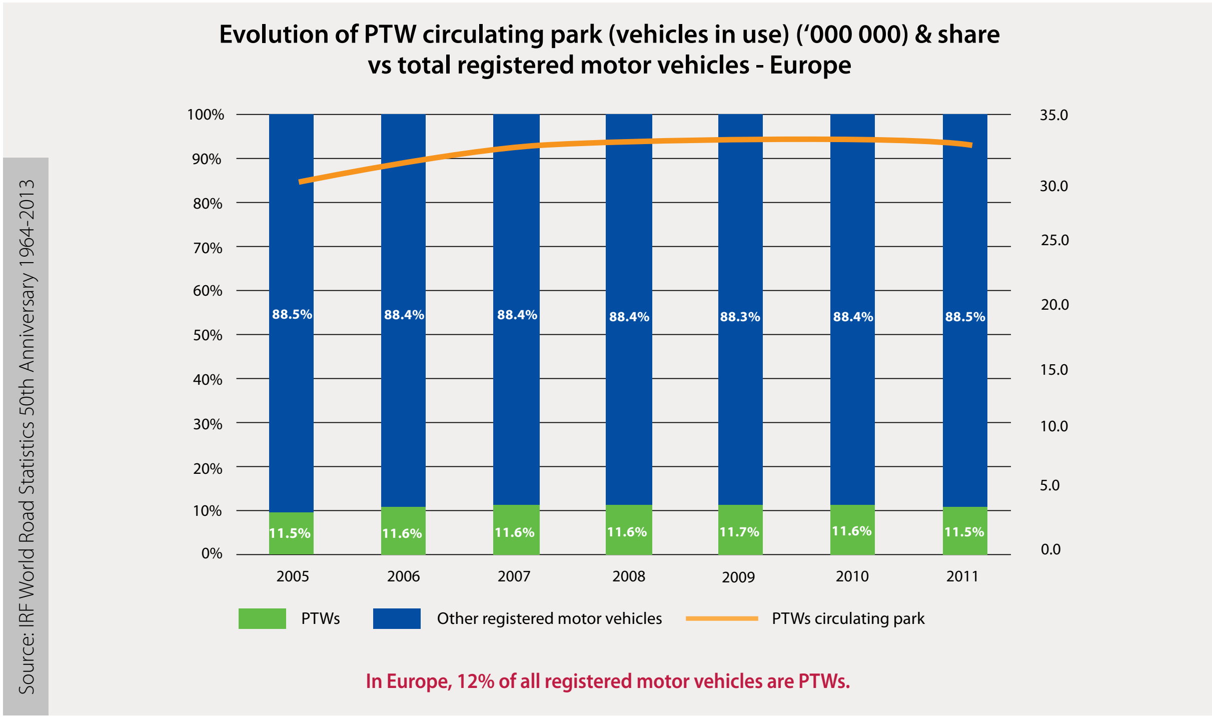
In India and Indonesia, the fleet of PTWs increased enormously in 6 years: India +73% (approximately +9% per year) and Indonesia +141% (approximately +16% per year).

In Brazil for example, the total circulating park (vehicles in use) increased with 68% in 6 years while PTW park numbers increased by 126% during the same period.



There is furthermore a steady increase of the PTW fleet in high income regions: USA +36% and Europe +10% for the period 2005-2011. In Europe 12% of all registered motor vehicles are PTWs, however traffic shares are low in the USA, Canada and Australia where the share of registered PTWs versus all motor vehicles is below 5%.





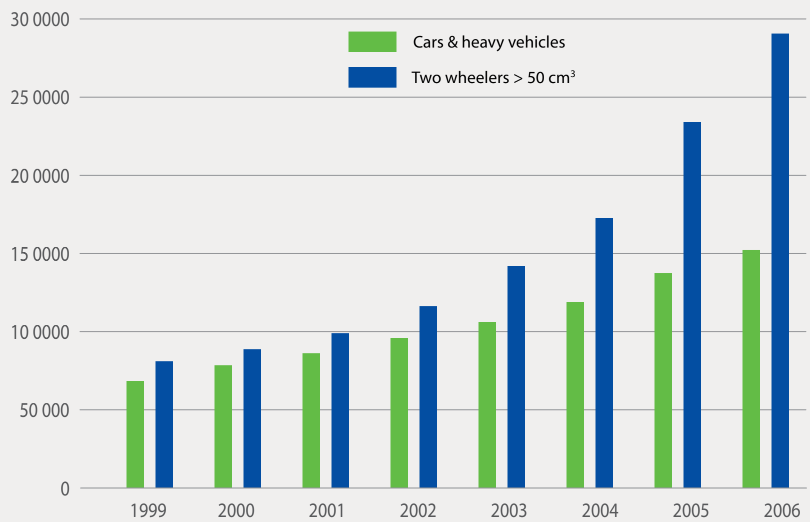
In many Latin American countries, the mass sales and use of the motorcycle has considerably increased in the past 10 years. The share of the PTW fleet in the motorised vehicle fleet varies greatly from 3% in Chile to 52% in Uruguay. In Mexico, PTWs represented only 4% of the fleet in 2011, but the fleet is growing very fast and almost doubled in 5 years. *(Source: OECD - ITF Joint Transport Research Centre draft Report "Safety of Powered Two Wheelers", 2014)*.

Information gathered from a few countries shows that PTWs for use as commercial vehicles have substantially increased over the past decade in big African cities. In particular, the fleet of PTW 'moto taxis' has significantly increased in these cities, as a consequence of a lack of public transport services. *(Source: OECD - ITF Joint Transport Research Centre draft Report "Safety of Powered Two Wheelers", 2014.)*

This phenomenon has also been observed in some European regional (Barcelona) or national (Paris) capital cities in which small logistic deliveries provided by PTWs and mototaxi fleets are common.

Rapid motorisation in Burkina Faso - Growth of vehicle fleet, 1999–2006 (number of vehicles)

In 1999, there were just over 80 000 Two wheelers with an engine capacity of 50 cc and above on Burkino Faso's roads; during the next 7 years, their number increased almost fourfold.



Source : World Health Organization, 2013, Geneva, Switzerland, Strengthening Road Safety Legislation : A practice and resource manual for countries

◢ PTWs Stimulating Economic Growth

PTWs are the most affordable forms of motorized personal transport in many parts of the world. In various regions, primarily in emerging regions, PTWs are therefore also the most common type of motor vehicle used. Indeed, in South-East Asia, PTWs represent more than 60% of the motor vehicle circulating park. In this region, PTWs are crucial to national economies. This is because a very high proportion of such economies are organized around this means of transportation: commuting, post, delivery, police, fire fighters, rescue teams, humanitarian workers and volunteers, etc.

In high-income countries, the mobility situation is very different, with a higher utilization of personal cars and public transportation. PTWs represent less than 5% of the total motor circulating park in the USA, Canada and Australia. In this context, PTWs are mainly used by specific groups for leisure activities, tourism and sport. Motorcycle tourism has enhanced importance in these regions and can represent notable economic generators for some communities.

In Europe, where approximately 12% of registered vehicles are PTWs, PTWs are used for leisure, sport, and increasingly as an answer to traffic congestion, especially in big cities. The diversity in motorcycle usage reflects the overall geographic, cultural, and historic diversity of EU member states.

The growth since 2005 in transcontinental motorcycling, or 'overlanding' is worthy of note. Increasing numbers of riders use the PTW to visit other countries and conduct extensive tours. Such activities can lead to enhanced tourism 'spend' and benefit to local economies, particularly in the case of guided tours of several PTWs. An added fringe benefit is the wave of positive publicity and journalism that has accompanied much of this activity – often in the mainstream press and TV. This results in a sharing of knowledge about different societies with the public as 'overlanding' riders travel – a distinct social 'good', which can help breach social barriers.

Motorcycling provides quality of life, among other things, through: access to jobs and services, affordable mobility, and the enjoyment of sports, leisure and tourism.

Promoting Advanced Safer Riding through Sport and Leisure

Many riders enjoy the great outdoors, endeavouring on exciting trips to reach remote tourist destinations, or simply going for a weekend trip in the countryside. Professional motorcycle sport is followed by millions of spectators and viewers worldwide, reaching out beyond the riding community itself. Enthusiasts enjoy motorcycle sport at amateur level, where new generations are also taught the positive values of sportsmanship through the numerous events that animate communities around the globe.

Such activities also have the valuable role of engaging young people in sport and personal development. This can be of particular benefit in disadvantaged areas of developed countries, where the social engagement of young people is of major concern. Off road and amateur motorcycle sport provides a valuable opportunity for addressing such key issues.

Motorcycle sports and leisure offer numerous opportunities to effectively reach and influence the motorcycle enthusiast with regard to road safety. Firstly, the sports environment leads to greater interest to choose, and equip the rider with state of the art equipment, to keep a well maintained vehicle and to use protective gear. A sports environment can also impart the importance of rider planning, or the 'systematic approach' to safe riding. Off road sport in particular can be of enormous help in imparting machine control skills.

The sport activities are structured in hundreds of motoclubs and federations around the world, most of them placed under the umbrella of the International Motorcycling Federation (FIM).

The opportunity to improve riding skills on tracks and in off-road environments enables riders to test the limits of their own and their vehicle's abilities under safe conditions. In many regions of the world, manufacturers and sports federations organise track-days and off-road tours allowing enthusiasts to improve their skills with the support of professional coaching. **These sports activities have been a strong contributor to introducing a safety culture among riders and in promoting advanced riding skills.**

◢ The Wider Societal Benefits of Powered Two Wheelers

Motorcycling also contributes towards the wider economic and social goals of society as a whole. In some cases PTWs are core to the delivery of essential public services. **The following examples illustrate the very positive benefits which can be realised if PTWs are accorded proper positioning in social, healthcare and transport policy.**

Health Care delivery

Indonesia, Asia

A healthcare logistics project on the island of Flores, provides 10 small motorcycles for use by healthcare workers in remote rural areas where roads are poor or non-existent. **The ability for basic services to be provided via motorcycles (to a population of over 50,000) has seen a dramatic improvement in basic healthcare indicators since 2002** - www.motorcycleoutreach.org

Africa

Across Africa, the charity 'Riders for Health' has significantly developed the role of motorcycles for healthcare delivery and originated the concept of 'Transport Resource Management' (TRM) by motorcycle. **"Riders" operates in several countries, providing a vital role in healthcare infrastructures. "Riders" has improved health care access for 12 million people across Africa.** A mobilised outreach health worker can see nearly 6 times more people, allowing better monitoring of diseases and dissemination of prevention and control information. - www.riders.org

UK, Europe

"Blood Bikes" have been a feature in the UK since 1969. In recent years the number of blood bike groups has grown significantly and there are now hundreds of motorcyclists who freely volunteer their time to this service. There are times when blood, or other medical items need to be transported urgently because a patient's life is at risk.

Vaccination campaign, Motorcycleoutreach, Indonesia

A "blood bike" can be relied upon to respond quickly and move with ease through busy traffic, even if it is not fitted with emergency lights and sirens. All the groups promote good practice among their volunteer riders, who hold an advanced riding qualification to ride on a marked-up "blood bike". http://www.bloodbikes.org.uk/index.php/why

PTWs' importance in the event of natural disasters

Indonesia, Asia

The eruption of Mount Merapi in 2011 affected a multitude of small villages including Jumoyo Village with a total number of 7,376 inhabitants. **Motorcycles were used for rapid delivery of mobile health services** - http://satu-indonesia.com/news/219/14

Japan, Asia

PTWs were able to provide significant support to recovering areas of the Great Hanshin Earthquake (1995) and the Great East Japan Earthquake (2011). **The authorities and large numbers of volunteers used motorcycles in these crises because of their great mobility.**

Even with blocked roads, collapsed buildings and mountains of debris, motorcycles managed to negotiate the rough road conditions and cramped spaces. PTWs were used to send messages and information, to transport injured people, to deliver basic supplies, and to conduct numerous emergency relief activities immediately after the quake. Moreover, when the gasoline supply network failed, the subsequent severe fuel shortages meant that highly fuel-efficient motorcycles proved extremely valuable.

General

Motorcycles are also used by public authorities, police, ambulance and breakdown services in many countries around the world. They are also sometimes used by traffic managers looking to quickly reach the source of a given transport problem on the roads. Traffic information reporters are also known to utilise PTWs in their work.

PTWs as an Urban Mobility Solution

The motorcycle circulating park is increasing at an impressive rate in urban areas because of the convenience of PTWs and their advantages in terms of door to door mobility, flexibility, parking, costs and fuel consumption.

Compared to other road vehicles, PTWs benefit from intrinsic advantages and even in countries and regions in difficult economic conditions PTWs represent an economic and efficient means of individual mobility.

Global society faces an on-going and worsening problem of traffic congestion and the apparent inability of traditionally accepted alternatives to solve the problem. This is likely to be enhanced and become more urgent against the background of the increasing 'urbanisation' of the global population. **Embracing the PTW as a tool in policies to mitigate traffic congestion and to meet the challenges of urban mobility, could represent a considerable step toward sustainable urban mobility.**

The following examples demonstrate some of the reasons people choose to ride PTWs around the world:

Small shift from cars to motorcycles, great benefits – Belgium, Europe

A study published in 2012 by the University of Leuven considered the impact of a relatively small shift from cars to motorcycles for a heavily congested urban area in Belgium. Modelling showed that if just 10% of drivers swapped their cars for motorcycles, the time spent in traffic would decrease by 40%. When 25% of car drivers switched a congestion was eliminated entirely. The time benefits on the Belgian highway network were estimated at 50 M€/ year.
http://acem.eu/images/stories/doc/pressreleases/2011/PTW_Belgium_Study_FEBIAC_ENG.PDF

100 million additional KM made by PTWs – Paris, Europe

A study was conducted in Paris to consider the contribution of two wheeled motor vehicles in this large city. The study revealed that 100 million additional passenger km were made by PTWs in 2007 compared to 2000. The increase was due to the shift from public transport (53%) and from private cars (26.5%). The shift resulted in a positive cost/benefit ratio with a €115 million improvement in prosperity being registered. This significant switch to PTWs occurred through natural modal shift and not as the result of any particular campaign by the public authorities. The study concluded that PTWs are a valuable solution for personal transport in urban areas where congestion is a problem. The study also concluded that compared to the bus and other public transport, PTWs are a mode of transport which lends itself to the high flexibility requirements of individuals' mobility.
http://www.acem.eu/images/stories/doc/mobility/PTW_study_Kopp_Paris_EN.pdf

Wheels 2 work – United Kingdom, Europe

The 'Wheels 2 Work' government funded scheme has helped several thousand, mainly young people to have the means to travel to work since it began 16 years ago. This award winning scheme has focussed on loaning mopeds to people in mainly rural areas, who would not otherwise be able to get to and from work.

Commenting on Wheels to Work, Prime Minister David Cameron said: "Wheels to Work does a great job of tackling the basic issue of making sure everyone who needs to travel to a job is able to do so. This is an invaluable service without which many of these young people would have to move away from their friends and families. It also helps young people to find employment and stay in the rural villages where they have grown up which is important in maintaining these diverse and vibrant local communities."

Parking places for PTW riders – Spain, Europe

Barcelona City Council has introduced several measures to improve the city mobility and accommodate the growing number of PTWs. According to the statistics, 28% of private motorized transport in Barcelona is comprised of PTWs, with more than 248,000 trips made per day. One of the Council's measures was the provision of 40,000 parking places for PTW riders. www.areaverda.cat/en/types-of-spaces/motos/

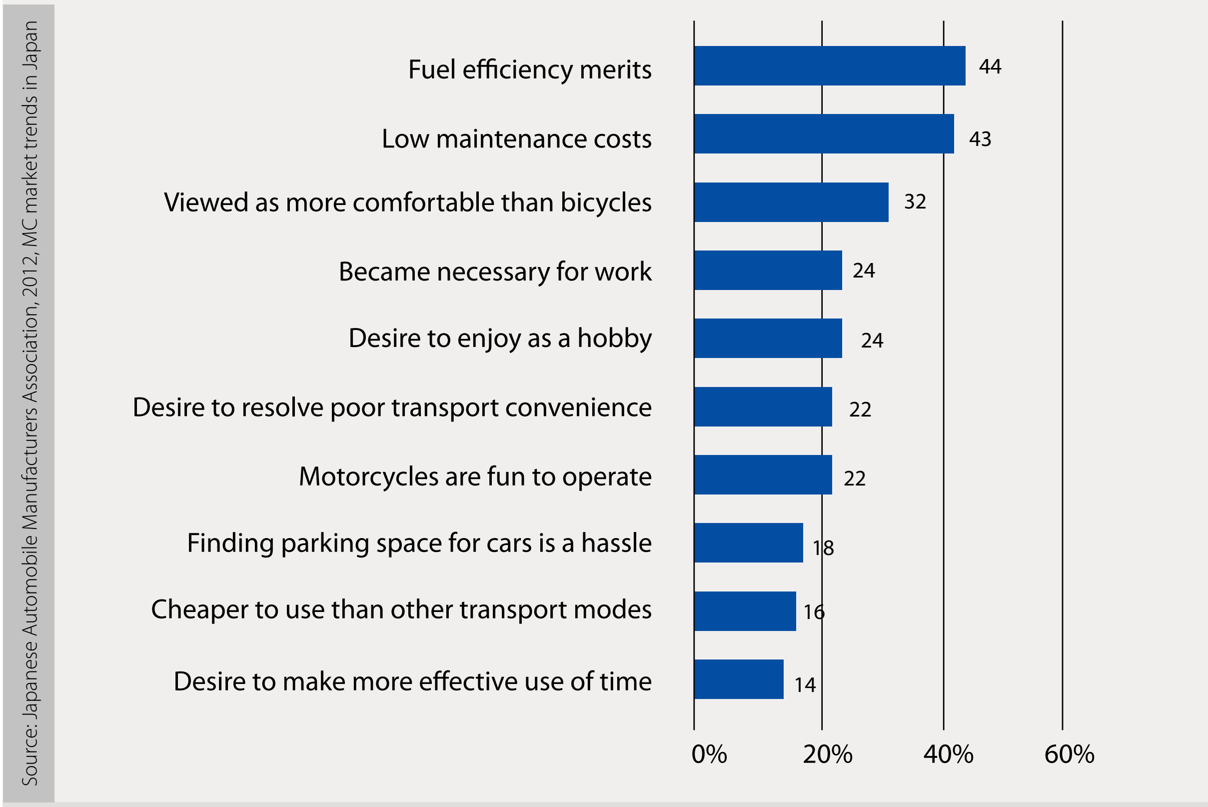
PTWs substitute for public transport – Brazil, Latin America

As in many Latin American countries, the growth of mass sales and use of PTWs has been more recent. In 2012, the total number of motorcycles in Brazil was above 16 million, representing 26% of all vehicles in the country. The most common reasons for buying a PTW are: as a substitute for public transport (60%): for pleasure/leisure (19%), as a mode of transport for reaching work (16%). 10% of people use PTWs as a substitute for their automobile. The boom of motorcycles can be also explained by the increase of people´s purchasing power, the availability of credit and the fact that two-wheeled vehicles are relatively inexpensive and agile for congested city streets. *(OECD - ITF Joint Transport Research Centre draft Report "Safety of Powered Two Wheelers", 2014).*

PTWs - most efficient option on both congested and non-congested routes – Japan, Asia

A simulation study was carried out on the efficiency of different transport modes in urban traffic conditions in Tokyo, in 2013. The study explored the travelling speeds of different transport modes (PTW, cars, bicycles, trains and buses) on congested and non-congested routes. When a specific percentage of vehicular traffic on congested main arteries in Tokyo was hypothetically replaced by motorcycles (assuming specific real-world use purposes), thereby increasing the ratio of motorcycles on the road to between 9 and 18%, average traffic flow speed, as a result of reduced congestion, increased to over 20 km/h. The simulation results indicated that motorcycles offer the most efficient option on both congested and non-congested routes (in particular, PTWs from 51cc to 125cc). It has been concluded that motorcycles are the most efficient vehicles for urban transport in a big city. (Motorcycle Market Trend Survey (2011)", http://www.jama-english.jp/release/release/2012/120404-4.html; http://release.jama.or.jp/sys/news/detail.pl?item_id=1554)

Motivations to Purchase include Fuel Efficiency Merits & Low Maintenance Costs (i.e. environmental performance & financial benefits)

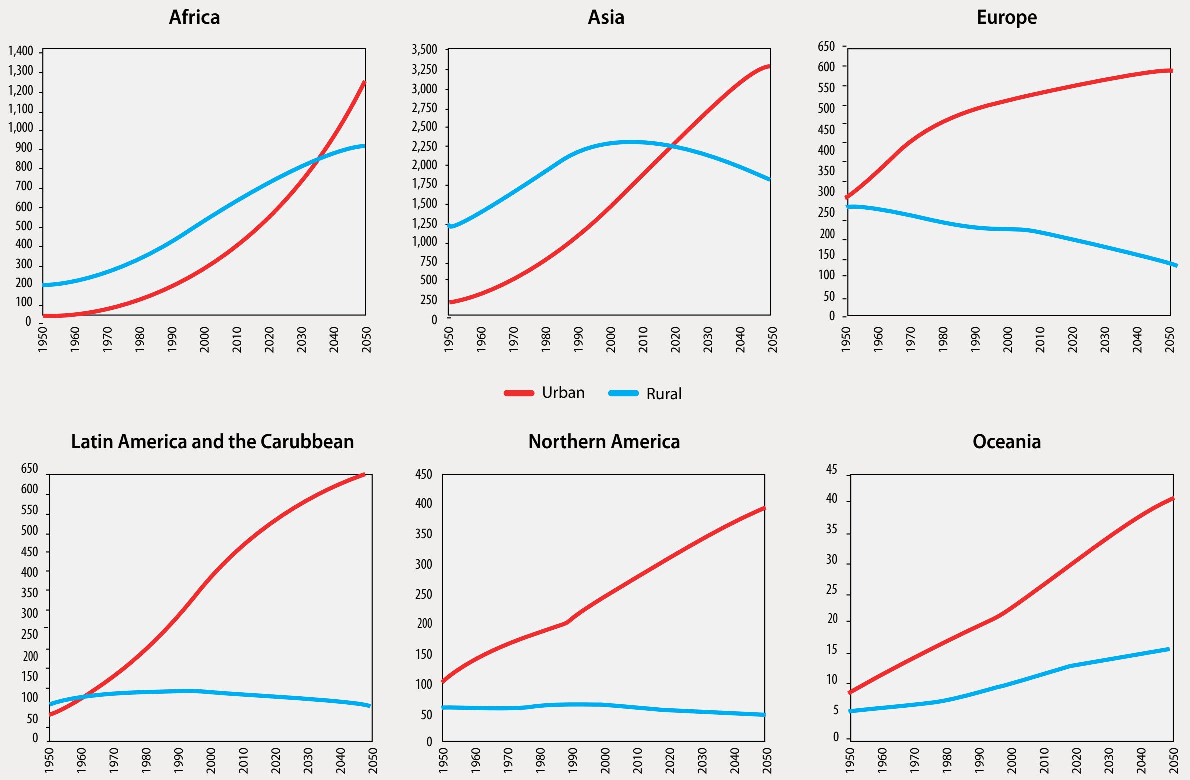


According to the Japan Automobile Manufacturers Association's Motorcycle Market Trends Survey, conducted once every two years, the leading reasons for purchasing motorcycles are «fuel efficiency merits» and «low maintenance costs».
In other words, experienced motorcycle riders give these vehicles a high evaluation for their excellent environmental performance and economy.

◢ The importance of PTWs will continue to increase worldwide

In all regions of the world, more and more people are living in cities. The UN projects this trend to continue in the coming 40 years. Only in Africa and Oceania will rural populations continue to increase during the same period, albeit at a lower rate than the urban population. In 2050, in all regions of the world, a majority of the population will live in cities.

Urban and rural population by major regions, 1950 - 2050 (million)



The United Nations projects that more than 60% of the world's population will live in urban areas by 2050 while it was less than 30% in 1950.

Source: United Nations, Departement of Economic and Social Affairs, Population Division: World Urbanization Prospects, the 2009 Revision. New York, 2010

Urbanization trend & impact on PTWs

In high-income regions, cities continue to grow resulting in more congestion and saturation of parking facilities. Consequently, more attention is given from governments to environmental pollution and emissions.

It can be foreseen that use of PTWs will continue to grow due to:

Their ease of movement in crowded urban environments;
Smaller parking areas needed;
Reduced environmental footprint;
Benefit of a personal door-to-door solution.

In emerging regions, cities will also significantly grow as a result of the urbanisation trend. The United Nations projects that more than 60% of the world population will lie in urban areas by 2050 while it was less than 30% in 1950.

In these rapidly growing cities, public transport is not always well organized or adequate in terms of capacity, frequency, available routes, or reliability. Personal average income is increasing and also the need for personal mobility solutions. **PTW usage is expected to steeply grow due to:**

Their relative low purchase cost and low fuel consumption and increasing personal average income;
Limited public budgets and the lack of flexibility in public transport systems remaining obstacles;
PTWs often being the only affordable means of motorized transportation for the household;
The increasing need for personal mobility solutions for commuting as a result of economic development.

Chapter 3:
Creating a favourable environment for safer motorcycling: a four stage strategy

There would be many benefits, in terms of mobility and traffic management as well as traffic safety, in a better integration of PTWs into mobility plans and in the development of national and local transport strategies"

(*OECD - ITF Joint Transport Research Centre draft Report "Safety of Powered Two Wheelers", 2014*)

IMMA's recommended approach to improving road safety across the world can be summarised in a four stage strategy:

Public Policy
Infrastructure
Training & Education
Technology Advances

Each of these areas play a vital role in improving safety for PTW riders.

The four stage strategy

1. Public Policy - Incorporating PTWs into Transport & Safety Public Policy

1.1. A holistic Road Safety policy should include PTWs

All countries should be strongly supported in integrating a strategic motorcycling framework into transport planning in order to achieve a better traffic system design.

This will allow safer operations, addressing users' responsibilities in light of current knowledge and best practice.

International and regional institutions have an important role to play in encouraging actions at national level that will lead to the adoption of realistic and achievable holistic PTW safety action plans. Such plans should involve major stakeholders and the active participation of industry as part of their development.

In order to maximise the success of such plans, government policy needs to properly 'mainstream' motorcycling as part of their overall transport policy. This inclusive approach would allow the proper development of measures which would improve safety, support riders and help realise the positive potential of PTWs for society as a whole.

The success of the transport policy depends largely and considerably on a systematic approach, without favouring arbitrarily one or the other transport mode, and at the same time applying realistic and economically viable principles, such as:

Fair and equal access between and within ALL transport modes.
Freedom of choice by users/business and accordingly the respect of rights and choice to select the most appropriate transport mode for their mobility needs.
Transport and mobility efficiency, encouraging the most suitable and effective mode of transport according to the circumstances.
Integration of motorcycles, as well as other vulnerable road users, in transport and urban policy plans.

Focussing policy merely on supporting public transport, walking and cycling, denies the opportunity to create fully rounded transport policies, which are relevant to all who need to use transport for differing purposes and in widely varying circumstances. This narrow approach to transport policy also fails to maximise the opportunities that exist to reduce urban traffic congestion and pollution – an area where PTWs can play a significant role.

Ignoring PTWs in transport policy also has the added negative consequence of sustaining an environment for PTW users which is subject to greater vulnerabilities than should exist, and opportunities to improve safety are therefore lost.

Not including motorcycling positively in transport policy because of safety concerns actually becomes a self-fulfilling prophesy by the proponents of such a view, as PTW safety then remains unaddressed in the holistic manner that it should be.

1.2. Recognition of the economic and social contribution of motorcycling

Improved access for motorcyclists, and explicit recognition of the role of motorcycling, in transport policy will encourage economic and social benefits, including reduced overall transport costs to individuals and business, plus increased mobility and lower CO_2.

An expanding motorcycle industry means job opportunities and economic progress. This industry contributes to growth in a wide range of related sectors, such as parts suppliers, mould makers, machining, product 'finishing' and the protective clothing and helmet industries. This in turn provides careers, not only to those who build motorcycles and their components, but also to a wide range of logistics, transportation, sales, maintenance, motorcycle equipment businesses and service support businesses and industries.

The PTW sector is an important part of local business and economy in developing countries in particular. In developed nations sport has positive economic impacts in areas where activities are held. By way of an example, motorcycle sport in the UK was estimated to contribute £0.75billion to the UK economy in 2010.

Although figures vary from region to region, especially for the retail sector, it is estimated that worldwide up to four million people are employed by the PTW industry. Motorcycling and the industry is therefore an important part of global efforts to realise economic growth as the world emerged from the economic downturn after 2008.

Increased sales and market size mean economic growth, more jobs and more income to the state, factors that should be recognised and welcomed by government and society.

In order to support such growth, it is clear that much needed safety actions for PTWs need to be strongly linked to other policy actions to support this mode of transport and leisure, thus enabling motorcycling as a whole achieve its full economic and social potential.

1.3. Adapting Policies to Local Situations

It is important that safety policies for PTWs do not merely imprint developed countries' initiatives onto developing countries' situations. This is because all too often in developed countries an approach has been taken which involves little more than restricting access to PTWs, coupled with strong regulation of PTW use.

Such an approach may be popular among some road safety academics, Governments and safety lobbying organisations, but it fails to address many opportunities to reduce casualties that exist through integrating PTWs in wider transport policies. This is an extremely important consideration in countries where PTWs are important to society and the economy.

Without a tailored, holistic and dynamic approach to the already important economic and social role of PTWs in developing countries, this 'developed country' view of PTW safety is likely to lead to unintended economic and social consequences.

Any temptation for a Government to implement a 'quick political fix' to PTW safety, through 'importing' a restrictive policy from elsewhere should be avoided at all costs.

For example, simply banning the use of PTWs in cities could create a crisis in public transport capacity in those countries not in a position to develop advanced public transport solutions.

A further example would be a complicated, bureaucratic and expensive licensing regime which discourages PTW riders from seeking training and licence testing, a safety measure that would work against its stated intention.

It is important to remember that **'one size does not fit all'.** Road safety policy towards motorcycles and other transport modes needs to integrate with local patterns of usage and be sensitive to the role that PTWs play in local societies – plus their importance economically and socially.

To design integrated, targeted and effective policies, safety issues should be 'pre-audited' and assessed by all important stakeholders: road operators, policy makers, legislators, road users, industry and media.

It has to be recognised that several factors (in addition to helmet wearing) have a key impact on both motorcycle and other road user safety. Such factors include: infrastructure, road safety education, licencing and training of riders and drivers, vehicle maintenance and public policy.

IMMA strongly believes that PTW safety can be enhanced only by applying an integrated comprehensive approach and by involving policymakers and other relevant stakeholders at global, regional and national level working together towards the creation of a favourable environment for safer motorcycling.

This will ensure that local needs and differences would be successfully addressed.

Such an approach needs to involve all stakeholders with an influence on road transport including: education, awareness raising and training of PTW riders, car and truck drivers; the planning and building of infrastructure which is safer for preventing or mitigating PTW accidents; policies which account for PTW riders.

Best Practice Example: The Victorian PTW Strategic Action Plan, Australia

With such significant increases in the numbers of PTWs on Victoria's roads, the need has been identified for greater consideration of PTWs in road use and transport policy development and planning. It has been acknowledged that those working in these fields need to become more aware of the needs of PTWs and the role they can play in the transport network. In an environment where PTWs are an increasing component in Victoria's transport mix, the plan now seeks to identify initiatives and actions that will:

- significantly reduce the number of riders and pillion passengers killed or seriously injured
- ensure that PTWs are given appropriate recognition in transport and road use policy and planning

The four stage strategy

2. Infrastructure - Committing to Safer Infrastructure

In the last 10 years, there have been great improvements in the design and maintenance of roads and road features in the developed world. Regional initiatives under the International Road Assessment programme among others have helped point out the continuous need for validating the importance and design of crash barriers, the absence of objects on the side of the roads, and the importance of signage to warn road users of complex and hazardous situations ahead.

However, many challenges remain – particularly in developing countries where many roads are unpaved, road user licensing systems undeveloped, rider training virtually non-existent, and administrative structures in a 'fledgling' situation. This in itself is a key reason why the 'one size fits all' approach is not appropriate and a more holistic approach is needed.

A number of publications have been created through collaborative efforts by government officials, road design engineers and industry experts to identify specific issues of attention and to improve riding conditions for PTW users.

This shared expertise has provided best practices which can be adopted in other countries or regions. These lessons and best practices need to be further promoted and disseminated to infrastructure planning officials in the developing world.

While no single infrastructure or road design change can be singled out, a combination of improvements have assisted in providing safer roads for PTW use and there are some proven and tested best practice examples, including inter alia:

- Inclusion of PTWs in infrastructure policies
- Improvement and maintenance of road surface conditions (including avoiding poor quality road building leading to rapid deterioration, as can be seen in parts of West Africa and elsewhere)
- Regular road safety audits to assess safety levels of both existing and new road infrastructure projects (EU/USA/Others)
- Quality standards for unsealed roads (even 'Grade A1"large chip' gravel roads are often hazardous for motorcycle users – firmer types of unsealed surface should be used and regularly graded and rolled. This problem applies worldwide)

- Standards for marking or signing road hazards, plus illumination at night of dangerous hazards
- Bus lanes which allow PTWs
- Safe roadside barriers which are motorcyclist friendly
- Advanced stop lines at traffic lights for riders
- Remedial action towards black spots, with special attention to intersection design and traffic signs dedicated to warn riders at places of recurring accidents
- Consideration of motorcycles in addressing traffic issues, land use and parking
- Consideration of motorcycle users in design and construction of tolling plazas on motorways

Infrastructure is by far one of the most important issues for motorcycle safety in developing territories in particular. Adequate maintenance of roads and infrastructure should remain a priority for authorities, even in a context of economic difficulty.

- *Motorcycles are more likely to be involved in a fatal collision with a fixed object than other vehicles. In 2011, 23% of the motorcycles involved in fatal crashes collided with fixed objects, compared to 18% for passenger cars, 13% for light trucks, and 4% for large trucks (NHTSA - National Highway Traffic Safety Administration, "Traffic safety facts 2011 Data, Motorcycles", USA, May 2013).*

- *Accidents caused by the infrastructure account for 8% of the total. Poor conditions of many roads and the fact that PTWs are often neglected by transport plans are the principal reasons for this situation. Roadside barriers were found to present an increased danger to PTW riders, causing serious lower extremity and spinal injuries, as well as serious head injuries. (ACEM, "MAIDS – In-depth investigations of accidents involving powered two wheelers", Europe, final report 2.0, April 2009).*

- *The quality of road surfaces, the condition of the infrastructure and obstructions limiting riders' vision played a very important part in urban accidents. (ACEM, "MAIDS Urban Accidents Report", Europe, September 2009).*

Additionally, transportation planners should consider motorcycles in addressing traffic issues, land use and parking.

- *"The important role that road infrastructure can play in reducing injuries among all road users, including pedestrians, cyclists and motorcyclists. It recommends that governments implement regular road safety audits to assess safety levels of both existing and new road infrastructure projects." : ("Global status report on road safety 2013: supporting a Decade of Action", Geneva, Switzerland, World Health Organization).*

- *"PTWs are very sensitive to the road and traffic environment, including infrastructure design, maintenance and interaction with other road users. Due to this sensitivity, defects on the layout are likely to create more difficulties on PTW riders than on operators of other motorised vehicles." (OECD - ITF Joint Transport Research Centre draft Report "Safety of Powered Two Wheelers", 2014).*

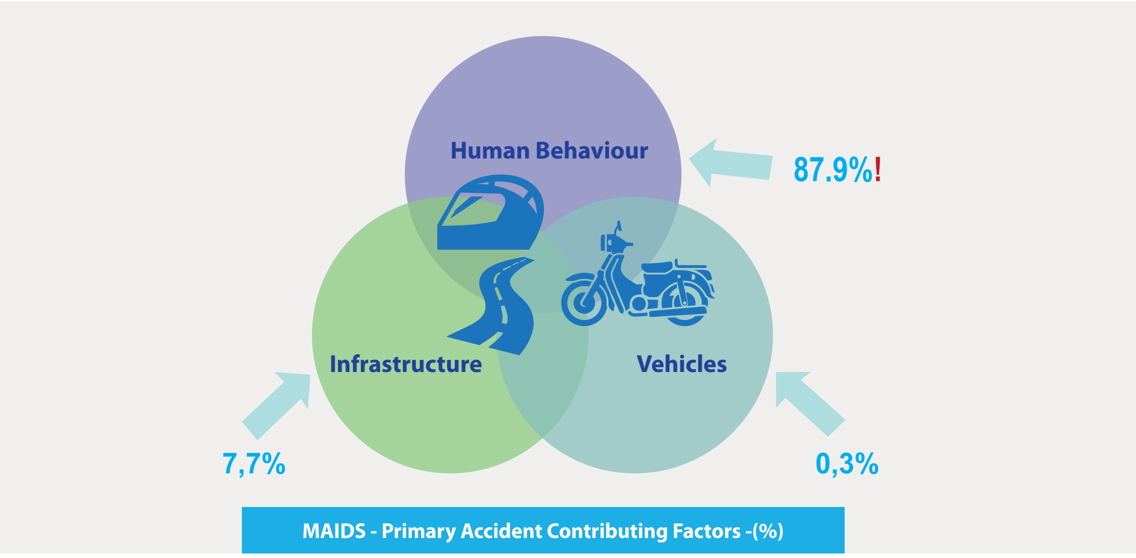
The four stage strategy

3. Awareness, Education and Training for all Road Users

Human error – major accident cause

The MAIDS Study, "Motorcycle Accidents In Depth Study" found that the major accident cause was human error - in 87.9% of all accidents. Infrastructure is the main causation factor in 7.7% of accidents and vehicle related in only 0.3% of all accidents. From this research, it can be assumed that the **Human Factor is of critical importance to any efforts to improve road safety for PTW riders and therefore encouraging behavioural change should be at the forefront of all activities and initiatives related to human factor.**

ACEM, "MAIDS – In-depth investigations of accidents involving powered two wheelers", Europe, final report 2.0, April 2009



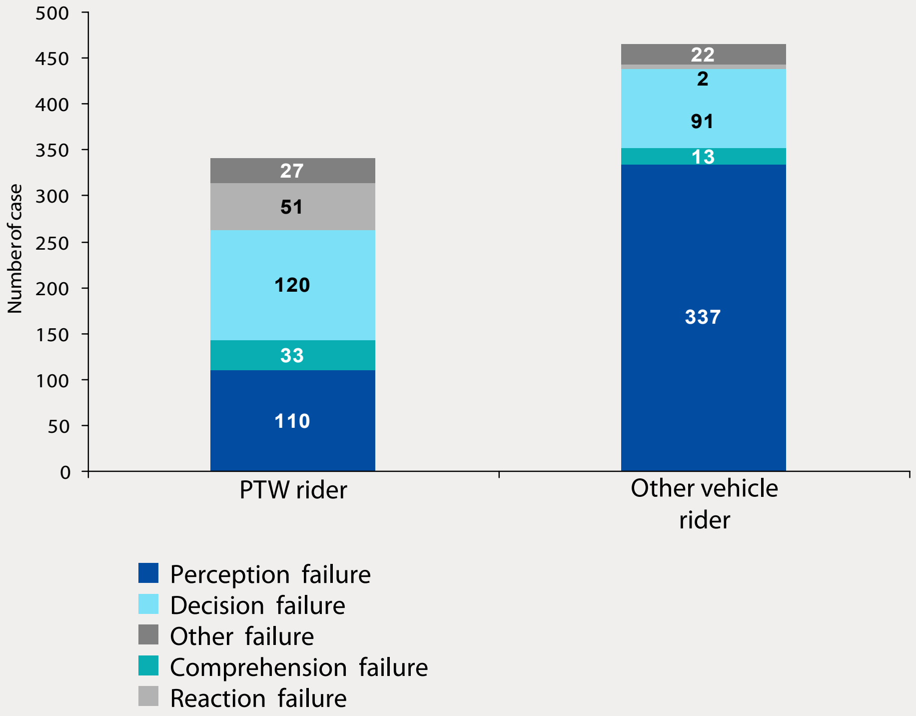
Other conclusions drawn from the MAIDS data were:

- *Other vehicle drivers are largely responsible for PTW accident causation - 61% of the multi-vehicle accidents*
- *However, PTW riders are responsible in 52% of fatal accidents cases.*

It would therefore be appropriate to place emphasis on training and educating not only of PTW riders, but also of other road users who may be involved in or even cause an accident with a PTW.

3.1 Awareness Raising for All Road Users

Greater emphasis is needed in the licensing curricula of all vehicle types to ensure more awareness of the behaviour of other road users. This would not only benefit PTW riders but also, for example, raise awareness among heavy goods vehicle (HGV) drivers to look out for cyclists when turning, and for car drivers to understand the difficulties HGVs have when braking or accelerating when fully laden. There is also the need to explain the potential hazards from misjudging the speed and approach of a PTW.



Source: : ACEM, "MAIDS – In-depth investigations of accidents involving powered two wheelers", Europe, final report 2.0, April 2009

The most frequent cause of accidents involving PTW riders is perception failure by other drivers. In such instances, the best vehicle technology in the world will not prevent the accident if the rider or driver has not perceived the relevant hazards and therefore make no attempt to avoid or mitigate the situation being faced.

- *In 70% of the accidents involving PTW riders car drivers were the primary causation factor - whereas motorcycle riders are exposed to a higher risk of being a victim in an accident (ITARDA - Institute for Traffic Accident Research and Data Analysis, "Information n°91", November 2011, Japan)*
- *Other vehicle drivers, who also have a motorcycle licence are much less likely to commit a perception failure in relation to the oncoming motorcycle (or misinterpret its distance and speed) than 'other vehicle' drivers who do not have a motorcycle licence (MAIDS, Europe)*
- *Car drivers overlook riders - in over 80% of crossing collisions and collisions while turning right, the cause was a delay in the car driver noticing the motorcycle and in nearly 70% of instances this delay was due to an insufficient check on the traffic (ITARDA - Institute for Traffic Accident Research and Data Analysis, "Information n°91", November 2011, Japan)*

Greater emphasis is needed in the licensing curricula of all vehicle types to ensure more awareness of the behaviours of other road users.

3.2. Lifelong Training of PTW Riders

As well as understanding and anticipating the behaviours of other vehicles, PTW riders can also benefit from both pre- and post-license training.

Rider training and education is fundamental to PTW safety. Critical skills can be enhanced for both novice and experienced riders to include hazard perception and vehicle control. IMMA members are actively involved in rider training and often participate in conjunction with government agencies or working groups on rider education.

Through these efforts, they are able to provide affordable, accessible and effective training to PTW users. The industry will encourage continued outreach to new and existing motorcycle riders on the importance of life-long rider training, including pre-licencing and voluntary post-licencing formulas.

IMMA members consider that training plays a crucial role for enhancing safer motorcycling and they will continue offering high quality and well - tailored voluntary training options across the globe.

Rider training courses vary widely between countries due to the different training requirements, vehicle fleets and training resources. There is also a multitude of countries where organized training does not yet exist.

Initial rider training provides the basic skills and awareness needed for novice riders. Subsequently, more advanced courses provide riders with additional opportunities to increase rider proficiency and safety and hazard perception skills. In addition, a variety of training options are offered within the context of motorcycle sports on dedicated tracks and off-road terrains which allow riders to greatly enhance their skills and control of the vehicle.

Due to the sheer number of two wheeler riders in the Asian region and the limitations of space and suitable facilities, the industry will continue advocating for an introduction of riding simulators in these regions, on a large scale, to help to educate and train PTW riders.

Industry is also willing to work with Governments in this region to assist any efforts they may make to develop sensible, achievable and affordable training strategies.

The training should be designed to enhance motorcycle safety by putting the rider's hazard awareness and perception at the core of the training curriculum

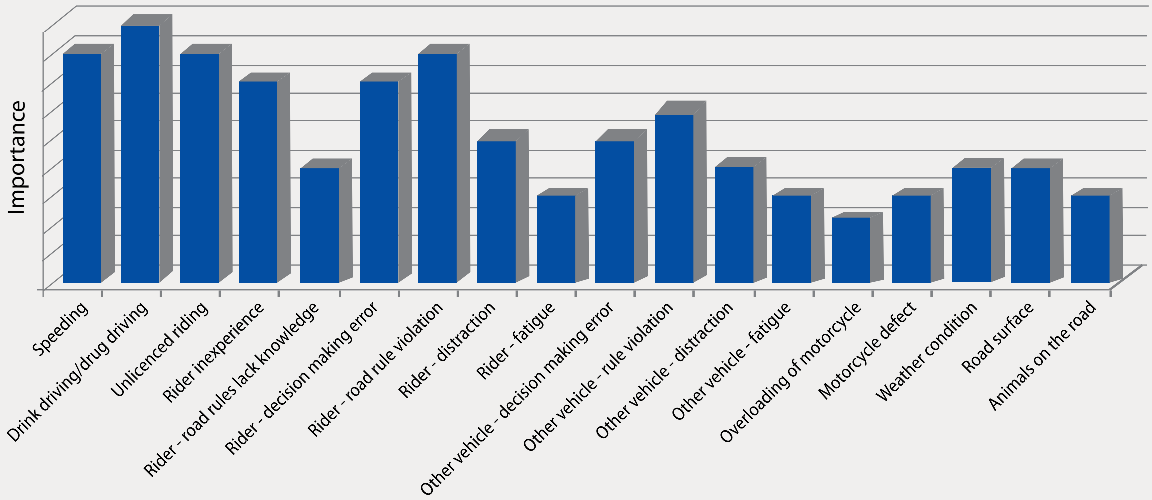
3.3. Preventing Impaired Riding

Riding without a proper license, riding under the influence of alcohol or drugs are all considered to be examples of impaired riding.

- *Out of 5,075 motorcyclists involved in fatal crashes in the USA in 2012, 27% (1,390) of the riders were under the influence of alcohol. That is more than 1 in 4 fatal motorcycle accidents attributed to drinking and riding (NHTSA - National Highway Traffic Safety Administration "Traffic Safety Facts 2012 Data, Alcohol-Impaired Driving", USA, December 2013)*
- *In Europe, riders involved in urban accidents were found to be less trained and less skilled than the total number of MAIDS surveyed riders - 47.6% of urban riders did not have an official training, (ACEM, "MAIDS Urban Accidents Report", Europe, September 2009)*
- *In the USA, almost one out of four motorcycle riders in fatal crashes in 2011 were operating their vehicles with an invalid license (NHTSA - National Highway Traffic Safety Administration, "Traffic safety facts 2011 Data, Motorcycles", USA, May 2013).*

- *In Cambodia in 2011, PTWs represented 83% of the motorized vehicle fleet and 66% of all fatalities. Excessive speed was responsible for more than 50% of them. Drinking & driving and lack of helmet usage were also major causes of road casualties ("Global status report on road safety 2013: supporting a Decade of Action", Geneva, Switzerland, World Health Organization).*

Overall rating of importance of selected causes of death from a motorcycle or scooter user in APEC economies in the last year (survey conducted 2010)



Source: APEC, Compendium of Best Practices on Motorcycle and Scooter Safety [TPT 06/2009A], July 2010 (www.apec-tptwg.org.cn/new/Projects/Compendium%20of%20MSS/files/survey%20report%20final.pdf)

Reducing impaired riding requires combined enforcement and education. IMMA strongly encourages governments to introduce combined campaigns, education and enforcement on drink and riding, tampering and riding without a proper licence.

3.4. Protective Riding Gear

While protective gear by itself does not prevent a crash from occurring, proper riding gear can reduce the effects of a crash.

IMMA promotes the safety benefits of protective gear considering riders' specific needs and different climatic conditions within regions of the world.

- *Evidence based benefits of personal protective equipment – analysis of MAIDS data base:*

Moped riders (Upper Torso and Upper extremities)

Light and medium garment – in 73% of all cases the protective equipment was effective in preventing or mitigating injuries.

Heavy garment – in 93% of all cases the protective equipment was effective in preventing or mitigating injuries.

Motorcycle riders (Upper Torso and Upper extremities)

Light and medium garment – in 69% of all cases the protective equipment was effective in preventing or mitigating the injuries

Heavy garment – in 92% of all cases the protective equipment was effective in preventing or mitigating the injuries.

Light garment= thin cotton; Medium garment= denim, light leather or nylon; Heavy garment= Kevlar, imitation or heavy leather

Protective equipment should also be considered for the riding environment. Good quality gloves and footwear can do much to mitigate accident injury. Basic eye protection is also important.

The benefits of good quality motorcycling clothing are still widely underestimated and there is a need of continuous efforts for encouraging a wider take-up of protective gear amongst riders suitable for their riding environment.

Use of Helmets

Global action for motorcycle safety rightly focusses on helmet wearing. However, this is only one important part of a bigger PTW safety picture. Despite the high safety value of helmets, the creation and enforcement of helmet laws should not be regarded as a simple political 'fix' to PTW safety.

Positive injury reduction rates can be expected from increased helmet wearing rates, but in isolation such a policy can only mitigate the consequences of an accident rather than seeking to prevent the accident in the first place. The highest priority should be given to preventing accidents through integrated policies and by improved safety behaviours of all road users.

Wearing a helmet of a proper quality standard and in the proper way can provide protection to riders to significantly mitigate head injury.

- *Wearing a standard, good quality motorcycle helmet can reduce the risk of death by 40% and the risk of serious injury by over 70% ("Global status report on road safety 2013: supporting a Decade of Action", Geneva, Switzerland, World Health Organization)*
- *Helmets saved 1,617 motorcyclists' lives in 2011 in the USA, and 703 more lives could have been saved if all motorcyclists had worn helmets. (NHTSA - National Highway Traffic Safety Administration, "Traffic safety facts 2011 Data, Motorcycles", USA, May 2013)*

Choosing a helmet should be at the discretion of the rider: it is his responsibility to select the adequate type and size fitting with his/her specific use, climate and economic considerations.

In countries where helmet wearing rates are very high, emphasis should be placed on the correct usage of helmets, with the chinstrap fastened correctly.

Diversity in approach also needs to be recognised. For example, in some of the ASEAN regions, governments are considering the development of an alternative specification of helmets, which are lighter and could be considered more appropriate for use in hot and humid climates. IMMA supports the discussion of this topic at UN level.

IMMA strongly supports the proper use of helmets as part of an integrated comprehensive approach.
The efforts in this area should be orientated towards social marketing and awareness campaigns about the benefits of using proper helmets, and fitting/fastening them correctly combined with effective enforcement.

3.5. Regular maintenance of the vehicles

Periodic inspections reduce the incidence of safety related defects to tyres, brakes and lights, particularly those of which the owner is unaware. Regular checks of vehicles would possibly have a much greater impact in developing countries, where running damaged or dilapidated vehicles can be common on the roads. Countries developing an inspection regime should adapt regulations to meet national characteristics and needs – not a blanket, 'one-size-fits-all' approach.

For example the very highest standards of Periodic Technical Inspection (PTI) regimes may not be appropriate in territories where incomes and economies are a challenge and the ability of users to afford costly in-depth inspections is absent. In such cases, an initial PTI regime should focus on a basic inspection of the operation of vehicle safety items such as tyres, brakes, lights etc. Such PTI regimes can develop as the local situation evolves in a positive economic and social direction.

Riders should be strongly encouraged to maintain initial construction standards, and their vehicle should undergo regular maintenance and servicing.

The four stage strategy

4. Technology Advances

The motorcycle Industry is committed

When developing products, manufacturers strive to achieve the highest standards of construction and technology, taking into account specific aspects of different global markets. New products are subjected to a series of stringent tests that aim to protect the safety of riders and improve environmental performance. In order to implement increasingly advanced regulatory and industry standards, manufacturers need to resort to complex designs, refined construction methods and advanced technologies.

Safety of the products is of utmost importance for IMMA members.

A comprehensive, multi-level quality management system ensures quality in all work processes as well as components and materials, and ultimately - products. But above all, the IMMA members orient their quality management system to the needs of their customers. To strengthen customer trust by offering products founded in safety and offering a new level of outstanding quality, IMMA manufacturers have created a quality cycle that continuously enhances quality at every stage: design, development, production, sales and after-sales service.

Industry has been driving advances in preventive, primary and secondary safety.

Preventive safety aims at improving riding and driving standards. Primary safety refers to functions such as vehicle stability, braking, traction control, innovative ergonomics and chassis designs that improve the rider's control of the vehicle.

As various studies from around the world have demonstrated, the majority of PTW accidents are caused by the driver of the other vehicle who 'did not see' the PTW (rider). Therefore, PTW conspicuity comes to mind when referring to preventive safety. Conspicuity has been and is continuously being improved through advances in vehicle daytime and night-time lighting technologies.

Conspicuity is also anticipated to be improved in the future through electronic devices, whereby the PTW (rider) can be "seen" by the other vehicle through Cooperative Intelligent Transport Systems (ITS).

Industry has also developed and successfully introduced various secondary (passive) vehicle safety improvements. However it is clear that due to the specific nature of two-wheeled vehicles, such as the exposed position of the rider, the possibilities for secondary safety are limited and very complex.

Along with introducing the many new vehicle technologies over the years, additional competencies have been developed and acquired by manufacturers. Examples of such relatively new fields are Intelligent Transport Systems, functional safety of electrically propelled vehicles and safety of batteries for electrically propelled and hybrid vehicles.

Industry is proactive

As a result of the industry's motivation to deliver high performing and appealing products in a competitive environment, manufacturers are proactive in implementing value-added innovative features suited to meet specific regional needs.

Industry has a significant record in developing and introducing a wide spectrum of improvements on vehicles. These include, among others:

Vehicle lighting technologies
Braking systems
Ergonomic design of rider position and controls
Use of light and durable materials
Design and construction of the vehicle frame
Innovations improving overall vehicle stability
Suspension, tires, fuel system integrity.

In addition, as a result of regional and global cooperation between the manufacturers, the industry has initiated a number of new and updated international standards as well as new international UN Regulations and amendments. This is to properly describe new technologies and enable their implementation, with the aim of continually improving vehicle and road safety.

To illustrate some industry policies of proactively introducing improvements at worldwide or regional level, reference is made below to the advancements in:

Vehicle lighting
Braking

Vehicle Lighting

Vehicle lighting technology is subject to rapid technology evolution. The industry has been deeply involved in adapting these technologies to PTWs to improve rider vision, visibility and the lighting signature of PTWs. In addition, various specific concepts for PTWs have been introduced to provide additional lighting to increase vision for the rider during banking/leaning of the vehicle. Thanks to the increasing spectrum of lighting technologies available, including advanced ones such as LEDs, lighting signatures and vision during different environmental conditions are constantly improving.

The lack of conspicuity - being seen and being perceived correctly - has been identified by various studies as a very important factor in PTW accidents. In addition, various researchers have raised concern of reduced conspicuity for PTWs due to Daytime Running Lights (DRL) or driving with headlights-on with cars.

Headlamp-on riding has generally been considered as an important measure to improve the PTW rider's individual safety in most regions in the world. The promotion of this measure by IMMA resulted in its formal introduction in the 1968 Vienna Convention on Road Traffic, with 72 Contracting Parties.

Aiming to support headlamp-on policies, manufacturers developed the Automatic Headlamp-On (AHO) feature on PTWs. The AHO system ensures that the front light is automatically turned on when the engine runs. In 2003, ACEM, the European IMMA-member, introduced AHO as a voluntary commitment and in that same year IMMA introduced a proposal to amend existing lighting legislation at UNECE/WP.29 to include AHO as a standard for motorcycles in the corresponding UN Regulation. Furthermore, manufacturers continue to develop and introduce additional lighting solutions, with these applying to specific vehicle types and/or to meet local market needs and conditions.

Markets where headlamp-on policies have not been introduced may need to be assessed as part of a process that leads to the introduction of Headlamp On or AHO. Such an AHO assessment may be particularly meaningful in countries with high PTW density (e.g. above 70%) and in which average speeds in the traffic mix are relatively low.

It should however be remembered that PTW conspicuity is strongly related to the behaviour of riders. Whether or not the rider is seen largely relates to the observational skills and behaviour of the other vehicle driver and to aspects of behaviour and planning on the part of the PTW rider. Examples of issues that impact conspicuity are the position of the PTW in the traffic lane, the distance of the PTW to other vehicles within the lane and differences in speeds between the PTW and the surrounding traffic.

Braking

As a result of industry's ongoing work in the area of vehicle stability and braking, the brake/tyre combinations on today's PTWs have very high performance capabilities in a very wide variety of traffic and road conditions.

However, it is important that riders are taught to using the full potential of PTW brakes in a proper way, as incorrect braking can be a contributory factor in accidents.

To introduce a global regulatory framework for braking, encompassing advanced braking systems, IMMA has led the discussion on the creation of a new global technical regulation (UN GTR) on PTW braking under WP.29.

In this new 'GTR 3', the highest levels of performance requirements for PTW braking have been brought together.

Through updating and aligning UN Regulation N° 78 with the GTR, combined with the introduction of UN GTR N° 3 in other countries, these new braking system requirements have received the broadest geographical coverage.

Countries should first apply this important worldwide regulatory standard before considering government incentives for the introduction of policies associated to new technologies (e.g. advanced braking systems).

Over the years, the motorcycle industry has developed and introduced several braking technologies on vehicles, enhancing the effectiveness of these devices and adjusting them to specific manoeuvres and needs. Advanced braking systems encompass different systems, technologies and approaches such as anti-lock brake systems (ABS) acting on one or both wheels, combined brake systems (CBS), rear wheel lift-off protection (RLP) and automatic brake force distribution. Such systems can be present individually or in combination.

To speed up the introduction of advanced braking systems in the European market, ACEM (IMMA's European member) made a voluntary agreement in 2004. This was undertaken in order to contribute to the aims of the European Road Safety Charter. ACEM members committed to introduce, at least as an option, advanced braking systems on more than 50% of street motorcycle models offered on the European market by 2010. This commitment was renewed in 2008, to extend the coverage to 75% by 2015 and the preliminary results indicate that the manufacturers will be in a position to meet the commitment.

While the potential benefits are considerable, it should be remembered that the benefits and limitations of various Advanced Braking Systems vary significantly per type of PTW. The vehicle weight and the vehicle centre of gravity can be very different between models, which can have an important impact, together with the rider's braking behaviour.

Also the typical riding environment and patterns of riding can have a strong impact on the effectiveness of, for example, an anti-lock braking system. This can often be the case in relation to off road environments, or roads which are constructed mainly of dirt, gravel or 'piste'. Therefore, manufacturers need to consider factors such as customer expectations, regulatory requirements, intended vehicle usage costs and the primary roads infrastructure when determining which types of systems to offer for a given vehicle in each market.

IMMA additionally emphasises the importance of the education of riders on the benefits and limitations of advanced braking systems. Without proper training, the introduction of advanced braking technology may lead inexperienced riders to demonstrate over-confident behaviour which can reduce or eliminate the desired safety benefits.[2]

Holistic perspective

As noted in the two examples above, IMMA and its associated manufacturers have a track record of advancing vehicle technology and performance.

It should be remembered that providing PTWs with additional vehicle related options or technologies - or introducing vehicle specific regulation - is not on its own sufficient without a strong and continued focus on rider training and behaviour of the rider. Adequate vehicle maintenance by the owner and attention to the quality of the road infrastructure is also vital.

Enforcement, inclusion in integrated transport policies, plus training and education, as a result of the adequate inclusion of PTWs in mainstream transport policies, are issues that require particular and regular attention. Introduction of new technologies and solutions require education of the customer.

As a consequence, IMMA member manufacturers invest significant effort in educating customers and promoting new safety solutions, in order to allow the market to adapt to new features and technologies. In

2 The NHTSA automotive ABS effectiveness study for four-wheelers, provides support for the point above - http://www-nrd.nhtsa.dot.gov/Pubs/811182.PDF

addition, IMMA members have been very active at national, regional and international level in promoting PTW road safety with policy makers.

Future technology challenges - outlook

Looking ahead, with new technologies evolving and becoming applicable, PTW manufacturers will continue to develop their competencies, and continue to develop the technical performance of PTWs.

Concretely, Intelligent Transport Systems (ITS), such as cooperative systems and Advanced Driver or Rider Assistance Systems (ADAS) are coming into focus. It is apparent there are a number of challenges related to the fitment of these systems on PTWs. This section will provide an outlook on some possible future technologies, and on the associated issues.

Intelligent Transport Systems (ITS)

ITS technology provides information and communication technology to transport infrastructure and to vehicles in an effort to improve safety, reduce the environmental impact, and render trips more efficient and comfortable. Besides extensive efforts within PTW manufacturers' in-house R&D departments, there are numerous collaborative initiatives in Europe, the United States, Japan and Korea. These are aimed at developing cooperative or standalone technologies, undertaking feasibility studies and promoting standardisation. These collaboration initiatives involve the vehicle and supplier industries, and governments. Road, telecom, and other technology partners are also involved.

As traffic systems, traffic mix, telecom and road infrastructure quality are very different from country to country and region to region, the solutions that may be successful in the future are likely to be diverse.

As manufacturers cannot be involved in all developments, IMMA emphasises that PTWs should not be forgotten or overlooked whenever ITS are considered in road infrastructure upgrades, and in work on other vehicle types like cars and trucks. Although initial design and development for ITS will primarily be focussed on 4-wheelers, the application of advanced technologies to PTWs, as well as the impact of advanced technologies on PTWs, should be considered in the initial design stages. An example of the lack of consideration of PTWs in an ITS system is the non-opening of barriers at toll-plazas due to the relatively low weight of the PTWs.

It should be remembered that the fitment of ITS on PTWs can be a complex challenge. Vehicle-centered ITS, before application to PTWs, is developed and introduced on 4-wheelers and in particular on commercial vehicles. The application of such technologies on PTWs is in most cases far from a simple carry-over from car technology. This is because the characteristics of PTWs (vehicle size, use, weight, space, balance, dynamics, handling, usage environment) vary considerably and often require many specific adaptations before being applied to PTWs. This multiplies the development challenges.

To illustrate the complexity, Advanced Driver Assistance Systems (ADAS) primarily engineered for use in cars, have the potential to be dangerous if applied to a PTW without modification. Any system not specially designed for PTW which intervenes in the control of the brake, throttle, or steering could severely affect the stability of the PTW and may lead to loss of vehicle control.

IMMA members are working actively on ITS for motorcycles. Some Driver Assistance Systems (DAS) for motorcycles are already on the market, mainly as optional equipment, mostly on high-end vehicles for the time being, due to the additional consumer cost of these systems. These DAS comprise of equipment such

as: ABS, Traction Control, Tyre Pressure Monitoring System, Electronic Adjustable Suspension, Electronic Cruise Control, Gear Shift Indicator/Assistant, Fuel Economy Assistant, Proximity Activation, In-vehicle Navigation System and Riding Mode.

◢ Cooperative Systems

Motorcycle safety, comfort and environmental performance may be further enhanced via vehicle-to-vehicle and vehicle-to-infrastructure communication (V2X). Additional communication frameworks are expected to improve safety in critical scenarios for PTW riders (intersections, blind spots, rural roads, poor visibility areas, etc.).

Vehicle-to-Infrastructure Communication (V2X) will progressively appear in cars in the medium term. In the long term, vehicle-to-vehicle and V2X will potentially address many common PTW accident configurations (54% of PTW accidents occur at an intersection according to MAIDS) and they may offer solutions in certain cases where conspicuity plays a critical role.

Once the necessary infrastructure has been developed and initial economies of scale have been achieved in the car sector, motorcycle safety will benefit from including the PTWs in this connected world. One potential benefit could be the development of a level of electronic conspicuity, which can be shared between riders and drivers of other road vehicles

It is expected that vehicles will be equipped progressively with cooperative ITS and certain regions may be more suited than others to roll out these new technologies. As a number of these systems are in the research phase, their effectiveness, technical feasibility and market acceptance are being investigated.

◢ International standards and regulations need to be promoted and protected

World Forum WP.29

Complementary to the development and implementation of technologies, IMMA has been involved for over half a century in the World Forum WP.29 for the development and maintenance of regulations, together with representatives of governments, type approval authorities, research bodies and other interested stakeholders. At WP.29, IMMA speaks on behalf of the global PTW industry. IMMA ensures that the process of rulemaking in which all decisions are taken by governments, is facilitated through the provision of technical information, argumentation and scientific data, resulting in the development of technical legislation to appropriate levels.

When considering implementation of new technologies in legislation, policy makers should recognize the diversity in PTWs, users and their usage in the different regions where there is a great variety in road infrastructure, traffic conditions, and stages of economic development.

In some cases, before new technologies are considered for mandatory application by government administrations, the application of the latest international standards and regulations should be the first step.

Referring to the four step strategy outlined in this document, it must be noted that whilst technical advances in motorcycles will continue to play a role in rider safety, the primary focus must be placed on public policy development, rider behaviour and safer roads for riders.

IMMA strongly promotes the activities of WP.29 to expand and promote global harmonised regulations on safety and environmental performance.

The creation of globally harmonised markets would benefit motorcycle production, reducing costs, improving economies of scale, and help manufacturers roll-out new technologies more quickly. It would bring considerable efficiencies with more accessible products for customers all over the world. All these elements favour the safety of vehicles and benefits the end users.

IMMA invites countries, who are not a signatory or have not acceded to the instruments managed by the World Forum, such as the 1958 Agreement and 1998 Agreement, to join WP.29, accede to the agreements, and adopt worldwide regulations for safety and environment.

Protection of Intellectual Property Rights (IPR)

As a result of globalization, economic development and rapid motorization in various emerging and developing countries, manufacturers face complex issues related to IPR.

Today, trade in counterfeit products is reaching epidemic proportions, particularly in developing countries, which are highly price sensitive. Customers can be easily attracted by low cost, but low quality, counterfeit spare parts marked illegally with well-known global brand names designed to mislead customers. Counterfeit products, being cheaper, are usually made of low quality raw materials and rarely go through any safety tests or quality certification. The most commonly counterfeited spare parts are those which are fast moving in the aftermarket and those which are frequently replaced, such as all types of filters, spark plugs, brake pads, clutches, suspension items, electrical items etc.

Often the customer either cannot distinguish between genuine or counterfeit parts or is not concerned by it because the low price point is the most important factor and the spare part works at the time of fitment. However, these customers may not fully understand the adverse impact counterfeit spare parts may have on other vehicle systems and ultimately on their own road safety.

Consumer awareness is the key to eliminating this problem and original manufacturers have started regular campaigns and various outreach programs in educating influencers and end consumers on the benefits of using genuine parts. Many of these manufacturers have hired agencies specialized in trademark and copyright protection to identify infringements and support the authorities to conduct raids on outlets, manufacturing and/or selling counterfeit parts.

Nearly all markets in the world are affected at different levels by counterfeit products. For example, distribution of illegal counterfeit components or distribution and promotion of full counterfeit vehicles.

To protect customers from accidents caused by the use of counterfeit products of inferior quality and safety, IMMA emphasizes the importance of enforcement of measures to prevent the marketing, distribution, sale and use of either non-compliant, or unsafe motorcycles and their parts or those in which intellectual property rights are infringed.

A vehicle in its original form has been configured and designed in such a way as to ensure legal compliance. Modifications using components that are not recommended by the original manufacturer for proper use on on-road vehicles or not installed by its authorised representatives, pose significant threats to overall compliance and performance.

Intellectual Property protection is everyone's responsibility. A strong commitment and consistency on IP enforcement from all agencies involved in IPR is needed. In parallel, those efforts must be intensified to increase public awareness of IPR and the seriousness of IPR infringements as counterfeiting puts in danger consumer's health and safety.

Therefore, education and awareness strategies require further attention in many regions, to develop enforcement initiatives and best practice. In some regions, significant efforts are necessary to improve rules and procedures, capacity building of law enforcers strengthen the monitoring of counterfeit sales, and warning to counterfeiting manufacturers and retailers.

Chapter 4: A Strategy needs Support

4.1 A Strategy needs Support: The Integrated Approach

"A safe system approach is required to improve the safety of PTWs
Growing PTW traffic makes it imperative to adopt safety interventions targeting this mode of transport, while integrating it into a safe system approach.
Improving the safety of PTWs should be a shared responsibility.

All relevant stakeholders need to be actively involved in the process of drawing up and implementing a shared road safety strategy which includes safer behaviour of all road users, safer infrastructure and vehicles with enhanced safety features. As the economic costs associated with PTW crashes are significant, investing in PTW safety can bring important societal and economic benefits."

(*OECD - ITF Joint Transport Research Centre draft Report "Safety of Powered Two Wheelers", 2014*)

Only a truly comprehensive approach integrating knowledge, policy, human behavioural change, infrastructure and vehicles can address the needs of PTW riders for a better and improved road safety performance.

IMMA members actively support the **'shared responsibility'** concept and are committed to reducing accidents by participating in research, road safety initiatives and projects and supporting forums and platforms, acting towards the common objective of improving PTW safety.

IMMA and its individual members and associated manufacturers have been involved in various regional, national and local undertakings and consider that further developments in this area are strongly recommended in different regions in the world.

It is for this reason that IMMA has stepped up its involvement at the international level and contributed to activities under the International Transport Forum and joined International Road Traffic Accident Data (IRTAD) and United Nations Road Safety Collaboration (UNRSC).

IMMA and its members will persevere in their efforts to participate in various initiatives and projects, including in-depth and naturalistic riding studies to support the bringing together of all key stakeholders who can provide a positive and even handed approach to road safety.

4.2. A Strategy needs Support: Research, Data & Analysis

In order to better understand the road safety situation in each region, data needs to be available according to harmonized definitions. It is not possible to analyse which are the right solutions to employ in a particular region if there is no data to illustrate the most frequent or severe types of accidents.

In-depth analyses and comparisons between different regions can only be relevant if raw data is collected using standardised definitions and methodologies. In-depth analysis will provide a deeper understanding of the situation, whereas general statistics may provide first high level indications only.

Unfortunately, there are still too many countries where PTW accident statistics are not collected at all or not maintained at an adequate level. Definitions of key variables may vary from one country to another, some variables are not collected in all countries, data is missing, or is not in line with other sources.

The absence of data relating to km/miles travelled by different vehicle modes is a serious deficiency. This means that accurate records of casualty rates per distance travelled – the most accurate measure of relative safety - is unavailable.

Harmonised data is useful for looking into global trends or patterns of progress. However when studying accident data it is crucial to realize, as outlined in chapter 1, that traffic systems, climatic conditions, road infrastructure, and the PTWs themselves (both their purpose and usage patterns) vary widely, from region to region, country to country.

Factors which vary most from one country to another include the balance of PTWs in the traffic mix, plus whether the PTW is being used functionally (such as for commuting) or for leisure. Hot countries often tend to have a greater proliferation of scooters than larger motorcycles. Poor road conditions can dramatically and negatively impact the number of accidents in developing countries.

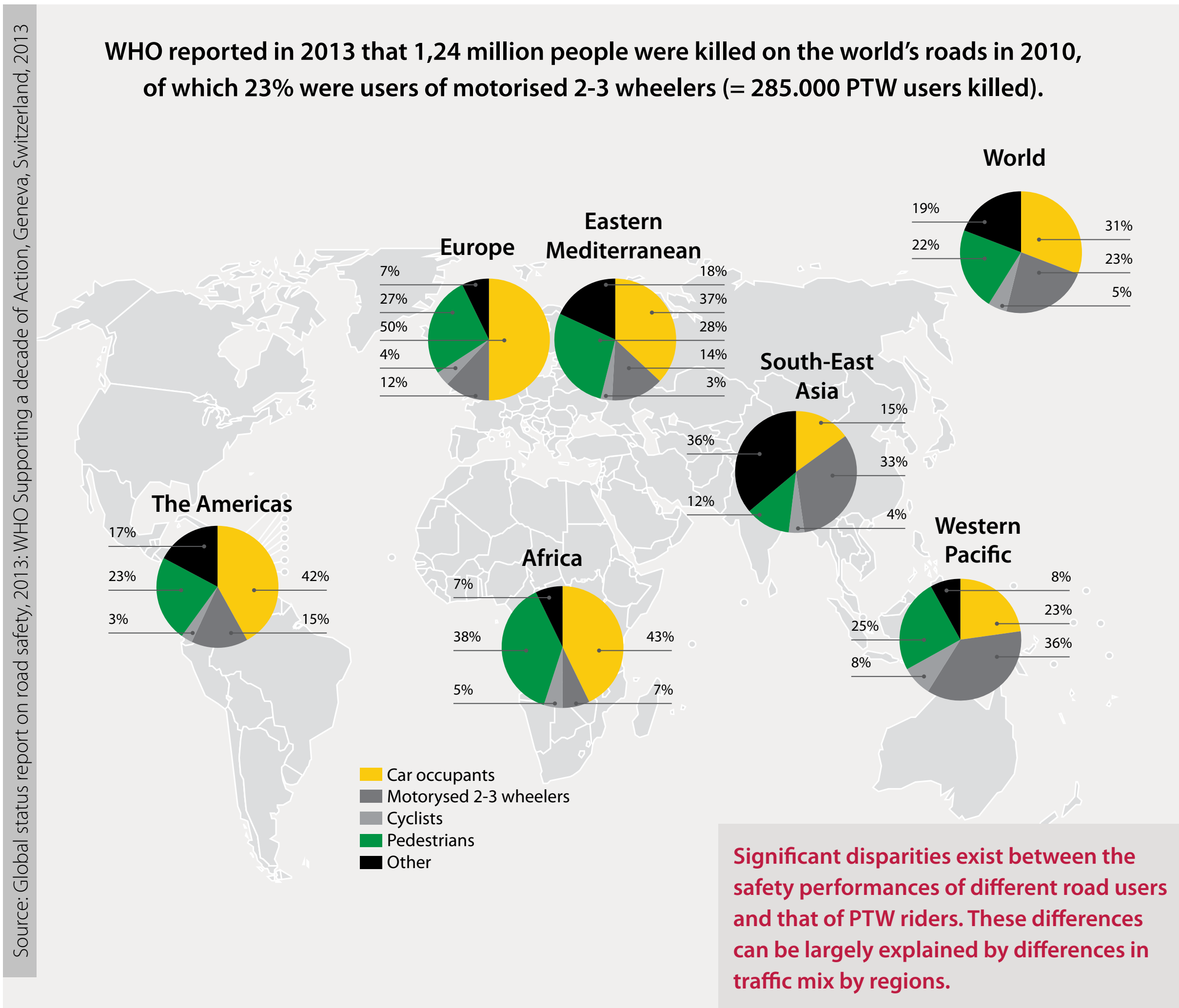
When studying the road safety situation in the regions, such differences should be taken into account. **To adequately understand the PTW safety trends, local studies are required.**

Consequently, it would not be accurate to analyse the global situation on the basis of one consolidated dataset. An in-depth analysis by countries or regions (grouping countries with similar data collection methods, similar vehicles and similar use) would appear to be one useful way of summarising worldwide trends.

The most recent comprehensive overview of accident statistics was created and reported in the WHO publication "The Global status report on road safety 2013". The overview indicates that "the safety of riders remains of particular concern worldwide as in many countries the number of riders killed and seriously injured has not been reduced in line with improvements for other categories of road users."

This statement in itself underlines the importance of the need for robust casualty data, so that policies and actions to mitigate the situation underlined by the WHO can be targeted effectively, and avoid an approach which may not be appropriate in some countries or regions. One size does not fit all.

Road traffic deaths by type of user by WHO region



Significant disparities exist between the safety performances of different road users and that of PTW riders. These differences can be largely explained by differences in traffic mix by regions.

IMMA emphasises that the analysis of the trends in road safety is most important. Analysis of the absolute number of fatalities can lead to misinterpretation and inadequate comparison as the growth or decline of the riding population is not taken into account.

Below, the trends have been identified by comparing indicators over time with number of PTW fatalities per 10.000 vehicles in use. It should be noted that this table offers general information only. **IMMA contends that care should be taken when comparing the performance between countries. This is because there are major differences in the actual traffic context or traffic mix in the regions. Examples being different use of PTWs, large differences in the state of the infrastructure, different driver licensing schemes, climate conditions or other factors. A further important notion is that data collection efforts and methods are very different between regions, and generally improve over the years, which should be well considered when interpreting data and trends.**

Rider safety performance - Trends in the regions 2006-2011

	Comparison between 2011 and 2006			
Region/Country	PTWs fatalities/10,000 PTWs 2006	PTWs fatalities/10,000 PTWs 2011	Evolution (in %)	Evolution of the circulationg park (vehicles in use) during same period (in %)
Australia	5.16	2.93	-43.2%	46.7%
Europe*	2.02	1.50	-25.7%	4.4%
India	2.91	3.01	3.3%	57.3%
Japan	0.97	0.80	-18.2%	-5.7%
Malaysia	4.95	3.72	-24.9%	33.9%
Philippines	3.14	1.77	-43.7%	56.1%
Thailand	5.35	3.84	-28.3%	16.0%
Taiwan	1.07	0.71	-34.1%	11.9%
USA & Canada	7.05	5.24	-25.7%	27.3%

* Europe includes Austria, Belgium, Czech Republic, France, Germany, Greece, Ireland, Italy, The Netherlands, Poland, Spain, Sweden, United Kingdom

Source: IMMA

In many regions results are really encouraging with PTWs fatalities decreasing while circulating park figures are constantly increasing - the greatest boost of all transport sectors for the last decade.

There has been a significant improvement in PTW fatalities per 10.000 vehicles in most countries/regions (2011 vs 2006). In most cases reduction observed is lower for the PTWs than the reduction for the total fatalities/10.000 motor vehicles.

This relative reduction of PTWs fatalities needs to be associated with the high increase of the PTWs circulating park during the same period. In other words, the risk of having an accident on PTWs has fallen despite fatality records not having improved as fast as is desired.

The accident trends demonstrate that PTWs, and their rapid growth, have not been successfully considered in transport and mobility plans. A significant change in approach is required. The great disparity in road safety performance and risk exposure for PTW riders between countries, regions and cities in the world requires further exploration and proper analysis.

There is a strong need to deliver periodic reviews of PTW road safety performance at national level that will provide policymakers and safety practitioners across the world with easily accessible factual and useful information.

For the study of PTW safety trends, IMMA recommends investigation of the following:

1. The trend and absolute number of fatalities and number of registered vehicles (circulating park) by category of road users (moped, motorcycle and all PTWs).
2. The trend and absolute number of kilometres ridden by the different categories as exposure risk data.
3. When kilometres/miles travelled are not available, the ratio of riders killed per 10,000 circulating PTWs will provide insight to identify trends. However, one should remain careful comparisons of the PTW road safety situation with other localities, countries or regions, because particularly for PTW use the context can be very different.

4. Comparisons between countries require the consideration of a great number of different indicators (including economics, demographics, etc.). These indicators should be accounted for when setting goals or targets at a global level.
5. Analysis into any great disparities in road safety performance and risk exposure for PTW riders between countries, regions and cities in the world, showing where there may be greatest potential for safety improvements.
6. Statistics on helmet wearing rates, results of awareness raising campaigns combined with enforcement actions targeting specific groups of riders in certain localities or areas. Note: It is essential that targeted enforcement is only used as part of wider actions to engage riders in safety awareness in a positive way.
7. Local conditions such as infrastructure condition, local laws and administrative/enforcement structures should also be considered as part of the background to country/region studies in particular.

Detailed and complete set of PTW accident and exposure data is needed at global, regional and national levels.

PTW in-depth studies

PTW accident in-depth studies help to better understand the causation of PTW accidents and may allow for estimates of the effects of introducing new technologies, new licensing and training schemes, as well as new motorcycle friendly infrastructure. Thanks to the great insights they provide, in depth studies help to better target specific challenges and identify appropriate countermeasures.

Naturalistic riding studies

The naturalistic riding studies observe the natural behaviour of road users during ordinary every day trips with their own vehicles. To collect the necessary data, the vehicle is equipped with various instruments, in an unobtrusive manner, which register the vehicle movements (like speed, acceleration/braking, direction), driver behaviour (e.g. eye, head and hand movements), and external conditions (road features, traffic, weather etc.).

This yields a large amount of information about the relationship between person, road, vehicle, weather and traffic conditions, not only under ordinary circumstances, but also in (near) crashes. Naturalistic riding studies are considered as an essential tool for collecting and analysing extensive exposure data on PTW rider behaviour and trajectories, which can be used for the evaluation and potential improvement of training, the design of Human Machine Interfaces (HMI), and road signage, among many other factors.

Improved knowledge on PTW accident causation, normal riding and safety critical events is fundamental to identifying the right safety priorities.

Therefore, the industry calls upon the international and national institutions to consider the opportunity of implementing in-depth accident and large-scale naturalistic riding studies.

4.3 A Strategy needs Support: Tailoring Strategies to meet Localised Needs

Fundamental to pulling together the many factors which influence PTW safety, is the need to tailor any strategies or actions to the local environment. Action towards motorcycle safety in one country may not be workable in another. In order to assess what is appropriate for a particular country or region, a collaborative approach is required where the two wheeler community, the police, policy makers, industry and city planners work together to agree on what is right for a particular road network.

The major causes of accidents or injuries also vary greatly from one country to another, and the responses to these causes should be adapted accordingly. In order to isolate the most prevalent causes of accidents, localised studies are first required. For example, the most significant factor causing PTW fatalities could be poor road conditions in a developing country, whereas in a more developed but extremely hot country, a major factor in saving lives could be the increased rate of helmet wearing.

Chapter 5:
Global Best Practice Examples

Introduction

Key to the development of road safety policy in any country or territory is the sharing of best practices. This can help to facilitate activities, save time in developing strategies and ensure that 'wheels are not reinvented' where this is not needed.

Clearly each country will have local conditions, cultures and attitudes that are unique and a 'one size fits all' approach would not always be appropriate. However, there is a wealth of safety knowledge that exists in relation to PTWs on a global sense. This knowledge is ripe for sharing and with suitable local adaptation implementing and exercising.

IMMA has pooled the extensive knowledge and resources that exist across the world to create a resource which is now available to the global institutions, governments, public authorities and other stakeholders with an interest in PTW safety.

Available as annex to the current document, the IMMA Best Practice resource covers the following areas:

Safety and Transport Policy
Infrastructure
Awarness, Training and Education
Data & Analysis

The above themes all fit within the Four Stage Strategy principles. In many cases, the initiatives outlined have been developed by IMMA members in collaboration with public authorities, or they may be initiatives that have been initiated by Governments themselves.

In all cases they represent 'sharable' best practice and a resource for those who are looking to improve PTW safety.

Education & Training
Road Safety education for the youth
Japan, Indonesia, India...

Safety & Transport Policy
Motorcycle Confederation – the voice of the riders
Canada...

Safety & Transport Policy
European Safer Urban Motorcycling Project
Europe...

Infrastructure
PTW Guidelines for road design operators
Europe...

Infrastructure
Advanced stop lines for riders
Spain, Indonesia...

Data & Analysis
In-depth accident studies
Europe, USA, Japan...

Awareness campaigns
Promotion protective equipment for riders
Japan, Thailand, Canada, Australia, Europe...

Safety & Transport Policy
Adaptation and application of suitable best practices
India, USA...

Education & Training
Training and education for riders and specific groups
Europe, India, Japan, Canada, Philippines, USA, Malaysia, Indonesia...

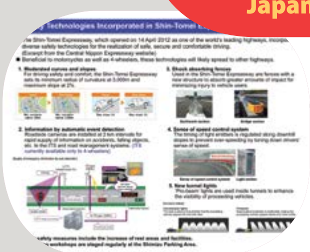
Infrastructure
Treatment of specific PTWs black spots
Australia...

Awareness campaigns
Road Safety campaigns for the general public
Malaysia, Asia, Thailand, Japan...

Safety & Transport Policy
PTW Safety Strategies
Sweden, Thailand...

Awareness campaigns
Safety awarness campaigns for riders
Japan, Canada, India, Philippines, Thailand...

Infrastructure
Advanced safety technologies in highways
Japan...



Education & Training
Police-led education and enhanced enforcement for riders
Australia...

Safety & Transport Policy
Regional Safety initiatives, UN Decade for Action
Philippines...

Infrastructure
Motorcycle lanes/bus lanes open for riders
Japan, UK, Taiwan, Canada, Malaysia...

Chapter 6:
Recommendations & Conclusion for Safer Motorcycling

Creating better motorcycle safety involves a fully holistic approach, which as a key fundamental must recognise the vital role of the PTW in the social and business life of many nations. There is an extremely strong need to involve all stakeholders in the process of creating a favourable environment for safer motorcycling.

While providing PTWs with the most advanced safety technologies is important, it is only one part of the comprehensive approach to motorcycle safety. The industry carries out a wide variety of activities such as rider training and public awareness campaigns in addition to the continuous R&D efforts by manufacturers leading to the innovation of PTW technologies. Nevertheless, road safety cannot be achieved single-handedly by the motorcycle industry without the cooperation of international organizations and governmental authorities. Industry is keen to play a part in an integrated approach alongside other stakeholders.

Transport and mobility policies need to integrate PTWs together with walking, cycling, and public transport to create fully rounded transport strategies for citizen and business mobility and safety.

National strategies need to be balanced towards integrating the characteristics of the use of PTWs within their country, and the important role PTWs have in social, utility and business life. Installing a PTW policy framework in each country taking into account the particular country's context is critically important. Countries are encouraged to study the best practices established in this document and evaluate adoption and implementation considering the specific needs of the regions.

In regions where there are populations of millions of PTW users, safety policy development should be directed at further enabling sustainable PTW use. The objective should be to maximise opportunities to ride on roads, which will be safer, while recognizing that PTWs continue to remain vitally important in terms of affordability, mobility, the economy and the environment.

Concrete recommendations

The Four Stage Strategy

- Public Policy
- Infrastructure
- Training & Education
- Technology advances

A Strategy needs Support

- The Integrated Approach
- Research, Data & Analysis
- Tailoring Strategies to meet Localised Needs

The Four Stage Strategy

Public Policy

Motorcycling contributes towards the wider economic and social goals of the society as a whole. Examples include:

- The importance of PTWs to low personal income economies,
- The importance to public service in developing countries (healthcare delivery),
- The role of PTWs in public service globally (emergency and rescue services),
- Importance as a business 'enabler',
- Importance as a mobility provider,
- Importance as a means to reduce overall congestion and pollution,
- Importance as a means to increase social inclusion and the engagement of young people,
- Importance for accessing areas affected by emergencies such as natural disasters (humanitarian response),
- The role of the industry in creating economic growth,
- The social and economic contribution of motorcycle sport,
- A mode of transport that deserves to be recognised and promoted by policy makers.

To realise the opportunities outlined above, the safety of PTW riders is essential to successfully reducing the total number of global road fatalities. This can most effectively be done by adopting an integrated, comprehensive approach including mainstream transport policy inclusion, infrastructure improvements, advances in vehicle technology and lastly, with added emphasis on the human factor, education and training for all road users.

Recommendations

- Governments, as a key requisite to developing genuinely effective safety policies for PTWs, must include PTWs as a mainstream aspect of their transport policies, alongside walking, cycling and public transport.

Infrastructure

Safer roads for riders will create significant potential for better rider safety performance. Meaningful effort is needed to make road infrastructure safer for PTW riders.

Recommendations

- Governments need to consider how PTWs can be integrated into more sustainable and safer transport systems.
- Inclusion of PTWs in infrastructure policies and regular audits to assess safety levels of both existing and new road infrastructure projects are crucial points for a safer environment for PTW users.
- Predictable road geometry, good visibility, obstacle free zones and good quality road surface with high levels of skid resistance are some major examples. While important for all road users, they are essential for PTWs.
- The use of existing best practices in the area of PTW and the roads infrastructure are strongly recommended.

Training and Education

The human factor: Influencing human attitudes and behaviour is crucial for enhanced safer motorcycling.

Recommendations

Rider training should be affordable, accessible and effective

- Initial rider training for novice riders, prior to licencing, should be encouraged and made available in countries where this option is not provided.
- There is a need to allocate resources and infrastructure for systematic motorcycle training and education, especially in countries where the volumes of motorcycle usage far exceeds the usage of cars.
- There is a need to improve the quality of the available training. Minimum standards and certification of training and trainers should be introduced. Training should be designed to enhance motorcycle safety by putting rider's hazard awareness and perception at the core of the training curriculum.
- Lifelong training and voluntary post-licence training should be promoted.

Education of drivers to better understand and perceive PTW riders on the road is essential for improving PTW safety

- Targeted mandatory components on the interaction drivers/riders and perception of PTW riders as part of the training curriculum and licensing assessments of other vehicle drivers are strongly recommended.
- Impaired riding – one driver for changing the attitude of the riders towards safer and risk-free behaviour (drinking and riding, tampering, riding without a proper PTW licence).
- There is a strong need for widespread awareness raising campaigns to highlight the dangers of impaired riding combined with appropriate and consistent enforcement.

The mitigation of riders' injuries is important for decreasing the severity of the impact of an accident on riders

- The usage rate of safety helmets should be brought to 100% with a mix of stronger enforcement and awareness raising campaigns, geared towards local conditions.
- The promotion of the benefits of proper personal protective equipment amongst riders should be done in line with riders' specific needs, local context and climate conditions.

Technology Advances

Industry continues to develop state of the art technologies to enhance the stability and control of PTWs. With appropriate consideration for the economic conditions of each vehicle market, manufacturers will promote technologies suitable for the road conditions and usage patterns of the customers in each country or region.

Whilst many advances have already been made, the industry is committed to striving to make PTW use safer, easy and more attractive across the world.

Recommendations

- IMMA invites developing countries to join WP.29, accede to the Agreements and adopt harmonised worldwide regulations for safety and environment.

It should be remembered that providing PTWs with additional vehicle related options or technologies – or introducing a vehicle specific regulation is not on its own sufficient without a strong and continued integrated policy involving rider behaviour, training and infrastructure.

Making it Happen - A Strategy needs Support

1. The Integrated Approach
2. Research, Data & Analysis
3. Tailoring Strategies to meet Localised Needs

The Integrated approach

Recommendations

- The integration of the strategic elements in this document requires the involvement, consideration and commitment of all stakeholders. Creating a system which enables safer riding and driving for all, requires the collaboration of the PTW industry, all road user groups, engineers, road designers, road safety experts, the police, national policy makers and local authorities.

Research, Data & Analysis

Recommendations

- Setting realistic goals and targets based on reliable scientific analysis of PTW data should be supported by a detailed and complete set of PTW accident and exposure data at global, regional and national level.
- The improvement of global data gathering, with an emphasis on improving knowledge of usage patterns and distances travelled by modes is essential step to address PTW safety properly.
- Selecting efficient countermeasures by fully understanding the accident causation and contribution of human behaviour requires improved knowledge on PTW accident causation, normal riding and safety critical events. Accident in-depth studies, naturalistic riding studies and related projects should be encouraged and implemented at regional and national level. This would allow for the identification and application of best practices that could be easily transferred and adapted to other countries.

Tailoring Strategies to meet Localised Needs

Recommendations

- A multitude of good examples from across the globe are available. The identification, adaptation and application of best practices across the world are promising paths in delivering safer motorcycling. However, in order to ensure that policy actions are appropriate to the local environment and the people they are trying to serve, every policy action should be accompanied by a pre- and post- evaluation so that the safety impact of the measure can be assessed, and the measures further improved and ultimately shared with others.

Conclusion

Acting Together to Improve Safety

This paper has set out the key elements that taken together comprise an effective and sustainable approach to PTW safety. Although it may be a temptation for authorities to merely take some of these elements and implement these in a 'piecemeal' way – perhaps as a way of satisfying a political imperative to 'do something' about safety - this approach will be unlikely to result in the outcomes desired.

Adopting, in full, the principles outlined in the Shared Approach to Road Safety offers a realistic opportunity to address PTW safety within the context of a properly managed approach to transport use and safety. But key to success will be to integrate the principles of working in partnership with all involved in PTW safety and to ensure that a holistic approach is taken. By doing this, public authorities will have the greatest chance of securing safety improvements while at the same time realising the PTW opportunity that exists in relation to transport networks and citizen mobility.

IMMA recommends this document and its principles to the global road safety and transport policy community.

Annex 1:
Best Practices – Concrete examples

Safety & Transport Policy
Infrastructure
Awareness, Education & Training
Data & Analysis

Safety & Transport Policy

Safety and Transport policies which account for PTWs and are adapted to local specificities

11. Encouraging riders to attend voluntary training courses
Canada

1. Motorcycle Safety Strategy
Sweden

7. Active collaboration of motorcycle manufacturers with the National Administration
USA

6. Safe Annual Convention
India

3. National Road Safety Agenda (2011-2021)
Thailand

5. Increased number of trained riders
Malaysia

2. Call to Action towards Unity, Safety and Equality
Philippines

9. Operation yellow flag
Australia

Subcategory	Examples	Aim/Results	Partners
Regional safety initiatives, UN Decade of Action for Road Safety	**1. Motorcycle Safety Strategy, Sweden** www.fim-live.com/fileadmin/user_upload/documents/CAP/2012_194_increased_safety_for_motorcycle_and_moped_riders.pdf	**Unique example in Europe, a specialy designed for PTW riders national safety strategy.** To halve the number of rider fatalities and reduce the number of rider injuries by 40% between 2010 and 2020 by involving all stakeholders. The strategy presupposes that all stakeholders within their own areas of responsibility implement, individually or cooperatively, initiatives at the local, regional, national and international level. The prioritisations and the work is based on facts and scientific grounds as much as possible.	All major stakeholders in Sweden: Industry, Swedish Transport Administration, Swedish riders' association, Police, Insurance association, Swedish association of driving schools, Swedish Association of local authorities and regions
	2. Call to Action towards Unity, Safety and Equality, Phillippines	**Pursue "Helmet On, Headlight On" (H20) Program - increasing awareness on the advantages of switching headlight on and proper wearing of standard helmets;** Launch of 2W Ride for a C.A.U.S.E. (Call to Action towards Unity, Safety and Equality) - a nationwide relay ride done every weekend from September to November culminating during the World Day of Remembrance. The Ride is organized trough out the country using local government as communication channels and riders as messengers.	Department of Transport and Communications and Global Road Safety Partnership Philippines (GRSP)
	3. National Road Safety Agenda (2011-2021), Thailand http://www.grspasia.org/download12/Chayan-Sirimas_Thailands-Road-Safety-Strategy.pdf	**Comprehensive approach towards safety, aim = 50% reduction of road fatalities in Thailand by 2021.** The agenda encompasses 8 main domains: 1. Helmet wearing 2. Riding/driving and drinking 3. Reduce "risky" road areas 4. Speed limit violation 5. Vehicle Standards 6. Training of drivers and riders 7. Emergency help 8. Road infrastructure management system	Thai government
Various initiatives	**4. European Safer Urban Motorcycling, Europe** www.esum.eu	The reduction in PTW collisions and casualties is feasible, by involving all stakeholders and embracing holistic approach - user behaviour, vehicle design and road infrastructure. **The eSUM project provides immediately applicable tool (Action Pack) to improve the safety of traffic in cities and towns and could be easily replicated even beyond Europe.**	4 European principal motorcycling cities, Industry, Academic and research organisations, supported by the European Commission
	5. Increased number of trained riders, Malaysia www.bl1m.my	To encourage riders to undergo training and obtain riding licence. **Providing more affordable training options and reduced licence fees to riders in difficult economic situation. 103 000 new motorcyclists participated in this program.**	Malaysian government and Road Transport Department
	6. Safe Annual Convention, India	To improve the safety of riders in India by adopting best practices from Indian States and other countries and regions. Based on integrated approach: safety management system, infrastructure, training, enforcement and vehicles. **In 2012 edition more than 150 officials took part in the event inaugurated by the Transport Commissioner of Himachal Pradesh.**	Industry, Government and local administration

	7. Active collaboration of motorcycle manufacturers with the National Highway Traffic Safety Administration (NHTSA), USA	In efforts to collaborate with government regulators, industry representatives participate in quarterly meetings of NHTSA .**The industry also provides support for crash studies and sponsors a wide range of safety initiatives through state and national motorcycle riding groups.** In the absence of meaningful exposure data, the US rider community is encouraging the government to develop policy based on actual vehicle miles travelled (VMT) rather than comparing the total number of accidents of automobiles versus motorcycles.	Industry, National Highway Traffic Safety Administration (NHTSA)
	8. Motorcycle Confederation, Canada http://motorcycling.ca/	To enable riders' active participation in the national motorcycle debate. At the initiative and financial support of the industry, **37 motorcycle clubs and federations have joined forces and have established Motocycle Confederation of Canada (MCC). The MCC is the voice of organized motorcyclists in Canada and advocates positions that benefit public policy and traffic safety issues related to riding and riders.**	Industry and riders
	9. Operation yellow flag, Australia	**To improve motorcycle safety through integrated police-led education and enhanced enforcement. Police is discussing safety awareness with both riders and drivers during roadside stops. In 2010, over 20,000 riders and drivers were intercepted and given some education pamphlets.** Enforcement activities were undertaken in a visible, well publicized and repetitive way to reduce identified high risk behaviours such as excessive speed, failing to give way and riding while impaired. Result: reduction in the number of traffic offences, with the majority in the speeding offences category;	Victoria Police
	10. Developing pro-motorcycle policies and initiatives, U.S.A.	**Collaborative and thoughtful approach to motorcycle safety through training, licensure and safe riding programs.**	Motorcycle Industry Council (MIC), American Motorcyclist Association (AMA), Motorcycle Safety Foundation (MSF), Motorcycle Riders Foundation (MRF), and various state motorcycle rights organization.
	11. Encouraging riders to attend voluntary training courses, Canada http://motorcycling.ca/	Next to the provided financial and logistical support for rider training programmes across Canada by the industry, the incentives offered by many insurance companies have contributed to attracting a huge number of novice riders. **Approximately 85% of new riders take a riding training course to get their license in Canada. It is estimated that around 25,000~30,000 people take rider training courses before getting their motorcycle license each year.**	Industry, Provincial Ministries of Transport, Rider Training Institute

Infrastructure

Safer and PTW friendly infrastructure

4. Motorcycle Lane
Malaysia

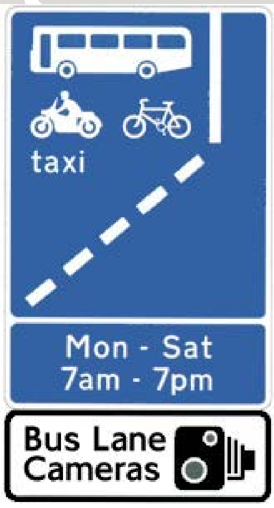
3. High Occupancy Vehicle Lines (HOV) lines
Canada

1. Bus lanes open for riders
United Kingdom

6. Advanced stop lines
Spain

2. Bus lanes open for riders
Japan

7. Advanced stop lines
Indonesia



1. Bus lanes open for riders
United Kingdom

Subcategory	Examples	Aim/Results	Partners
Motorcycle lanes/bus lanes open for riders	**1. Bus lanes open for riders, The United Kingdom** http://www.tfl.gov.uk/roadusers/redroutes/10151.aspx	To separate the traffic flow between motorcycles and automobiles for improving road safety and increasing traffic flow speed. First trial - opening 107 km bus lanes to PTWs in London: 51% PTW switched to ride the bus lanes, comparing the 'before' and 'after' figures for 28 Control sites - decrease of 50.7% for PTW collisions; second 18 months trial – accompanied by focussed safety awareness campaign and increased enforcement **Final result:** **- PTW riders are able to drive in bus lanes in London on a permanent basis** **- Smooth traffic, cut CO_2 across London and improve journey time reliability for motorcyclists on the network.**	First stage – consortium of the European Safer Urban Motorcycling project (eSUM): Industry, Universities, City authorities: Barcelona, Rome, Paris and London, supported by the European Commission Next steps: Transport for London
	2. Bus lanes open for riders, Japan	There are few bus lanes open for motorcycle riders today. **The Japan Research center for Transport Policy will evaluate the shared bus lanes and complete the report in 2015.**	National Police Agency
	3. High Occupancy Vehicle Lines (HOV) lines, Canada www.mto.gov.on.ca/english/traveller/hov/lines.shtml	HOV lanes help motorcyclists to ride safer in dense and congested traffic; it could be considered as an incentive for people commuting to work that gain some important time every day. **There is no statistics yet available.**	Provincial Ministries of Transport
	4. Motorcycle Lane, Malaysia http://forums.sgclub.com/singapore/north_south_motorcycle_329194.html	To build a special motorcycle lane (the longest one in Malaysia) by 2020 in an area with high concentration of road fatalities. **Estimations: halving the number of road fatalities in this area.**	Ministry of Labour (Transport and Road Safety Department)
	5. Motorcycle Exclusive / Priority Lane, Taiwan http://www.fami-motorcycle.org/report/report_20100919031917_11.pdf	Motorcycle Exclusive Lane = lane only for motorcycle riders and banned for the other vehicles; Motorcycle Priority Lane = the motorcycle rider has the priority to drive in first, available for other users as well. **Infrastructure measures recently introduced, no concrete results for the moment.**	Labour Ministry, Ministry of Transport and communication
Introduction of advanced stop lines	**6. Advanced stop lines, Barcelona, Spain** www.esum.eu/index.html	To provide a special stop space for PTW riders at traffic light and reduce conflicts between PTWs and PTWs and cars. Barcelona introduced "advanced stop lines" at 3 junctions in the city. Large reduction of movements involving risk - from 29% to 8% were observed. **Based on the successful case, Advanced Stop Lines were introduced in 36 sites in 2009 and the activity is now expanding.**	Consortium of the European Safer Urban Motorcycling project (eSUM): PTW industry, Universities, City authorities: Barcelona, Rome, Paris and London, supported by the European Commission
	7. Advanced stop lines, Indonesia www.kabarpublik.com/2012/01/dllaj-kota-bogor-terapkan-ruang-henti-khusus/	First implemented in Bandung city in 2010, now this initiative will be progressively introduced in other cities. **Increased comfort and safety of all road users - traffic conflicts reduced by 72% and the traffic flow increased with 11%.**	Ministry of Transport

Various initiatives	**8. Speed limit 30km/h Barcelona, Spain**	To improve safety of all road users.Positive effect on the accidents trend - casualties decreased with 12.2%. The average monthly PTW casualties – reduced by 40.5% (five years prior to implementation). **This initiative is introduced for all vehicle categories. Very effective solution to reduce casualities within big city.**	Industry, Training institutes, City Traffic Police and State Transport Department
	9. Safety Technologies Incorporated in highways Shin-Tomei Expressway, Japan	**Introduces the most advanced safety technologies to a newly established highway (2012),** incorporates diverse safety technologies: moderated curves and slopes, improved tunnel light, shock absorbing fences, automatic event detection **for safe, secure and comfortable driving for all road users.**	Nippon Expressway company (NEXCO) Central
	10. Road improvement at black spots, State of Victoria, Australia www.vicroads.vic.gov.au/Home/SafetyAndRules/SaferRoads/BuildingSaferRoads.htm	To improve road environment and achieve rider safety by reducing the number of PTW causalities at these locations. Black spots are places where road accidents are frequently occuring based upon specific data. Improved rider safety by reducing the number of motorcycle casualties at over 119 locations. **A 24% reduction in injuries at all sites treated, a 40% reduction at 54 blackspot sites.**	State of Victoria, Australian government
	11. Report by the U.S Department of Transportation and the Federal Highway Administration on the infrastructure improvements made in five European countries, U.S.A. http://international.fhwa.dot.gov/scan/12028/	In 2010, a team of safety and engineering experts joined industry representatives in assessing and evaluating infrastructure improvements made in five European countries. **The experts recommended that transportation agencies in the U.S.A. should establish goals to reduce motorcycle injuries and fatalities through roadway design, operations and maintenance practices. Additionally, transportation planners should consider motorcycles in addressing traffic issues, land use and parking.**	Federal Highway Administration, the American Association of State Highway and Transportation Officials, National Cooperative Highway Research Program, American Motorcyclist Association, and several universities.
	12. Guidelines on Safer Road Design for Powered Two-Wheelers , Europe www.acem.eu/images/stories/doc/safety/d_SafetyPlanforAction_94993.pdf	**A handbook published with the aim of explaining how PTWs differ in their use of the road from other vehicles and the specific riders' needs.** Predictable road geometry, good visibility, obstacle free zones and good quality road surface with high levels of skid resistance are some major examples. **While important for all road users, they are essential for PTWs.**	Industry

Education and training

Education for all road users
Training options: specific groups, novice riders, returning riders, advanced riders, etc.

5. Rider Training Institute
Canada

9. Rider's Edge programme
USA

8. Voluntary Safe Training
Spain

17. Road safety education for children
Japan

2. Female Safety Riding Training
India

11. Certification of training courses
Germany

18. Road safety education at school
Indonesia

3. Safe riding school events
Japan

10. Road Safety Outreach Seminar
Philippines

Subcategory	Examples	Aim/Results	Partners
Training for novice riders	**1. Initial Rider Training (IRT) Programme, Europe** www.initialridertraining.eu/	Established European model of initial rider training programme. The modular concept is rider orientated, based on the initial appraisal of the rider's expertise, striving to build upon his experience and skills already acquired on the lower category motorcycle. **The concept is putting emphasis on the rider's hazard awareness and perception. IRT manual translated by the European Commission in many EU official languages.**	Industry, European Riders Association (FEMA), International Motorcycling Federation (FIM), supported by the European Commission
	2. Female Safety Riding Training, India	To educate and train female riders and enable them to become safe riders while commuting daily. This initiative started in 1985, **more than 32,500 female riders have been trained.** This is a regular program in the PTW dealerships across India.	Industry
	3. Safe riding school events, Japan	Various courses provided to meet different riders' needs: novice riders, newborn riders, female riders, aged and advanced riders. **The program adds up to a total of over 1,000 events with the participation of 20,000 riders across Japan every year.**	Industry
	4. Ride Safe Program, India	Practical training for novice riders.	Industry, Riders, Traffic Police
	5. Rider Training Institute, Canada	To further enhance the availablility of training programs. The Canadian industry established the Rider Training Institute in 1999. **The Institute alone has trained 37, 200 people – on average 3 500 riders per year.**	Industry, Provincial Ministries of Transport
	6. Safety Corner' in 4S Dealer Concept (Sales, Service, Spares and Safety), India	Dealerships have a specially designed interface called the 'Safety Corner' where they educate customers on correct riding techniques and provide important information related to the safety environment, including road signs, first aid, etc. using specially designed audio visual communication. This activity started in 1985. **In the year 2012-2013, a total of 13.5 million customers were educated at the dealerships across India and 12 500 underwent practical training.** Safety education at the dealership is an ongoing and regular activity.	Industry
Voluntary, post-licence training	**7. Bike Safe, The United Kingdom** www.bikesafe.co.uk	To help riders to increase their ability and confidence, so they can become safer and more competent riders. Bike Safe is an initiative run by police forces around the United Kingdom who work with riders by passing on their knowledge, skills and experience. The main concept of Bike Safe is that riding should be fun and by improving skills, knowledge and hazard awareness will make riding safer and more enjoyable. The Bike Safe Observer give assessment and feedback which highlight areas where the rider needs to develop. Riders should continue to train throughout their riding years and not just stop once they have passed their bike test. **Bike Safe assess around 5,000 riders per year.**	Police, Transport Administration, Industry
	8. Voluntary Safe Training, Spain www.honda-montesa.es/inscripciones/index.php	To provide high quality voluntary training. The centre created in 1992 attracted more than 170,000 trainees. 4 courses offered: Kids/Schools, Scooter 125, Beginners/Re-entry, and Advanced/Professional. Courses are free of charge. The average customer satisfaction index is 9.45 (max.10), 91% of all participants consider that they have increased their riding skills/safety level, 84% of all trainees have never had an accident after the riding course.	Industry Training Center, Barcelona

Training of riders	**9. Rider's Edge programme, USA** www.harley-davidson.com/en_US/Content/Pages/learn-to-ride/learn-to-ride.html	To provide rider training that is effective, affordable and accessible. Through its branded rider training program, the industry works with government officials to integrate into and complement existing state-sponsored rider education courses. Currently the "Rider's Edge" program is offered in 42 out of the 47 states that offer rider training. **Since 1999, the program has trained over 300,000 riders**	Industry and state officials
	10. Road Safety Outreach Seminar, Philippines www.mdppa-inc.org www.fami-motorcycle.org/news/news_20130916104759_13.pdf	To educate and train motorcycle riders on topics such: safe riding, protective riding gear, vehicle inspection and intellectual property rights. This activity started in 2009. **More than 10,000 participants. 60 weekend seminars held per year.**	Industry, Motorcycle riders' federations, local government and Petron Corporation
Lifelong training	**11. Certification of training courses, Germany** www.dvr.de/betriebe_bg/sht_shp/infos_qsiegel.htm	To guarantee the high quality of training provided to PTW riders with a special focus on safety. Training providers apply to the German Road Safety Council to obtain the quality seal. If their programmes, trainers and training facilities are in line with the quality criteria established by the Council they could get the label. The Council is making constant monitoring of the trainings marked with the seal. The Quality seal guarantees high quality for the customers. **The accent is on safety. Currently, more than 3 000 training courses are attributed with the quality seal.**	German Road Safety Council, Industry
	12. Life-long learning and education for riders, USA online2.msf-usa.org/msf/Default.aspx#&panel1-1"	To provide high-quality life-long learning options for riders. The Motorcycle Safety Foundation is the internationally recognized developer of comprehensive, research-based rider education and training system. Their curricula promotes lifelong-learning for motorcyclists and continuous professional development for certified rider coaches and other trainers. **Since 1974 over 6 million students have graduated from a MSF- approved programmes (on average 400,000 riders per year)**	Motorcycle Safety Foundation (MSF), Industry
Training for specific groups	**13. Corporate Safe Riding Training, India**	To **train corporate employees riders.** The training encompasses: workshop for corporates employee, theory session and safe riding training on simulator.	Private sector, Industry
	14. Training for traffic police officers, India	To enhance safer riding for traffic police members by providing refreshing courses. This activity started **in 2006 and more than 500 police officers were trained.**	Industry, Traffic Police, Local Administration
	15. Training for commuters, Malaysia issa.int/layout/set/print/layout/set/print/content/download/171139/3395839/file/2Malaysia-PKS-2012-2.pdf	To engage employers to enhance the safety of their employees commuters. Studies showed that for employees riders 88% of the accidents occurred while commuting to work (52% - on the way to work and 36% on the way back). **Launch of commuting outreach programme for employers and employees,** concrete results not available for the moment.	Teknologi Mara University & Social Security Organization

Road safety education for the youth	**16. Family Road Safety Classroom, Japan**	This training targets children in kindergartens and elementary schools. School teachers and community volunteers are serving as instructors in this program. Parents are encouraged to take an active part and many training lessons are organised during patents' days. **Every year the program is performed 150 times at various locations in Japan, attended by more than 3,000 parents and children.**	Industry
	17. Road safety education for children, Japan	To educate children on road safety and provide training to school teachers, parents and volunteers on how to teach children on traffic safety. This program started in 1995. **In 2012, a total of 350,000 children took part in the program across Japan.**	Industry
	18. Road safety education (kindergarten + elementary school + secondary school), Indonesia www.facebook.com/ safetyriding.jawatengah	To increase the road safety awareness of society in general, the industry strives to educate children from a very early age. **This project started in 2002, 500 events carried out per year and over 50.000 persons were trained in 2012.**	Industry, Schools and Traffic Police, Indonesia
	19. Road safety and safe riding at school, India	Various courses organized targeting different age groups: kids (5 – 8 years old), young students (8-15), junior students (15-18) by using "Catch Them Young" approach**. This programme started in 2010 and it is a regular full year activity. More than 50 000 kids and students participated in total.**	Industry


HONDA

Education & Training

Awareness rising campaigns for all road users

6. Welcome to our family campaign
Canada

8. National Road Safety Week
India

16. Promotional Helmet Campaign
Asia

7. Moped safety promotion for commuting students
Japan

4. National safety riding contest
Japan

10. Road Safety Jamboree
Philippines

15. Promotion of personal protective equipment
Europe

17. PTW Service check-up campaign
Thailand

10. Road Safety Jamboree
Philippines

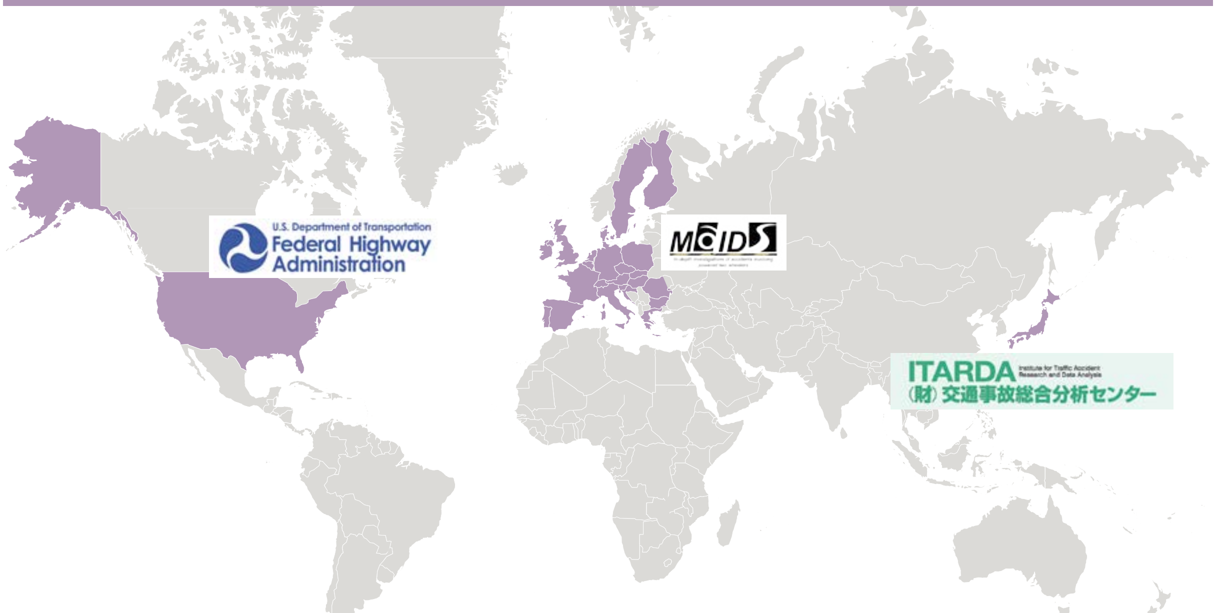
Subcategory	Examples	Aim/Results	Partners
Road Safety Awareness - Competitions/ contests	**1. Road Safety Mural Competition at schools, Malaysia** www.mufors.org.my/Mural_Competition.aspx	First initiated in 2009, **the mural competition drew interest of 250 schools nationwide** (at final stage judges evaluated the artwork from 50 preselected schools). Due to the success of the first year initiatives, the contest is since then organised once every two years.	Malaysia Unit for Road Safety, Nippon paint, Berita Harian, and Ministry of Education
	2. FAMI Road Safety Photo Contest, Asia www.mdppa-inc.org/mdppa-safety-riding-on-two-wheels-photo-contest/ & www.aisi.or.id/news/detail/read/pengumuman-pemenang-fami-photo-contest-2012/	**In 2011, Domestic Photography Contests (DPC) were carried out in Indonesia, Japan, Philippines, Republic of China, Singapore and Thailand.** The best photos by country entered the FAMI Photography Contest with the main theme "Ride safely, enjoy life & be friendly to our environment". Industry members utilized awarded photos for creating promotional tools: poster, screen savers, calendars.	Industry
	3. Road Safety Culture Contest, Thailand www.dlt.go.th	The creativity of students for developing proposals for road safety improvements to be implemented at schools were at the core of the contest. An evaluation of the road safety habits of the students of the schools involved was also part of the contest. **129 schools participated in the contest held in 2012-2013.**	The industry, The Department of Land Transport and Thai Police
	4. National safety riding contest, Japan www.jtsa.or.jp/topics/T-234.html	Launched in 1968. The contest is for individual riders and groups of riders. The contest promotes safe riding, meaning no accidents and no traffic violations and it is held in all Japanese prefectures. The winners of the prefectural contests are invited to compete in a national contest. **2012 marked the 45th edition of the Safe Riding Contest with 1,675 riders participating while the total number of participants including management, volunteers and spectators exceeded more than 10,000.**	Japan Traffic Safety Association, Motorcycle Traffic Safety Promotion Committee
Road Safety Awareness - campaigns	**5. Safety Ride on Highways campaign, Japan** www.jama.or.jp/motorcycle/environment/pdf/prevent_accident_on_highway.pdf	To decrease the motorcycle accidents on highways in the light of the recent increase in motorcycle accidents. **Around 100,000 copies of specially designed booklet for safe riding on highways distributed at motorcycle shows and stores.**	Industry, Central Nippon Expressway Company Limited (NEXCO Central), Japan Motorcycle Safety Association (JMSA), Automobile Business Association of Japan (ABAJ), Japan Automobile Federation (JAF)
	6. Welcome to our family campaign, Canada	To increase safety awareness and educate riders to be safer road users. All promotional materials (posters, brochures, video, websites) are offered free of charge to motorcycle dealers and riders. **Some materials have been even adopted by some provincial authorities in their road safety programmes. The industry works with government policy makers to employ incentives and occasional punitive measures to achieve better results.** This program is to promote safety awareness by reaching out all new riders . The messages include available training courses, choosing the right bike, insurances, responsible riding.	Industry, Riders federations

	7. Moped safety promotion for commuting students, Japan	To promote safe riding amongst students commuting to school and train teachers to educate their students. To provide special training course for commuting students. Distributed promotional 20,000 brochures in more than 200 schools to students. Elaborated a special training manual for teachers. **In 2012, seven training courses were conducted and 171 students trained.**	Industry and Japan Traffic Safety Education Association (JATRAS)
Dedicated day/week for PTWs safety campaigns	**8. National Road Safety Week, India**	In the frame of the National Road Safety Week in India a multitude of safety activities implemented across the country – training and education for different group of riders, school programmes for schools and communication awareness campaigns. This activity was launched in 2000 and converted in an annual event. **Approximately 1 million persons reached every year.**	Industry, Training institutes, City Traffic Police and State Transport Department
	9. Motorcycle Day, Japan	To increase safety awareness of riders and other road users and to promote the enjoyment of motorcycling. Japanese Government has designated 19 August as the "Motorcycle Day", since 1989. The industry has been hosting an event every year including talk shows, motorcycling workshops for children, and other demonstrations by professional riders. **In 2013, the event attracted more than 1,000 people including riders and non-riders.**	Industry, Japan Motorcycle Promotion and Safety Association (JMPSA), Tokyo Metropolitan Police
	10. Road Safety Jamboree, Philippines www.fami-motorcycle.org/news/news_20130916104759_13.pdf	Enhanced riders' responsibilities as road users through their active involvement in team building activities, personal testimonies and dissemination and promotion of various awareness campaigns. **The first Jamboree in 2012 gathered 300 riders. To reach more motorcycle riders and enthusiasts in local municipalities, two Road Safety Mini-Jamborees were organized in 2013 and attended by more than 500 riders.**	Industry, Governmental Agencies, Motorcycle riders and Philippine National Red Cross
Road Safety Awareness - promotion of personal protective equipment	**11. Proper Wearing of Helmets campaign, Japan**	To educate riders to always fasten their helmets properly before starting off (according to the statistics 96.5% riders in Japan wear helmets, but 32.6% riders lost their helmets during accidents). The launch of the helmet campaigns goes back to 1971. **Annual campaign that is implemented two times per year. In 2013, an interactive communication tool was introduced and broadcasted on public places in 40 big cities, 100 rest areas of highways and various websites.**	Industry
	12. 100% helmet wearing campaign, Thailand www.aphonda.co.th/hondasafety/pdf/safety_news.pdf	This activity started in 2011 involving distribution of posters, education of riders and providing helmets. **In 2011: 3100 riders reached, in 2012: 3570 riders.**	Industry and Thai government
	13. Helmet standards, Canada	To promote the use of appropriate motorcycle helmets. Approved helmets are required in all Canadian jurisdictions. All provinces in Canada recognize the US, EU and internationally recognized institutes helmet standards. **Recognizing all the above standards helps consumers to have more options in purchasing a helmet.**	Industry, Provincial Ministries of Transport

	14. Promotion of the benefits of protective gear for riders, State of Victoria, Australia www.tac.vic.gov.au/road-safety/tac-campaigns/motorcycle-safety#protective-clothing	To increase the number of riders properly equipped by creating subsidies and incentives. **Riders provided with complete information about the benefits of protective gear in terms of safety and comfort and encouraged to use the relevant gear by offered incentives.** However, there is a need of a functioning star rating system to verify the performance of the gear being subsidized or subject to an incentive.	Transport Accident Commission, VicRoads, Victorian road safety agencies.
	15. Promotion of personal protective equipment, Europe www.acem.eu/index.php/media-corner/publications/protective-equipment-for-riders	To encourage a wider take-up of protective gear, by providing some simple guidelines to the riders supported by scientific evidence. Released a booklet in several languages about the benefits of a good motorcycling equipment taking into account the specific riders' needs and climate conditions. **On the very first day of the launch of the campaign the on-line English version was downloaded more than 5000 times.**	Consortium of the European Safer Urban Motorcycling project (eSUM): PTW industry, Universities, City authorities: Barcelona, Rome, Paris and London, supported by the European Commission
	16. Promotional Helmet Campaign, Asia	To encourage PTW riders to use helmets and to do it in a proper and correct manner. The main activity of the campaign was a distribution of stickers that riders could put on their motorcycles. **500,000 stickers distributed in Indonesia, 10,000 stickers distributed in Thailand.**	Industry
PTW Service check-up campaign	**17. PTW Service check-up campaign, Thailand** www.dlt.go.th	Conducted on national holidays (New year Festival and Songkran Festival), **the PTWs service check up campaign culminated in 62,272 free inspections in 2012.** This campaign will be organised on a yearly basis.	Industry and Governmental Department of Land Transportation

Data & Analysis

Accident studies - better understand the causation of PTW accidents, target specific challenges and identify appropriate countermeasures



Title	Examples	Details/Results	Partners
In-depth accident studies	**Motorcycle accident in-depth study (MAIDS), Europe** www.maids-study.eu	The Motorcycle Accident in-Depth Study (MAIDS) was accomplished in 2004. The investigation was conducted during 3 years on 921 accidents from 5 countries using the OECD common research methodology. The survey produced approximately 2000 variables for each accident. MAIDS is the most complete available in-depth study in Europe. **It is still the main reference for the industry and for all external researchers working in the PTW domain in Europe.**	Industry, European Riders Association (FEMA), International Motorcycling Federation (FIM), FIA, German Insurance Association (GDV), The International Commission for driver testing (CIECA), supported by the European Commission
	Motorcycle crash causation study, USA www.fhwa.dot.gov/research/tfhrc/projects/safety/motorcycles/MCCS/	The Motorcycle Crash Causation Study **is the most comprehensive investigation into the causes, rider demographics, and opportunities for countermeasure development to be conducted in the United States in more than 30 years.** When completed, a large and unique data set will be developed that is derived from both actual motorcycle crashes and riders with similar risk characteristics and will focus on the unique circumstances that produce motorcycle crashes. The findings of the study can be used to develop effective countermeasures, craft future safety standards, and reduce the risk of fatalities and injuries for motorcycle riders across the United States.	Federal Highway Administration, Oklahoma State University, American Motorcyclist Association, Dynamic Science, Inc., Westat, Inc., Dynamic Research, Inc., Collision and Injury Dynamics, Inc., Department of Transport from few states, Industry
	Study characteristics of motorcycle accidents, Japan www.itarda.or.jp/itardainfomation/english/info91_e.pdf	ITARDA study shows the characteristics of PTW accidents and **helps to understand the evolution of the causation of PTW accidents in Japan that would lead to better tailoring proper countermeasures for safer motorcycling.**	ITARDA (Institute for Traffic Accident ad Data Analysis)

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The safe ride to the future.
The motorcycle industry's commitment to road safety

Die sichere Fahrt in die Zukunft.
Das Engagement der Motorradindustrie für die Verkehrssicherheit

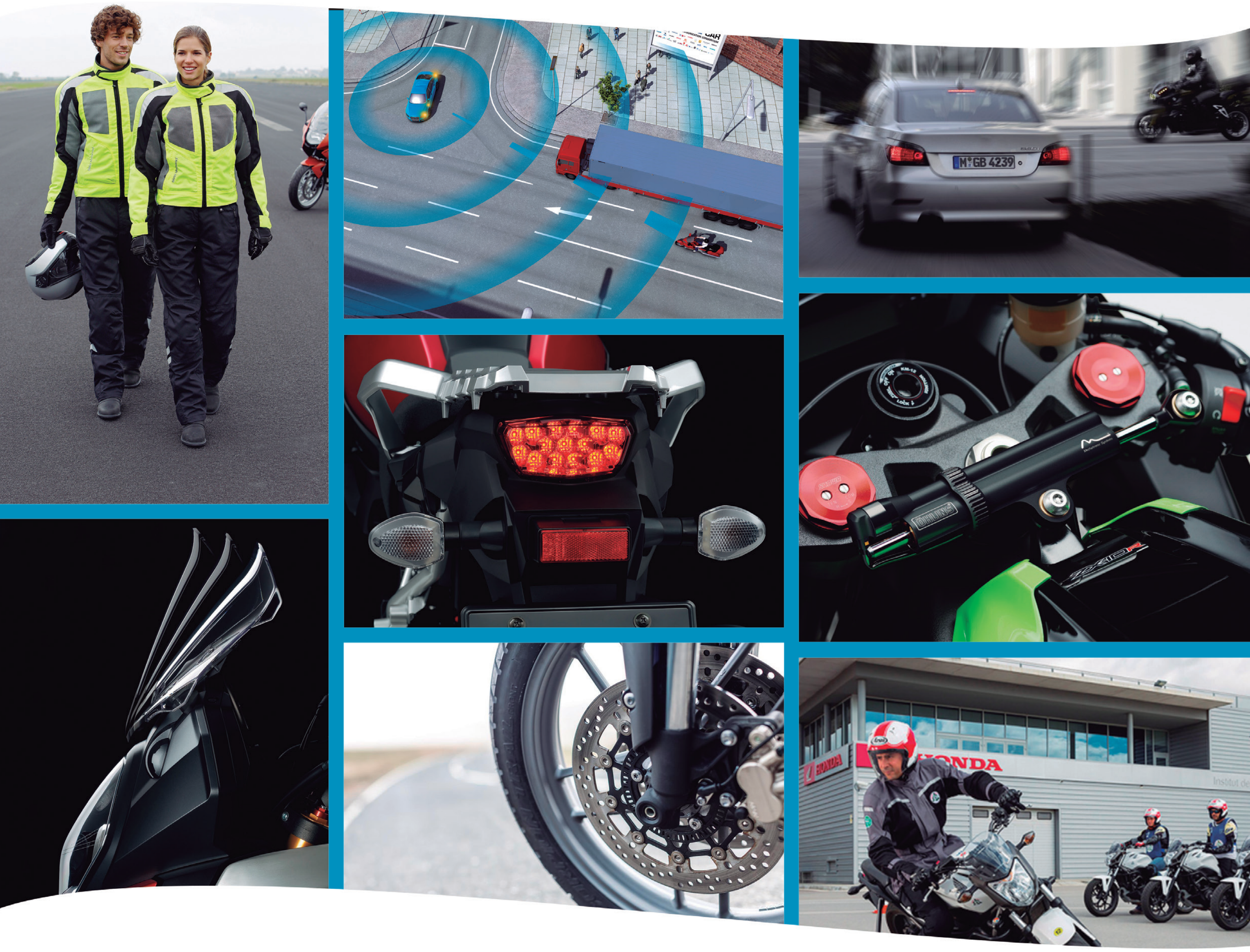
Antonio Perlot

Association des Constructeurs Européens de Motocycles (ACEM)

European
Association of
Motorcycle
Manufacturers
acem

The safe ride to the future

The motorcycle industry's commitment to road safety



September 2014

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Foreword by ACEM President

Over the last decade we have witnessed a substantial decrease in the number of road casualties affecting powered two-wheelers (PTWs). This decrease, albeit less pronounced than in other means of transport, takes place against a substantial expansion of the PTW circulating park. The motorcycle industry's long-term commitment to road safety has played an important part in achieving this positive result.

In 2001, for example, ACEM members voluntarily committed to fit all of their new vehicles with automatic headlamps on (AHO). In 2004, ACEM signed the European Road Safety Charter committing the manufacturing members to offering at least 50% of their street models with advanced braking systems as an option by 2010. After this initial target was surpassed, ACEM manufacturers set a further objective: 75% of street motorcycle models offered on the market in 2015 will be available with an advanced braking system as an option or as standard equipment.

Subsequently, some of these industry commitments were incorporated into Regulation 168/2013 (the type-approval regulation). Furthermore, ACEM strongly advocated for the strengthening of other safety provisions of this text including anti-tampering and market surveillance activities.

The important progress made on road safety, however, should not be a reason for complacency. Road fatalities still affect a high number of vulnerable road users, particularly powered two-wheeler riders. This is an issue that requires decisive action. To effectively address this major challenge, industry efforts must be complemented with action by other key stakeholders. We all have a responsibility for road safety – either as transport providers, road users or road authorities.

For this reason, better and more effective partnerships, particularly between vehicle manufacturers and policy-makers, must be established. We must build on the political momentum generated by the UN Decade of Action for Road Safety[1] and the European Commission's objectives to reduce the number of road deaths on Europe's roads by half[2] . We must redouble our efforts, at European, national and local level, in order to create a safer environment for PTW users.

By improving road safety levels we will also be able to further reap the considerable benefits that motorcycling brings to society. Motorcycling offers quality of life, among other things, through better access to jobs and services, affordable mobility, and the enjoyment of sports, leisure and tourism.

1. United Nations Decade for Action. Resolution A/RES/64/255 of 10 May 2010, the UN General Assembly.
2. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Towards a European road safety area: policy orientations on road safety 2011-2020.

Moreover, motorcycles produce lower carbon emissions in aggregate than cars, help to reduce traffic congestion, and resolve parking issues. These large societal benefits are sometimes overlooked in the public debate.

I am particularly grateful to all the people who contributed to developing *The safe ride to the future*. This report not only elaborates on past and ongoing safety initiatives, but also contains proposals that are a crucial step in making Europe's roads better and safer for all of us.

Stephan Schaller

ACEM President
BMW Motorrad President

Executive summary

- Data from the International Road Traffic Accident Database shows that between 2010 and 2012, the number of riders killed in Europe decreased from 5,275 in 2010 to 4,566 in 2012, a reduction of 13.4%. An analysis by segments shows that deaths of motorcyclists went down by 11.3%, whilst the number of moped riders that suffered fatal accidents went down by almost 27.9%. All this takes place parallel to the substantial growth of PTW use across Europe (25.2% between 2001 and 2012).
- The motorcycle industry has played a key role in this. Continuous improvement in safety features, including advanced motorcycle design, new intelligent features and new braking, lighting and suspension systems have been instrumental to increase motorcycling safety. Different road safety and training campaigns, often led by the motorcycle industry, have also made significant safety contributions.
- Currently ACEM members are working to improve road safety by deploying Intelligent Transport Systems (ITS) on PTWs in Europe. As part of this process, in March 2014 ACEM members adopted a Memorandum of Understanding on ITS. By signing this Memorandum, the motorcycle industry agreed to initiate the deployment of safety-relevant cooperative ITS on PTWs in Europe and committed to have at least one of their models available for sale with a cooperative ITS, either as standard equipment or as optional equipment, by 2020.
- Furthermore ACEM is currently conducting research on an embedded eCall system for motorcycles. The minimum technical requirements needed for such a system have already been defined and research activities are ongoing in order to address the technical challenges of this emergency system.
- Another key factor to improve safety records for PTWs is training. It is vital that riders receive the appropriate training so that they can ride confidently and safely. In order to help PTW users make informed decisions about their training, ACEM and the German Road Safety Council[3] have joined forces to start promoting high quality post license training schemes across the EU through DVR's Quality Seal. Moreover, other similar quality labels are currently being developed in the EU. Along with the DVR Quality Seal, these schemes could also help to increase the visibility of the best training programmes available and pave the way towards more uniform quality standards for training in Europe.

3. DVR, Deutsche Verkehrssicherheitsrat.

- Over the last decade substantial progress has been made in terms of reducing the number of fatal accidents involving riders. However, there is still room for improvement. The motorcycle industry has taken up the challenge to make a positive difference for motorcyclists across the EU. For this reason, ACEM will organise, in close cooperation with industry associations and other key stakeholders, a series of thematic workshops. Its objective will be to gain a better understanding of what actions can be taken at local, regional and national level in order to improve safety outcomes for PTW riders.
- Some of the topics to be covered by the workshops will include: mainstreaming of PTW needs into national transport strategies, prevention of safety failures through periodical technical inspections, fight against illegal tampering and implications of design and maintenance of road infrastructure on road safety.

Introduction

Powered-two and three-wheeler user[4] safety is an absolute priority for the motorcycle industry. Over the last decades ACEM members have made considerable efforts to develop technologically advanced vehicles with enhanced safety characteristics. The motorcycle industry has also taken the lead on road safety campaigns and promoted pre- and postlicense training among users. This effort has been instrumental in substantially reducing the number of fatal accidents involving powered two- and three-wheeler users in the EU.

As the latest data available from the International Road Traffic Accident Database[5] shows, the number of fatal accidents involving powered-two and three-wheeler users decreased from 7,554 to 4,566 between 2000 and 2012. This represents a reduction of 39%. More recently, between 2010 and 2012, the number of riders killed decreased from 5,275 in 2010 to 4,566 in 2012, which represents a reduction of 13.4%. An analysis by segments shows that deaths of motorcyclists went down from 4,303 in 2010 to 3,815 in 2012, a reduction of 11.3%. In the same period, the number of moped riders that suffered fatal accidents in the EU went down from 975 to 703, a reduction of almost 27.9%. All this takes place parallel to the substantial growth of PTW use across Europe. Between 2001 and 2012 the number of PTWs on Europe's roads increased from 29,230,320 in 2001 to 36,598,620 in 2012 (25.2%).

Although this downward trend is encouraging, it should not be a reason for complacency. ACEM believes that the number of fatalities amongst PTW users can, and must, be further reduced. The industry is also a supporter of the Commission's policy objective of halving the overall number of road deaths in the EU by 2020 which began in 2010.

ACEM members have a long road safety track record, based on innovation. However this is only one part of the integrated approach that is required to responsibly address the issue of road safety. A genuine integrated approach to road safety should include not only vehicle technology but also human behaviour and infrastructure. Therefore industry-led initiatives must be complemented by decisive public action. In particular, decision makers should address strategic policy areas including: enforcement of road traffic rules, riders' behaviour on the road and infrastructure design and maintenance. These areas should be addressed through inclusive policy plans at local, regional and national levels.

Safer motorcycling leads to more sustainable motorcycling and the realisation of the key benefits that motorcycles can bring to transport and the economy. The core motorcycle industry employs about 125,000 people in the EU and the aggregated turnover of the sector (manufacturing, plus direct upstream and downstream activities) amounts to 27 billion euros. Additionally, individual country based economic studies indicate that the economic

4. Throughout this document references made to powered two- powered two- and three-wheelers should be taken to include motorcycles and mopeds, as well as three wheelers.

5. The IRTAD database is an OECD programme that collects international accident, victim and exposure data on a continuous basis. It covers 29 OECD countries including 17 EU Member States.

contribution of the wider activity of motorcycling within society is considerable, with a fiscal multiplier effect that goes far beyond the basic industry figures illustrated above. This is particularly the case when areas such as travel and tourism, accessory manufacture and supply, the aftermarket industry, insurances, sport, fuels and oils are taken into account. All these sectors rely on a vibrant and growing motorcycle industry, with this illustrating how safety and transport policy needs to recognise and support the contribution of motorcycling to jobs, growth and economic recovery.

Furthermore, PTWs are increasingly used by commuters to provide an answer to traffic congestion. In many countries of the EU, for example, leisure machines offer a 'cross over' function, also being used for commuting. In the UK for example, the Government estimates that over 60% of PTW distance travelled is for commuting, utility or socially practical purposes. Further, the majority of motorcycling trips (60%) are for work, business or education purposes compared with only 27% for car trips[6]. PTWs are also used for sport and leisure and attract many around the world for the personal benefits they can bring: social interaction with others, the personal and economic perspective of PTW tourism and the pleasure of riding as an end in itself.

The most sustainable route to safer motorcycling lies within taking a comprehensive approach to safety policy and practice, based on a 'shared responsibility' approach and through exploring proper linkage with 'command' transport policy. Instead of public authorities approaching motorcycling issues via thinking such as 'what do we do about the motorcycle safety problem?', a new approach should be pursued. This will be based around the attitude of: 'Motorcycling carries many socio-economic benefits and an opportunity to offer the public a further alternative to the car for commuting. What do we need to do to support motorcycling, decrease casualties and reduce rider vulnerability?'.

In order to realise this and ensure that safety is managed with an even hand and on a level playing field, the first and most important step is to recognise motorcycling's place within society and the overall transport system. Indeed, the Organisation for Economic Cooperation and Development (OECD) firmly stated this key point in their primary recommendations from the 2008 Lillehammer safety conference. Similar conclusions were reached at "A Shared Road to Safety. A Global Approach for Safer Motorcycling", an event organised by the International Motorcycle Manufacturers' Association during the International Transport Forum, in May 2014.

Such an approach will open up the ability to integrate motorcycle safety as part of broader transport policy/planning and enable a reduction in rider vulnerability and improve accessibility as part of this. This will result in not only fewer motorcycle casualties, but also the important role that motorcycling plays in social, business, practical and leisure transport.

6. United Kingdom Department for Transport, "Transport Statistics Bulletin. Compendium of Motorcycling statistics 2009". The full document is available at http://goo.gl/t2atXR

Document structure

The safe ride to the future is structured in four main sections.

The first one provides an overview of the most significant industry-led initiatives in the field of road safety (e.g. key safety technology developments, advocacy actions, accidentology research).

The second section looks into the future of motorcycling. It discusses the industry's vision of intelligent transport systems and includes a memorandum of understanding agreed upon by ACEM members, which commits industry players to equip new vehicles with ITS features.

The third section of this document explains why there is an urgent need for tailored policy interventions at the national level and outlines upcoming industry initiatives in this area.

The fourth section elaborates on the DVR Quality Seal, an initiative to identify and promote high quality post license training schemes.

Lastly, the conclusions summarise the key points of this document. They also provide concrete policy recommendations to national and European decision-makers, with the aim of improving the road safety outcomes for PTW users.

A long-standing commitment to road safety

The motorcycle industry is committed to continuously improving road safety for motorcyclists and other road users. ACEM manufacturers have achieved high safety levels for their products, and continue to develop new technologies to facilitate the integration of powered two- and three-wheelers into the transport system. ACEM members have taken action to optimise vehicle safety, engaged with key policy-makers and users, and undertook research activities to develop effective safety countermeasures.

A strong commitment to safe and advanced vehicles

ACEM manufacturers work continuously to bring advanced and innovative products to the market while ensuring a high level of safety for users. Manufacturers have mainly focused on four key areas: intelligent transport systems, lighting devices, vehicle suspension, and stability and braking systems.

Recent developments in technology: intelligent transport systems

Intelligent Transport Systems (ITS) can be defined as the application of information and communication technology to different transport modes including road transport. It is a fast moving sector with research progressing constantly and new developments being continuously implemented.

For several years now ACEM manufacturers have been on the forefront of research in the area of rider assistance systems for motorcycles. They are mainly available today on high-end vehicles due to the additional complexity and consumer cost of these systems, or as optional equipment. They include equipment such as anti-lock braking systems (ABS) and traction control systems (TCS), which assist riders in maintaining vehicle control while driving on loose or slippery surfaces.

Other relevant features include tyre pressure monitoring systems (TPMS), electronic adjustable suspension, electronic cruise control, gear shift assistant, fuel economy assistant, proximity activation systems (i.e. keyless riding systems), in-vehicle navigation systems, adjustable vehicle riding modes, etc.

Furthermore, very promising developments are taking place in the field of cooperative ITS. Vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) technologies have a

KTM has fitted its newest model with Motorcycle Stability Control, a new ABS system that allows emergency braking in curves and provides additional stability to the vehicle.

high potential to minimise the risk of accidents by allowing powered two- and three-wheelers to effectively communicate with other vehicles.

ACEM manufacturers have, in close cooperation with the car industry, participated in a number of research projects that aim to develop V2V and V2I applications. Examples of these initiatives include the CAR 2 CAR Communication Consortium, the SIM-TD and the Drive C2X projects.

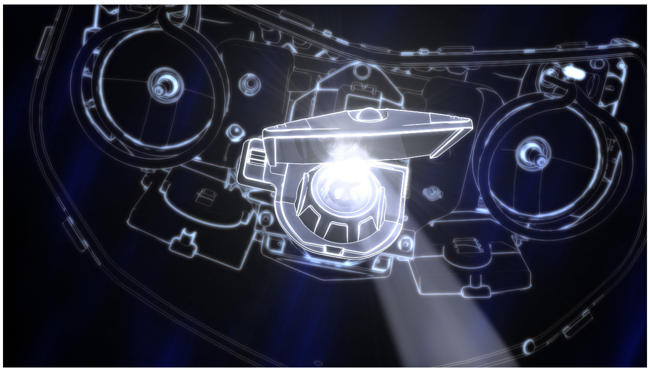
As a result of these efforts integration of PTWs into the transport system could be substantially increased in the future.

All of Peugeot's Metropolis are fitted with daytime running lights in order to increase their conspicuity.

Lighting devices: seeing and being seen

The ability of motorcycles to be detected by other road users is a critical aspect in crash prevention. In-depth studies have repeatedly shown that failure to see the PTW by other road users are a major contributor to urban PTW injuries.

This crash factor can be partially addressed by the introduction of specific technologies that improve the conspicuity of motorcycles. This is why ACEM members committed themselves to equipping all their models including mopeds with automatic headlamp-on technology (AHO) since 2003.



BMW Motorrad adaptive headlights improve road visibility when cornering at night, significantly increasing active safety.

Moreover, the motorcycle industry is also making use of daytime running lights (DRL) and amber position lights (APL). These systems make it easier for other road users to detect powered two- and three-wheelers.

Riding at night or in poor visibility conditions poses an important safety challenge. In view of this, some industry members are already producing vehicles fitted with adaptive lights which make night driving considerably safer. Other ACEM members have committed to incorporating adaptive lights to their newest models.

Additional relevant technologies available in the market include polyellipsoid headlamps, full LED lights (headlights, taillights and indicators), projector headlights and xenon headlights.

Suzuki stop and tail light uses LED technology for greater response and improved reliability.

Vehicle suspension and stability

Vehicle stability while riding a powered two- or three-wheelers is crucial. Highly performing suspension systems are required in order to safely adapt to different road surface conditions. Suspension systems also contribute to smooth handling and braking, and provide comfort to riders by keeping them isolated from road bumps.

Over the years ACEM manufacturers have developed a wide range of innovative vehicle suspensions adapted to different motorcycle usages. They include electronic suspension systems (standard or optional depending on the model), speed-sensitive electronic steering stabilisers (standard in various high performance models), semi-active suspension systems (which adapt the response of the suspension to road conditions, vehicle speed and driving style) and self-regulating suspensions.

All of these systems provide for maximum stability and increase users' control of the vehicle.

BRP's vehicle stability system (VSS) combines stability control, traction control, ABS and dynamic power steering to improve the safety of the rider.

Suzuki's traction control system help riders to accelerate, brake and steer properly and efficiently, making riding safer and easier.

Suzuki's adjustable wind protection reduces rider fatigue and improves concentration.

Kawasaki's 3-mode KTRC traction control provides enhanced stability in slippery conditions.

Kawasaki's Ninja ZX-10R is as standard equipped with an Electronic Steering Damper, substantially improving steering control.

Stopping right in time: braking systems

The motorcycle industry introduced the first anti-lock braking systems (ABS) in 1988, long before this area was considered a priority by policy-makers. Since then, the industry has developed different advanced braking technologies, tailoring these devices to the specific needs of consumers. Other advanced braking systems include combined braking systems (CBS), rear wheel lift-off protection, automatic brake force distribution, amplified braking systems and brake by wire. These systems can operate individually or in combination.

Furthermore, ACEM signed in 2004 the European Road Safety Charter committing itself to offering at least 50% of their street models with advanced braking systems as an option by 2010. After this initial target was surpassed, ACEM manufacturers set a further objective: 75% of street motorcycle models offered on the market in 2015 will be available with an advanced braking system as an option or as standard fitting.

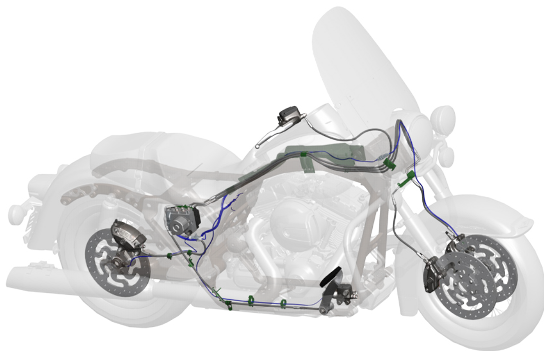
ABS systems will become mandatory for new motorcycles over 125cc from 2016. From that same date, new models up to 125cc will have to be equipped with either a combined braking system, ABS, or both. As a result of the ACEM commitment for the Road Safety Charter some manufacturers have decided to fit with ABS as a standard all of their models.

Moreover, national industry associations have designed schemes that give preferential treatment to ABS-equipped models in national markets. This has allowed some EU countries to achieve a high level of ABS uptake (73% in Sweden and 90% in Germany, for example).

Antilock brake systems, such as this one from Triumph, makes braking in any situation simpler and safer.

Engaging with riders and policy-makers

Rider education, training and continuous information campaigns, complemented by the enforcement of existing rules, are key instruments in achieving a safer road environment. ACEM members work closely with motorcycle users and other stakeholders, and lead on campaigns to improve rider safety and to encourage rider training. Moreover, the industry provides policy-makers with relevant information and formulates policy recommendations in different areas including infrastructure design.



Harley-Davidson's linked brakes combine ABS with electronically linked brakes to dynamically optimize front and rear brake balance.

Engaging with both policy-makers and riders is essential. Only an integrated approach that takes into consideration all the aspects of motorcycling (i.e. vehicle, human and infrastructure factors) can improve road safety for PTW users.

Better skills, better riding

The industry offers specialised and individually tailored rider training courses to meet all needs, from absolute beginners to highly skilled riders. These courses include training on motorcycle uses, such as motorcycling on public roads, touring, off-road enduro riding and race track riding. Furthermore, specific training schemes are developed by industry when new technologies or types of vehicles are introduced onto the market.

The main aim of these courses is to teach participants how to share the road with other road users, how to avoid potentially dangerous situations and how to better maintain control of the vehicle in extreme conditions. They take place under the guidance of certified instructors either in selected riding schools or in training centres established by ACEM members. Particular attention is paid to the training of young people looking to get a moped license or who hold a B license (a passenger car license) and want to follow a preparatory course to become riders.

Some manufacturers have set up specialised training facilities, such as the Honda Safety Institute in Barcelona, Spain.

Moreover, ACEM members have created specific training schemes to ensure that motorcyclists who have stopped riding for a prolonged period of time can come back to motorcycling safely. These efforts are supported by national police forces in several EU countries.

Next to practical training courses, some manufacturers have also developed riding simulators for helping especially novice riders especially, to learn to see potentially dangerous traffic situations without risk. Additionally, basic control skills can be perfected (e.g. hand and foot control coordination (clutch – throttle – gear – brake).

The Honda Riding Trainer offers hazard perception simulation as effective and complementary safety tool in motorcycle training.

National industry associations play a key role in ensuring that training schemes are delivered to a high standard. In Germany, for example, more than 3,500 motorcycle trainings have been assessed in cooperation with relevant national authorities. In Italy in 2012 more than 3,200 young people attended the "Bikers academy" programme which involved a total of 619 driving schools. In the UK, the industry works closely with the Police-led 'Bikesafe' initiative which assesses the skills of riders via one-day courses and ride outs. More than 15,000 participants across Europe participated in a training scheme run by one of ACEM members.

Raising awareness about protective equipment

The motorcycle industry has worked closely with protective equipment manufacturers for many years to develop and promote appropriate rider equipment. Research developed jointly by the motorcycle industry and equipment manufacturers has allowed for the development of new protective equipment products including special clothing designed for hot climates and airbag jackets.

ACEM members and equipment producers continue to develop body protectors, back braces, clothing in reflective colours and new improved helmets. Dedicated protective equipment, including neck braces and armoured clothing has also been developed for off-road, motocross and sport motorcycling.

In 2006, Honda launched the world's first production motorcycle air-bag system on the Honda Goldwing. The system helps to lessen the severity of injuries caused by frontal collisions.

Some motorcycle manufacturers have also designed their own protective equipment, taking into consideration the specific needs of riders and vehicles. Indeed, it is important to stress that the safety gear required to ride safely depends on the type the specific use of each vehicle. Powered two- and three-wheelers ridden in urban areas do not require the same type of protective gear that more powerful motorbikes which can be used for example in rural environments, at higher speeds, or in off-road activities.

Furthermore, manufacturers actively encourage riders to wear appropriate safety gear. Some ACEM members have launched campaigns offering back protectors to everyone who purchased a new motorcycle and distributed tens of thousands of back protectors all over Europe. These efforts are also supported by national industry associations which work closely with clothing manufacturers, insurance companies and national administrations to promote the use of appropriate equipment and offer complete protective package at preferential rates.

Ducati introduced in 2014 an airbag-equipped jacket that is operated wirelessly if sensors on the vehicle detect an accident.

Harley-Davidson has created its own line of riding gear that keeps drivers both safe and comfortable on the road.

BMW has developed an entire range of rider equipment and has done so since the 1970s - from motorcycle helmets to rider suits, boots and gloves.

Working together with public authorities

Establishing a legislative framework that recognises the importance of motorcycling in transport policies is a priority for the motorcycle industry. Such an approach can have a positive impact on rider vulnerability, as well as enabling the greater utilisation by governments and society of PTWs as a mode of commuter transport in particular. National associations actively participate in different public bodies and provide industry expertise to national administrations.

ACEM members have engaged with officials to support efforts to improve national road codes, formulated recommendations to improve European licensing systems and developed, in collaboration with other stakeholders, guidelines to make transport infrastructure friendlier to PTWs. The industry has also advocated for powered two- and three-wheelers to be allowed in bus and taxi lanes in order to increase riders' safety. As a result of these efforts these vehicles have been allowed to drive in taxi / bus lanes in London and Madrid.

Ensuring that legislation is properly enforced is vital in order to protect consumers and fight counterfeiting. ACEM members cooperate with public authorities at European and national level and support market surveillance activities in order to prevent non-compliant and unsafe products from being placed on the European market. The motorcycle industry also provides valuable and up to date information to national and European decision-makers (e.g. number of units sold in national markets, size of the circulating park, etc.).

ACEM members have participated together with relevant national authorities in several road safety campaigns. These campaigns have focused on encouraging drivers to look for motorcyclists on the road. This is particularly important given that a high number of collisions are caused by car drivers noticing very late or even completely overlooking riders. Safety campaigns have also focused on the promotion of voluntary post-license training and of conspicuous and protective gear among riders.

"Occhio alla moto" was a road safety campaign launched by ANCMA-Confindustria to raise awareness of motorcyclists among car drivers.

Developing safety countermeasures to improve road safety

Understanding the causes of motorcycle accidents: the MAIDS study

The industry has a long standing commitment to understanding the circumstances and causes of accidents involving PTWs. Between 1999 and 2004 ACEM, with the support of the European Commission and other partners, conducted an extensive in-depth study of motorcycle and moped accidents during the period 1999-2000 in five sampling areas located in France, Germany, Netherlands, Spain and Italy.

The methodology developed by the OECD for on-scene in-depth motorcycle accident investigations was used by all five research groups in order to maintain consistency in the data collected in each sampling area.

A total of 921 accidents were investigated in detail, resulting in approximately 2,000 variables being coded for each accident. The investigation included a full reconstruction of the accident; vehicles were inspected; witnesses to the accident were interviewed; and, subject to the applicable privacy laws, with the full cooperation and consent of both the injured person and the local authorities, pertinent medical records for the injured riders and passengers were collected. From this data, all the human, environmental and vehicle factors which contributed to the outcome of the accident were identified.

To provide comparative information on riders and PTWs that were not involved in accidents in the same sample areas, data was collected in a further 923 cases.

MAIDS remains the most important in depth database of powered two- and three-wheelers accidents in Europe. MAIDS results are still being used by researchers and manufacturers to improve knowledge about accidents and to develop appropriate safety countermeasures.

European and in-house research projects

The motorcycle industry is currently involved in the implementation of the UDRIVE project[7]. This initiative, which runs from 2012 until 2016, is a large-scale European naturalistic study[8] into the traffic behaviour of passenger car drivers, truck drivers and motorcyclists. A total of 240 passenger cars, 150 trucks and 40 motorcycles will be followed for the duration of one year. The road users' behaviour in traffic will be continuously registered with several sensors and cameras. This will yield a wealth of data about everyday traffic behaviour as well as about near-crashes and crashes.

In parallel to this, some ACEM members are taking part in the DRIVE C2X study[9]. DRIVE C2X is a comprehensive assessment of cooperative systems through field operational tests. It aims at creating a harmonized Europe-wide testing environment for C2X technologies, i.e. communication among vehicles (C2C) and between vehicles and the infrastructure system (C2I). Cooperative technologies are being deployed under real-world conditions in several European test sites (Finland, France, Germany, Italy, Netherlands, Spain and Sweden). The project supports efforts to standardise and commercialise ITS systems in Europe.

These ongoing initiatives build on a strong tradition of a cooperative industry efforts. ACEM members have participated in research projects focused on the usage of vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication systems, such as ConnectedRide[10], SIM-TD[11] and the CAR 2 CAR Communication Consortium[12].

These projects aimed to utilise V2X technology in urban areas to lessen the risk of collisions, especially at traffic junctions in urban areas, which represent more than 50% of powered two- and three-wheelers accident scenarios[13].

7. http://www.udrive.eu/
8. Naturalistic riding studies involve the installation of sophisticated cameras and instrumentation in participants' personal vehicles, providing researchers with thousands of hours of data in order to better understand actual driving behaviour and improve vehicle safety performance.
9. http://www.drive-c2x.eu/project
10. More information on the Connected Ride project is available at http://goo.gl/HmtzQQ
11. More information on the SIM-TD project is available at http://goo.gl/GSbOUw
12. http://www.car-to-car.org
13. 52% of the fatal accidents analysed in the MAIDS study happened in traffic junctions.

Between 2010 and 2012, as part of the MUSS project, the industry carried out research on the benefits of passive safety features in PTWs. Between 2009 and 2011, ACEM participated in the eSUM[14] project, a collaborative initiative between the motorcycle industry, local authorities of the principal European motorcycle cities and universities, which developed a good practice guide and an action pack to promote safer urban motorcycling in urban areas.

eSUM was a collaborative initiative between the motorcycle industry, local authorities of the principal European motorcycle cities and universities, to promote safer urban motorcycling.

In parallel to this, the Safespot project (2009-2011) aimed at improving road by safety using cooperative applications based on data exchange among vehicles and between vehicles and infrastructure through an ad-hoc network.

The Saferider project (2008-2010) studied the potential of ADAS[15] and IVIS[16] integration on motorcycles. The project aimed to develop efficient and rider-friendly interfaces for riders' comfort and safety, and to estimate the safety impact and user acceptance of the prototypes in a series of pilot applications.

Yamaha and Piaggio were involved in the testing of ADAS in simulators and vehicles within the Saferider project.

The WATCH-OVER[17] initiative (2006-2008) developed a cooperative system for the prevention of accidents involving vulnerable road users in urban and extra-urban areas using short range communication and vision sensors.

The SIM project[18] (2006 -2009) focused on active and passive safety aspects, mainly from a PTW point-of-view. As riders are one of the most vulnerable road users, the main objectives of SIM were to identify a suitable safety strategy for them, to enhance preventive and active safety acting on electronic vehicle management and human-machine-interaction and to focus on integral passive safety devices.

14. European Safer Urban Motorcycling (eSUM). More information on the Project can be found at http://www.esum.eu/

15. ADAS. Advanced driver assistance systems.

16. VIS. In-vehicle information systems.

17. http://www.watchover-eu.org/

18. The final report of the Safety in Motion project (SIM) is available at http://goo.gl/wwhxuP

Looking into the future: Intelligent transport systems

In the years ahead, further technological breakthroughs will come through innovative intelligent transport systems (ITS), which will allow vehicles to interact with each other and with surrounding infrastructure.

Some ITS devices have already been successfully introduced on the market by ACEM members. Moreover, the motorcycle industry is engaged in in-house R&D activities and actively participates in EU research projects on cooperative ITS.

ACEM manufacturers have also adopted a Memorandum of Understanding on ITS, committing themselves to install safety-relevant cooperative ITS onto at least one of their models by 2020.

A BMW Motorrad-run project, ConnectedRide, has developed specialised warning systems for bad weather conditions, obstacles and approaching emergency vehicles, among others.

The motorcycle industry's vision on ITS

ITS devices can further enhance road safety

Research shows that one of the most frequent human errors in accidents is the failure of other road users to see PTWs within the traffic environment, due to lack of driver attention, temporary view obstructions or the low conspicuity of the PTW[19]. This problem could be addressed by enabling non-PTW drivers to receive a 'motorcycle approaching indication' (MAI) or in case of an emergency situation, a 'collision warning' message. This form of 'digital' conspicuity of PTWs would result in a higher level of safety for riders. For this reason, the industry sees vehicle to vehicle (V2V) communication as a technology which has a high potential to improve road safety across the EU and may lead to better integration of motorcycles in the transport system.

The HMI developed by Honda provides a visual and an audible warning in safety critical situations. The visual element is located close to the rider's line-of-sight and uses changes in color and intensity to communicate the nature of the threat.

19. The final report of the SIM project is available at http://cordis.europa.eu/publication/rcn/11467_en.html

Some ITS applications have also the potential to improve the environmental performance of vehicles and to help meet the growing demand for mobility by optimizing the use of existing road infrastructure (e.g. by providing information on the shortest routes).

Examples of ITS applications include: collision prevention devices, emergency notification systems and road traffic management systems.

Specific vehicle usages must be taken into account

It is important to bear in mind that powered-two and three-wheelers encompass a wide-range of vehicles that have very different uses. Although the PTW market is often perceived as a whole, in reality, it is characterized by a great diversity of vehicles. Whilst the largest market segment (60%) is represented by urban oriented vehicles with a cylinder capacity below 125cc, PTWs above 500cc represent 25% of the market.

Certain ITS solutions would be better suited to a particular category of PTW because they would provide the most benefit with a cost level coherent to the market segment. Small urban PTWs, for example, could be equipped with ITS devices improving their electronic conspicuity, whilst high-end vehicles could benefit of more advanced optional features.

A mandatory approach, without distinguishing PTW categories, would be counterproductive. As long as core functions and interoperability are preserved, each ACEM manufacturing member should have the freedom to implement the most appropriate technical solutions and optional features, within a competitive business environment.

A Honda Goldwing with simple, logical and intuitive HMI for faster and easier recognition of potential risks, compensating for errors of perception or momentary lacks of concentration by the rider.

Technical considerations of relevance to PTWs

Notwithstanding the above mentioned benefits of ITS, important technical issues must be addressed in order to ensure market uptake. Further ITS deployment will require investments in research technology and infrastructure, as well as a clear and sound legal framework.

The driving dynamics of powered-two and three-wheelers are much more complex than those of automobiles. ITS applications, which may remove or interfere with the rider's control of the vehicle, cannot be utilised in the way they are for automobiles. Autonomous active interventions in the control or dynamics of the vehicle may be dangerous to a PTW rider, as this could destabilize the rider and the vehicle, potentially causing, instead of preventing, an accident. For this reason, ACEM members strongly support the use of warning systems.

Advanced Driver Assistance Systems (ADAS), Adaptive Cruise Control (ACCA) or Autonomous Emergency Braking Systems (AEBS), which have been primarily engineered for use in cars, have the potential to be dangerous if applied to a PTW without the necessary adaptation to PTW dynamics. Powered-two and three-wheelers require a dedicated approach and specific engineering solutions to optimize the potential of ITS for road safety.

It is also important to stress that these systems will require the development of appropriate human-machine interfaces (HMI). HMI must minimise rider distraction and should be specifically designed with PTW riding in mind. For example, messages should be prioritised so that safety warnings override more general notifications.

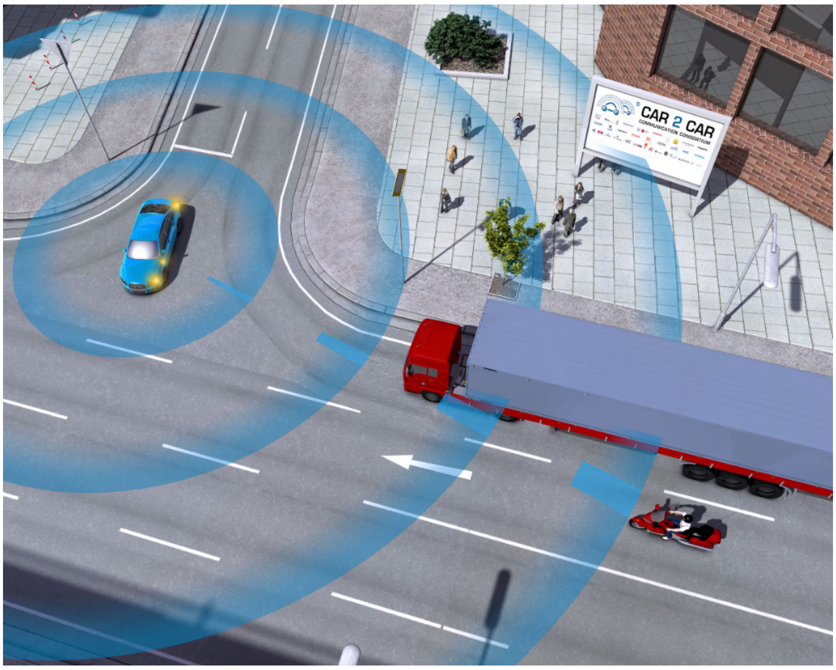
ACEM members are committed to ensuring that any safety related co-operative ITS applications are interoperable between both PTW manufacturers, and more importantly, with other road users.

The motorcycle industry will contribute to European and global ITS forums to ensure that cars, trucks and PTWs are all able to communicate using their various ITS applications. It is critical that all PTWs must be able to recognise messages from any other vehicle on the road, regardless of brand, vehicle type, etc. This can be ensured by adhering to established harmonised standards.

Other considerations: liability and training

ACEM members are closely observing the debate surrounding the liability of ITS. The implications of device or system failure; conflict between multiple ITS products; operator information overload; loss of operator attention; incorrect interpretation of information and liability arising as a result of the interaction of both ITS-enabled and conventional vehicles have not yet been clarified in terms of liability.

Last but not least, it is important to remember that ITS solutions should not be considered as a substitute for appropriate training. It should be ensured that the public does not become dismissive of ITS technology in the early phases of adoption where low penetration rates on the roads may prevent the systems from working to their



The CAR 2 CAR Communication Consortium is dedicated to the objective of further increasing road traffic safety and efficiency by means of cooperative ITS with vehicle-to-vehicle communication (V2V) supported by vehicle-to-infrastructure communication (V2I).

full potential. At a later stage, it is equally critical that drivers and riders do not become over reliant on safety technologies for warnings of potential dangers.

Training and education will remain the most important factors for safer road use. Drivers and riders will remain responsible for awareness of all other road users around them when manoeuvring.

Towards an eCall system for motorcycles

eCall technology allows for an emergency call to be made, either automatically or manually, from a crashed vehicle immediately after a road collision has occurred. The technology is already available in some cars, and the motorcycle industry has started research into how an embedded eCall system could work on motorcycles. The minimum technical requirements needed for such a system have already been defined and research activities are ongoing in order to address the technical challenges of the system.

One of the objectives of the C2X project is to develop systems that warn drivers about potential collisions with two powered two- or three-wheelers.

The development of crash sensor systems for PTWs is a highly complex task likely to require some years of preparation. Detailed accident analysis assessments, as well as cost-benefit analysis of the systems will be needed in order to develop devices that are reliable, protect consumers and are economically feasible.

Accident-recognition is also an area that will require further efforts. In the case of a severe car accident the driver of a car usually remains inside the vehicle but in the case of a motorcycle accident this situation may be very different. In the majority of cases the rider is usually separated from the vehicle and may come to rest at a distance from the motorcycle. Moreover, there are cases when a motorcycle falls over in a non-accident situation and where clearly there should be no eCall triggered. Also in the case of an accident, the motorcycle and its rider may experience very different events once that accident has started. These and other important challenges have to be properly addressed. In many cases, close cooperation with other stakeholders and organisations will be required.

The industry expects that the ongoing research activities will last for at least the next 18 months. After that, standardisation activities will require about 30 months to be completed. Standardisation will be followed by the development of a technical concept (6 months), the resolution of marketing issues (6 months) and, lastly, the series development phase (24 months). At the end of this process, a reliable and robust eCall system for motorcycles will be available for consumers.

20. Cooperative ITS is defined as a network of systems in which communication partners (vehicles, traffic infrastructure and/or service providers) provide and/or exchange information (i.e. 1- or 2- way of communication).

ACEM Memorandum of understanding on ITS

Another important step towards the deployment of ITS was taken in March 2014, when the motorcycle industry adopted a Memorandum of Understanding on cooperative ITS. The objective of this Memorandum is to accelerate and coordinate the deployment of safety-relevant cooperative ITS[20] on PTWs in Europe.

By signing this Memorandum ACEM manufacturing members agreed to initiate the deployment of safety-relevant cooperative ITS and committed to have at least one of their models available for sale with a cooperative ITS application available either as standard equipment or as optional equipment by 2020.

The Memorandum is an expression of the individual and collective commitment of the ACEM manufacturing members to build on the work of the C2C Communication Consortium (C2C-CC) and to realise a shared objective to the benefit of everyone. Specifically but not uniquely, ACEM manufacturing members aim for PTWs, as vulnerable road users, to achieve electronic conspicuity as foreseen in the second phase of the C2C-CC's MoU in collaboration with other vehicle manufacturers.

Initiation of market introduction will require the finalisation of ongoing activities on standardisation, validation and field operational tests, which are expected to be completed by 2015. It will also require the completion of a number of related activities by other players including infrastructure organisations and public authorities.

The need for more tailored safety policies

Despite overall progress there is a need for more tailored safety interventions

Between 2000 and 2012 the number of fatal accidents involving powered-two and three-wheeler users in the EU fell by 39%. More recently, between 2010 and 2012, this figure decreased by 13.4%. Although this trend is certainly encouraging, data from the International Traffic Safety Data and Analysis Group (IRTAD) shows that considerable disparities in terms of road safety remain between EU Member States. In a few countries, fatalities of motorcyclists increased between 2000 and 2012.

These variances must be understood in terms of road users' behaviour, differences in terms of training, law enforcement and quality of road infrastructure, among other factors. The motorcycle industry strongly believes that these elements must be closely looked at, taking into consideration the specific safety needs of different administrative levels (local, regional and national). This approach would allow to generate more durable and cost-effective safety improvements.

ACEM members also believe that all relevant stakeholders (i.e. public authorities, manufacturers, national associations as well as non-governmental and users' organisations) should come together to identify, adapt and apply measures that have a high potential to reduce the number of fatal accidents in the EU. The motorcycle industry can certainly provide expertise on vehicle safety technology, protective equipment and future technological developments, among others. But it is also vital that public decision-makers develop and implement sound local, regional and national PTW safety strategies.

Evidence suggests that Member States that have developed specific road safety strategies tend to have better road safety outcomes. Conversely, restrictive policy or simply ignoring motorcycling could result in reducing awareness from other road users, putting riders at higher risk.

Thematic workshops, the first step towards more tailored safety policies

The motorcycle industry will organise, in close cooperation with industry national associations and key stakeholders, thematic workshops in different parts of the EU. The main objective of these workshops will be to create a favourable environment for improving the safety of riders in the EU. ACEM has already had preliminary discussions with some organisations in order to promote this approach, essential for road safety.

Some of the key topics to be covered in these workshops will include:

The city of Barcelona increased road safety levels by introducing advancced stop lines at junctions.

- **Mainstreaming of motorcycling into transport policies.** In order to improve road safety results government policies need to properly 'mainstream' motorcycling as part of their overall transport policy. This inclusive approach would allow the proper development of measures which would improve safety, support riders and help realise the positive potential of PTWs for society as a whole. The adoption of a specific PTW strategy by local, regional and national administrations would also maximise the opportunities that exist to reduce urban traffic congestion and pollution – an area where PTWs can play a significant role. Conversely, ignoring PTWs in transport policy has the negative consequence of sustaining an environment for PTW users which is subject to greater vulnerabilities than should exist, and opportunities to improve safety are therefore lost.
- **Successful local strategies to increase PTW safety.** Successful examples of integration of PTWs into the transport system do exist in many European cities. In London and Madrid, for example, the opening of bus lanes to PTWs has substantially reduced the number of PTW collisions and has optimised the use of existing infrastructure. The city of Barcelona introduced "advanced stop lines" at some junctions to provide a special stop space for PTW riders at traffic lights. This reduced conflicts between PTWs and cars, with very positive results. National policy plans should also consider strategies to improve the enforcement of legislation on speed, drink and driving, helmet use, tampering and riding without a proper PTW license. Addressing these issues could save a considerable number of lives every year and contribute to achieving the European target of reducing road fatalities by 50% by 2020.
- **Safer infrastructure for motorcycling.** Road infrastructure is at the core of road safety, especially for PTW riders. Policy-makers need to ensure that infrastructure is well maintained, receives the necessary investment and creates a safer environment for all types of road users, particularly for vulnerable road users such as PTW riders. Consideration of PTW safety at the road design stage is essential to ensure that infrastructure is motorcycle friendly. Relevant aspects of well-designed infrastructure include good PTW visibility, obstacle free zones, use of appropriate road surface materials and predictable road geometry.

- **Raising awareness among road planners of the needs of PTWs.** The characteristics and infrastructure requirements of PTWs should be part of the basic training of road designers, highway and traffic engineers. The standardisation of data collection procedures for infrastructure-related accidents and the identification of sections with high accident concentrations can also help to reduce the number of serious and fatal accidents involving PTWs. ACEM has published an Infrastructure Guidelines Handbook that provides vital information on how to successfully integrate PTWs in infrastructure management. This document has been prepared by industry experts, road and traffic engineers, urban planners, and policy makers[21] .

ACEM has produced a set of guiedlines for policy-makers and urban planners to make transport infrastructure friendlier to PTWs.

- **Ensuring appropriate and high levels of training.** Studies consistently show that significant improvements in motorcycle safety can be made through better riding skills as well as increased and better hazard perception and safety awareness. The motorcycle industry strongly believes that novice riders and B license holders who drive PTWs should be subject to compulsory training. Public authorities should encourage riders with appropriate incentives to undergo voluntary post-licensing training in order to keep their skills honed to a high level. Moreover, training programmes should educate other road users, particularly car drivers, on the presence and vulnerability of motorcycles.

- **Vehicle technology and periodical technical and roadside inspections.** Evidence shows that defective or poorly maintained vehicles can lead to a higher safety risk. However, only half of the EU Member States have set up compulsory periodic technical inspections for powered-two and three-wheelers. The establishment of these mandatory safety checks in these countries would enhance the maintenance and repair of vehicles, prevent safety failures due to inadequate maintenance (e.g. failures or poor condition of lighting, tyres or braking systems) and assist in the prevention of

21. These guidelines are available on ACEM's website, at http://goo.gl/6uYe1D

irresponsible tampering. Furthermore, periodic controls would also offer a cost-effective measure to address pollutant emissions, which are mainly generated by older and poorly maintained vehicles. The motorcycle industry is ready to support any efforts by national administrations to introduce periodic roadworthiness tests for powered-two and three-wheelers by providing the necessary technical expertise and advice. In addition to this, national governments should reinforce roadside inspections of all vehicles in order to identify vehicles which could represent a hazard to traffic safety, when relevant safety requirements are not fulfilled.

- **Improved knowledge on accident causation and rider behaviour.** Accident in-depth studies and naturalistic riding studies are essential in order to develop appropriate countermeasures that avoid or minimise the risk of accidents. They provide detailed insight into normal riding tasks, near-missed accidents and accidents causation factors. In-depth and naturalistic studies should be encouraged and implemented at European, national, regional and local level. This would allow public authorities that lack vital information to devise more effective safety measures as well as realistic policy objectives.
- **Improvement of data gathering processes.** The improvement of data gathering processes is essential to adopt policies based on solid evidence. In this regard, it is important to stress that many national authorities do not collect exposure data, something which is essential in order to make complete and comprehensive road safety analysis.
- **Statistics on PTW use.** Statistics suggest that greater PTW use can lead to considerable safety gains as the proportion of PTWs on the road rises. Indeed, more PTW use can lead to far fewer casualties. The safety experience of higher levels of PTW traffic in different European countries suggests that when motorcycle use increases to 10% of the vehicle stock, sharp falls in casualties start to occur.

ACEM members strongly believe that addressing these and other relevant topics together with major stakeholders will be instrumental in reducing PTW fatal accidents across Europe. Furthermore, these exchanges can pave the way for concrete actions reflecting the national context and situation in the future.

BMW Motorrad offered its first rider training courses back in the 70's. Today it maintains a worldwide network of partners who provide practically oriented courses delivered by qualified instructors to small groups of participants.

Towards a European Training Quality Label

Appropriate training, a key element to improve road safety

The human factor has been shown repeatedly to be the most critical factor in accidents involving powered-two and three-wheelers. For this reason the motorcycle industry encourages continued outreach to new and existing motorcycle riders on the importance of life-long rider training, including pre-licensing and voluntary post-licensing formulas.

Pre-license training provides the basic skills and awareness needed for novice riders to use their vehicles safely on the road. Subsequently, more advanced post-license courses can provide riders with additional opportunities to increase their proficiency and safety as well as their hazard perception skills. Post-license training plays a key role in improving road safety, particularly for people who are upgrading to a more powerful motorbike, who are returning to riding after an extended period of time, or for those who want to improve their riding skills and perception abilities.

In addition, a variety of training options are offered within the context of motorcycle sports on dedicated tracks and off-road terrains. This allows riders to greatly enhance their skills and control of the vehicle.

The industry recognises the importance that training plays for enhancing safer motorcycling. ACEM members have offered for many years, and continue to do so, high quality and well-tailored voluntary training options across the EU. Furthermore, between 2004 and 2007, the industry participated in the Initial Rider Training Project, which developed a modular curriculum for training motorcyclists in Europe.

However, most of the training that riders have access to, both at pre- and post-license level, is not delivered by manufacturers but by training schools. These rider training courses vary widely between countries and schools due to the different training requirements, particular uses of vehicles in the country and vehicles made available to the trainee riders, among other factors. Moreover, the quality of the thousands of different training schemes across the EU is heterogeneous. And given their number, it is difficult for riders to identify the best options and make informed decisions.

To address this issue the German Road Safety Council (DVR, Deutsche Verkehrssicherheitsrat) and ACEM have joined forces to start promoting high quality post license training schemes across the EU.

Helping riders to identify better training options

DVR is an organisation based in Germany that brings together more than 200 members including the German Federal Ministry of Transport, transport-related Ministries of the Federal States, insurance companies, vehicle manufacturers, passenger transport operators and international organisations, among others.

DVR has developed a Quality Seal for certifying the quality of practical driving training courses and programmes. This quality label indicates that the awarded scheme complies with a set of standards defined. These criteria are separated into four pillars: relevance of the programme content, methodology used to deliver the training, technical expertise and communication skills of the trainers, and internal procedures to ensure consistent and high-quality teaching.

In addition to this, a list of exclusion criteria has been defined by DVR. These are a set of rules that disqualify prospective training schemes from receiving the DVR-Quality Seal (e.g. training schemes that serve mainly sportive purposes, insufficient practice in road traffic conditions, etc.).

The DVR Quality Seal ensures that the training is delivered in a fully-fledged manner whilst granting training schools the required flexibility to design a curricula adapted to the needs of riders and their vehicles. It is also important to stress that the quality label is awarded to the programme, not the individual or institution offering the training.

If the training programme meets the requirements of the label, DVR representatives will assess practical training sessions delivered by the applicant institution. If this second assessment has a positive result, the programme will receive the quality seal.

It is worth noting that awarded training schemes will undergo annual checks to ensure that they still comply with DVR training requirements. Moreover, all the institutions whose programmes have received the Quality Seal will be included in a database available at DVR's website in order to increase the transparency of the process and to provide relevant information to consumers.

The DVR label is open to any organisation that is based in Europe and is willing to submit their training programmes for evaluation (e.g. riding training schools, manufacturers, public bodies).

Institutions interested in the quality label will receive, as a first step, a list of criteria that their programmes have to comply with. They will be given time to analyse their internal procedures and existing practices and, if necessary, modify them to reach the quality standards certified by the label. An Independent Quality Label Commission will be in charge of assessing the information received by DVR.

The DVR Quality Seal has been very successful in Germany, where it helped many companies to identify high-quality training schemes for their employees. The fees of these trainings were covered by statutory insurance companies.

Logo used to certify that a motorcycle training scheme has received the DVR Quality Seal.

Promoting better training in Europe

The motorcycle industry is strongly committed to promoting high quality training in the EU in order to increase road safety. ACEM will build on DVR's expertise on road safety and training delivery to promote programmes that provide real added value for riders.

The objective is to help them to choose training options that allow them to ride confidently, enhance their skills and promote defensive riding in road traffic conditions. The awarded schemes should also help participants to become aware of their own abilities, behaviours and attitudes, and to identify areas where additional practice is needed.

In the medium and long-term the DVR Quality Seal, as well as other similar quality labels, some of which are currently being developed, could increase the visibility of the best training programmes available, paving the way towards higher quality standards for training in Europe.

Conclusions and policy recommendations

Road safety is one of the major challenges faced by the EU. Substantial improvements have been achieved in this area in recent years, but much remains to be done. The motorcycle industry believes that the number of fatalities amongst PTW users can, and must be further reduced. For this reason, it is essential that all stakeholders (i.e. industry, and public authorities as well as users and non-governmental organisations) join forces to promote an integrated approach to road safety.

Road safety initiatives and policies must take into consideration vehicles' safety features as well as users behaviour and infrastructure design and maintenance. It is only by working together in these three areas that the number of accidents that affect motorcyclists will be further reduced.

- **The industry is committed to improving road safety through better technology.** Today's motorcycles bear little resemblance to the machines that were circulating on Europe's roads 20 years ago. Advanced motorcycle design, new intelligent features as well as new braking, lighting and suspension systems have led to a substantial increase in motorcycling safety. ACEM members will remain at the forefront of progress in technology innovation and will continue to develop technologies that minimise the risk of accidents on Europe's roads.

- **Motorcycling should be mainstreamed into transport policies.** Whilst many improvements have been made to vehicle safety, with further developments likely to follow as PTW technologies evolve, a true solution to safer riding requires the involvement of public decision makers. Given that the number of PTW vehicles on Europe's roads can be expected to continue growing – probably at a faster rate as the economy recovers – it is important to ensure that they are adequately integrated into the transport system. Appropriate policies should be developed by European and national policy-makers. These inclusive policies should recognise that PTWs are a key mode of transport which fulfils a number of important and diverse roles – in many cases particularly important to local economies and citizens' mobility. As such, they should be integrated into policies and initiatives aimed at creating a safer environment for users. The promotion of PTW usage in transport policy can have a considerable and positive impact on reducing traffic density in heavily congested cities and can bring economic gains through access to jobs and social mobility where other transport modes are unavailable, impractical or too expensive.

- **Training remains vital to improve safety for PTW users.** ACEM manufacturers continuously invest in research and development and build some of the safest vehicles in the world. However, safe vehicles must be driven safely. It is for this reason that ACEM strongly supports both pre- and post-license training for motorcycle riders. Training is also an effective approach for instilling appropriate behaviours and attitudes in all road users. Improved driver training can reduce the number of driver errors and increase overall road safety also. It is furthermore crucial that other road users have an appreciation of the dangers of misjudging the speed or behaviour of a PTW rider – including the common error of failing to see an approaching PTW. Training for all types of license holders should include awareness of the characteristics and behaviours of other vehicles. This should include the common causes of accidents, such as perception failures or misjudgements of capabilities, understanding of vehicle blind spots, or the differences in stopping distances. Campaigns encouraging riders to improve their skills and hazard perception, as well as campaigns encouraging car drivers to pay attention to motorcyclists on the road have been instrumental in improving road safety. They will certainly continue to be in the future.

- **High quality training schemes should be promoted.** Post-license training plays a key role in improving road safety, particularly for people who are upgrading to a more powerful motorbike, who are returning to riding after an extended period of time, or for those who want to improve their skills. However, the quality of post-license training schemes across the EU is heterogeneous. Also, given their number, it is difficult for riders to identify the best options and make informed decisions. For this reason, ACEM and the German Road Safety Council (DVR, Deutsche Verkehrssicherheitsrat) have started promoting high quality training schemes through the DVR Quality Seal. Moreover, other similar quality labels are currently being developed in the EU. Along with the DVR Quality Seal, they could also help to increase the visibility of the best training programmes available and pave the way towards more uniform quality standards for training in Europe.

- **There is a need for more tailored safety policies.** The motorcycle industry has taken up the challenge of further reducing the number of fatal accidents involving riders. ACEM will organise thematic workshops in close cooperation with industry national associations in order to gain a better understanding of what actions can be taken at local, regional and national level to improve safety for PTW riders. Moreover the motorcycle industry believes that all relevant stakeholders (e.g. users' organisations, public authorities and non-governmental organisations) should take an active role and coordinate their efforts to further reduce PTW casualties.

- **ITS can help to improve road safety records in the future.** ACEM members are committed to developing new ITS safety solutions and to bringing them to market. The industry is currently participating in different European projects that aim to test cooperative ITS in real-life conditions, and joint industry research is ongoing on an eCall system for motorcycles. Furthermore, ACEM members have signed a Memorandum of Understanding on ITS committing themselves to install safety-relevant co-operative ITS onto at least one of their PTW models by 2020. It is important to stress, however, that not all ITS solutions may be suitable for all PTW categories. The industry must be able to explore, within a competitive business environment, the appropriate technical solutions for different types of PTWs and their different uses. Lastly, ITS systems should under no circumstances negatively affect the riders' control of the vehicle.

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The quality seal of the German Road Safety Council for Motorcycle Safety Trainings in Europe

Das Qualitätssiegel des Deutschen Verkehrssicherheitsrates e.V. für Motorrad-Sicherheitstrainings in Europa

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Abstract

The DVR quality seal can look back on a successful seven-year history. During this period, more than 40 training providers have made use of the possibility to provide their training with the DVR seal of quality. The vast majority of providers has the seal of quality for training programmes involving the use of motorcycles. Where the distribution of the seal has mainly been limited to Germany, it is now possible to apply for the seal of quality throughout Europe, to shift motorcycle safety training to a consistently high level of quality.

The focus of the scientifically based DVR seal of quality has so far been to apply a uniform set of criteria with the following quality dimensions to the various types of training:

- Content
- Method
- Training and continuing training system for trainers
- Quality assurance

Innovations in the training landscape made it necessary to adapt and expand the list of criteria. In the future, there will be five different catalogues for training on closed practice areas (classical form of training), for training in actual traffic and for three types of training with the use of simulators. The latter three types are mainly related to truck and bus simulator training for professional drivers as well as training for action teams from emergency services and the fire brigade.

The seal will continue to provide customers with a simple guide and the information that the trainee can expect a defined degree of quality and a reputable offer with the core objective of 'improving road safety'.

The content, structure and the assessment system of the DVR quality seal are introduced; information about the guidelines on and experiences with the awarding of the seal is also provided. Particular emphasis is placed on motorcycle training on training grounds and in actual traffic.

Kurzfassung

Das Qualitätssiegel des DVR kann mittlerweile auf eine erfolgreiche siebenjährige Vergangenheit zurückblicken. In dieser Zeit haben bereits über 40 Trainingsanbieter von der Möglichkeit Gebrauch gemacht, ihre Trainings mit dem DVR-Qualitätssiegel zu versehen. Der weit überwiegende Teil der Anbieter besitzt das Qualitätssiegel auch für Trainingsangebote im Bereich Motorrad. Beschränkte sich bislang das Verbreitungsgebiet des Siegels in der Hauptsache auf Deutschland, wird es nun möglich sein, das Qualitätssiegel europaweit zu beantragen, um die Motorrad-Sicherheitstrainings auf ein einheitlich hohes Qualitätsniveau zu bewegen.

Das wissenschaftlich fundierte DVR-Qualitätssiegel war bislang so angelegt, das für verschiedene Trainingsvarianten ein einheitlicher Kriterienkatalog mit den Qualitätsdimensionen

- Inhalt,
- Methode,
- Aus- und Fortbildungssystem für Trainer und
- Qualitätssicherung

Verwendung fand. Innovationen in der Trainingslandschaft machten es notwendig, den Kriterienkatalog anzupassen und auszuweiten. Zukünftig wird es fünf unterschiedliche Kataloge für Trainings auf abgesperrten Übungsgeländen (klassische Trainingsform), für Trainings im Realverkehr und für drei Varianten von Trainings mit Einsatz von Simulatoren geben. Letztere drei Varianten beziehen sich vor allem auf Lkw- und Bussimulatortrainings für Berufskraftfahrer sowie auf Trainings für Einsatzkräfte der Rettungsdienste und der Feuerwehr.

Auch zukünftig wird das Siegel dem Kunden eine einfache Orientierungshilfe bieten und darüber informieren, dass der Trainingsteilnehmer mit einer definierten Qualität und einem seriösen Angebot mit dem Kernziel „Erhöhung der Verkehrssicherheit“ rechnen kann.

Es werden die Inhalte, die Struktur und das Bewertungssystem des DVR-Qualitätssiegels vorgestellt sowie über die Vergaberichtlinien und über Erfahrungen mit der Siegelvergabe berichtet. Dabei wird besonderes Augenmerk auf Motorradtrainings auf Trainingsgeländen und im Realverkehr gelegt.

Das Qualitätssiegel des Deutschen Verkehrssicherheitsrates e.V. für Motorrad-Sicherheitstrainings in Europa

Einleitung

Erstmals berichteten Kerwien und Bente [01/] im Jahre 2008 über die Einführung des Qualitätssiegels des Deutschen Verkehrssicherheitsrates (DVR). Zum damaligen Zeitpunkt waren vor allem deutsche Anbieter von fahrpraktischen Trainings auf der Antragstellerseite zu finden. Der Hintergrund war und ist, dass in Deutschland Weiterbildungsangebote im Bereich Verkehrssicherheit häufig von Betrieben oder den Unfallversicherungsträgern bezuschusst werden, wenn die jeweilige Maßnahme zum Ziel hat, Unfälle zu vermeiden und sicheres Verhalten zu erzeugen. Aus diesem Grund ist es verständlich, dass diese Kostenträger sichergestellt haben wollen, dass es sich bei solchen Angeboten um qualitativ hochwertige Maßnahmen handelt.

Eine Kooperation zwischen DVR und ACEM (Association des Constructeurs Européens de Motocycles) macht es nun möglich, das Qualitätssiegel des DVR europaweit zu beantragen, um die Motorrad-Sicherheitstrainings auf ein einheitlich hohes Qualitätsniveau zu bewegen.

Veränderungen in der Trainingslandschaft erforderten indes eine Ausweitung des DVR-Qualitätssiegels auf Trainings, die im Realverkehr stattfinden sowie auf Trainings unter Einbeziehung moderner Fahrsimulatoren. Alle Qualitätskriterien wurden im Zuge der Ausweitung einer Prüfung unterzogen und wenn notwendig angepasst.

Das Qualitätssiegel beantragen können alle Institutionen und Personen, die Verkehrssicherheitsangebote mit fahrpraktischen Anteilen (auch Simulation) anbieten. Das Siegel wird dabei für das Programm und nicht für die Institution bzw. Person vergeben.

Die Inhalte des DVR-Qualitätssiegels

Die Basis der inhaltlichen Ausgestaltung des Qualitätssiegels lieferte eine Arbeit von Fastenmeier und Gstalter [02/], in der ein Schema entwickelt wurde, um Sicherheitstrainings zu klassifizieren und nach ihrem Nutzen zu bewerten. Die Entwicklung dieses Schemas beruhte auf teilnehmenden Trainingsbeobachtungen und auf Analysen von Evaluationsstudien über Verkehrssicherheitstrainings. Die daraus abgeleiteten Beschreibungs- und Beurteilungskriterien bestanden aus einer Reihe von sinnvoll erachteten Lernzielen sowie Kriterien zur Didaktik und Methodik der Trainingsmaßnahmen.

Einen weiteren wichtigen Grundstock für die Qualitätssiegelentwicklung lieferte das EU-ADVANCED Projekt [03/], welches zum Ziel hatte, Empfehlungen für die Gestaltung von freiwilligen und obligatorischen Sicherheitstrainings für Auto- und Motorradfahrer zu erarbeiten. Grundlage bildete dort neben den obligatorischen Literaturrecherchen ein elektronischer Fragebogen, der europaweit an Trainingsanbieter geschickt wurde, um ein Bild über die Rahmenbedingungen, Zielgruppen, Lernziele, Kursmethoden und Inhalte der verschiedenen Maßnahmen zu erhalten. Darüber hinaus hatte die EU-Projektgruppe verschiedene Trainings in den Ländern Europas besucht. Die Empfehlungen der Projektgruppe zu den Inhalten der Kurse basierten auf einem hierarchischen Modell des Fahrverhaltens [z.B. 04/, 05/,] bzw. auf der so genannten GDE-Matrix [06/].

Den hauptsächlichen Anteil zur inhaltlichen Ausgestaltung des Qualitätssiegels sowie zu methodisch didaktischen Durchführungskonzepten lieferten allerdings die bereits existierenden Sicherheitstrainings und Sicherheitsprogramme, die nach den Richtlinien des DVR (Deutscher Verkehrssicherheitsrat) durchgeführt werden.

Den Kern des Qualitätssiegels stellen eine Liste von Ausschlusskriterien sowie die vier Qualitätsdimensionen „Inhalt", „Methode", „Aus- und Fortbildung für Trainer" und „Qualitätssicherung" dar. Zusätzlich wird ein Wahlbaustein für den Trainingsplatz angeboten, der vom Antragsteller gesondert beantragt werden kann.

Ausschlusskriterien

Bei Erfüllung nur eines Kriteriums der Ausschlussliste kann das Qualitätssiegel nicht vergeben werden. Dies ist beispielsweise der Fall, wenn es sich bei der Maßnahme um ein reines Fertigkeitstraining handelt, wenn die Maßnahme deutlich sportliche Ambitionen hat, wenn es keine Übungsvariationen gibt, die das Gelingen trainierter Verhaltensweisen schwieriger werden lassen, wenn fahrpraktische Übungen losgelöst von realen Straßenverkehrssituationen durchgeführt werden, wenn das Training ausschließlich mit der Methode der Instruktion durchgeführt wird oder wenn die Trainer nicht ausgebildet bzw. regelmäßig fortgebildet werden. Darüber hinaus müssen bestimmte Kriterien für das Übungsgelände eingehalten werden, sofern es sich nicht um ein Realverkehrstraining handelt. So darf es beispielsweise keine spitzen, scharfkantigen Einrichtungen auf dem Trainingsgelände geben, die für Motorradfahrer gefährlich werden können und es müssen ausreichende Sturzräume zur Verfügung stehen.

Wenn es darüber hinaus erhebliche und schwerwiegende Verdachtsmomente gibt, dass das begutachtete Training kein realistisch-alltägliches Training des Anbieters ist, sondern eigens für die Qualitätssiegel-Begutachtung konstruiert oder beeinflusst wurde, wird das Qualitätssiegel ebenfalls nicht vergeben. Darüber hinaus müssen mindestens 60% der Trainingsanteile durchgeführt werden, die in der Antragstellung angekündigt wurden.

Qualitätsdimension Inhalt

Die Kriterien dieser Dimension betreffen u. a. die Notwendigkeit eines Realitätsbezugs der Übungen auf einem Trainingsgelände zum realen Straßenverkehr. So wird beispielsweise der Unterschied zwischen den idealtypischen Verhältnissen beim Bremsen auf dem Übungsgelände und der Realität (verschmutzte Fahrbahn, Regennässe, Glätte, Rollsplitt etc.) thematisiert. Des Weiteren sind Kriterien beinhaltet, die den psycho-physischen Zustand des Fahrers mit seinen Auswirkungen auf Wahrnehmung und Verhalten und die Rolle von Einstellungen, Motiven und Emotionen auf das Fahrverhalten betreffen. Darüber hinaus werden die Themen Arbeits- und Gesundheitsschutz, Risikobewusstsein und Risikovermeidung sowie vorausschauendes Fahren und Notmanöver berücksichtigt.

Qualitätsdimension Methode

Fahrpraktische Trainings sollten teilnehmer- und problemorientiert gestaltet werden. Die Wünsche, Interessen und Bedürfnisse der Teilnehmer sollten bei der Planung und Durchführung des Trainings berücksichtigt werden. Im Sinne einer modernen Erwachsenenpädagogik sollten Trainingsteilnehmer die Möglichkeit erhalten, selbst nach Lösungsstrategien für Fahrprobleme zu suchen und diese Strategien dann auch ausprobieren. Dabei ist darauf zu achten, dass eine Methodenvielfalt angewendet wird mit einem sinnvollen Wechsel zwischen Instruktion, Moderation, Selbst- und Fremdbeobachtungsaufträgen, Gruppenarbeit, Lehrgespräch, Einsatz von Medien etc.

Qualitätsdimension Aus- und Fortbildungssystem für Trainer

Anhand der Kriterien dieser Qualitätsdimension wird überprüft, inwiefern es für die Trainer der Maßnahme fixierte Eignungskriterien gibt und wie die Traineraus- und Fortbildung ausgestaltet ist. Die Tatsache allein, dass ein Bewerber in der Regel ein guter Motorradfahrer ist und die Übungen im Training selbst kompetent fahren kann, qualifiziert ihn nicht automatisch dazu, ein guter Trainer zu sein. Das Qualitätssiegel des DVR sieht eine Liste geeigneter Eignungskriterien vor, damit ein Bewerber die Laufbahn eines Trainers einschlagen kann. Wird die Bewerbung positiv beschieden, muss sich ein Traineraspirant einer Ausbildung unterziehen, die idealerweise folgende Kriterien erfüllt:

- Es existiert eine dokumentierter Ausbildungsplan für angehende Trainer. In diesem Ausbildungsplan sollten die Ausbildungsinhalte, Aufgaben, Anforderungen, zeitlicher Verlauf, Ausbildungsschritte usw. aufgelistet sein.
- Es gibt Hospitationsphasen für den Anwärter. Dazu sollte der Traineranwärter Trainings seines Ausbildungstrainers begleiten und beobachten. Er sollte dabei nicht als „Helfer“ fungieren oder gar als Teilnehmer.
- Es gibt es Lehrproben, die bewertet werden.
- Die Traineranwärter werden zu den Themen Kommunikation bzw. Gesprächsführung geschult und nicht ausschließlich zu den Themen Technik und Fahrdynamik bzw. Fahrtechnik.

Wenn der Trainer seine Ausbildungsphase erfolgreich durchlaufen hat, muss er die Möglichkeit erhalten, sich regelmäßig fortzubilden. Die Fortbildungsangebote sollten neben den Themen Fahrtechnik und Fahrzeugtechnik auch verhaltenswissenschaftliche Themen wie Unfallforschung, Verkehrspsychologie oder Verkehrspädagogik berücksichtigen. Darüber hinaus wären Fortbildungsangebote mit unterschiedlichen methodisch-didaktischen Schwerpunkten wie Seminarplanung und Methoden der Erwachsenbildung wünschenswert.

Qualitätsdimension Qualitätssicherung

Ein Anbieter sollte für die entsprechende fahrpraktische Trainingsmaßnahme einen ansprechenden „Pre-Sales-Service“ besitzen. Er sollte beispielsweise telefonisch erreichbar sein und es sollte eine ausführliche Beratung am Telefon stattfinden. Dabei sollte der Kunde freundlich und wertschätzend behandelt werden. Darüber hinaus wird überprüft, ob es ein System der internen Information und Kommunikation gibt, festgelegte Verantwortlichkeiten und Zuständigkeiten sowie ein funktionierendes Beschwerde- und Reklamationsmanagement. Des Weiteren sollte es Maßnahmen zur Wirkungs- und Nachhaltigkeitsmessung geben wie beispielsweise regelmäßige Teilnehmerbefragungen oder gar wissenschaftlich fundierte Evaluationsstudien. Einen weiteren Themenpunkt stellt die Informationsweitergabe an die Trainer und auch Teilnehmer dar. Es wird beispielsweise geschaut, ob die Trainer schriftliche Hintergrundinformationen zu verkehrspädagogischen bzw. verkehrspsychologischen erhalten oder inwiefern es für das Trainingsangebot Teilnehmerbroschüren gibt, in denen die wichtigsten Inhalte des Trainings beschrieben sind.

Wahlbaustein Trainingsplatz

Neben dem Antrag auf Erteilung des Qualitätssiegels für ein Programm kann ein Anbieter auch die örtlichen Rahmenbedingungen der Kursdurchführung prüfen lassen. Dieser Antrag ist freiwillig. Dieser Baustein wird hier nicht näher dargestellt, da er die Qualität der Maßnahme an sich nicht weiter berührt. Interessenten können sich die Kriterien auf der Internetseite des DVR (www.dvr.de) anschauen.

Bewertungssystem

Die Bewertung der Kriterien erfolgt mit Hilfe einer Checkliste mit den Antwortmodi „nein“, „eher nein“, „eher ja“ und „ja“. Die Auswertung erfolgt durch eine spezielle Software, die die Punkwertungen intern verrechnet und als Ergebnis den jeweiligen Erfüllungsgrad für jede Dimension ausweist. In den Dimensionen „Inhalt“, „Methode“, „Aus- und Fortbildung für Trainer“ und „Qualitätssicherung“ muss jeweils ein Erfüllungsgrad von 40 Prozent erreicht werden. Über alle vier Qualitätskategorien hinweg muss ein Erfüllungsgrad von mindestens 60 Prozent existieren.

Vergabeverfahren

Eine Antragstellung kann jederzeit formlos schriftlich erfolgen. Dem Antragsteller wird dann die Kriterienliste zugesendet. Danach reicht der Antragsteller seine schriftlichen Unterlagen auf der Grundlage der Kriterienliste ein. Diese Unterlagen werden auf formelle Vollständigkeit hin gesichtet. Die schriftlichen Unterlagen werden dann an zwei Mitglieder der unabhängigen Qualitätssiegelprüfkommission gesendet, die zu der eingereichten „Schriftform“ Stellung beziehen. Nach einer positiven Beurteilung der Unterlagen beobachten die beiden Prüfer das fahrpraktische Training vor Ort, um Aussagen darüber machen zu können, ob das Training auf der Grundlage des eingereichten Konzeptes durchgeführt wird. Beide Prüfer verfassen im Anschluss unabhängig ihre Stellungnahmen und Bewertungen. Über einen Konsensfindungsprozess einigen sich beide Prüfer auf ein abschließendes Urteil. Nach positiver Prüfung wird das Qualitätssiegel verliehen und das Training wird auf der Internetseite des DVR (www.dvr.de) aufgelistet. In der Folgezeit werden regelmäßige jährliche Qualitätskontrollen durchgeführt. Der Auftraggeber erhält eine regelmäßige Zusammenfassung der Prüfergebnisse durch den DVR.

Erfahrungen mit Begutachtungen auf der Basis des DVR-Qualitätssiegels in den Qualitätsdimensionen Inhalt und Methode

Inhalt

Fahrpraktische Trainings beinhalten Lerneinheiten, in denen zu einem gewissen Fahrproblem Übungen wiederholt durchgeführt werden, um beim Teilnehmer eine höhere Handlungssicherheit zu erreichen. Ein Beispiel stellt das Trainieren der Gefahrenbremsung dar. Es handelt sich hierbei um klassisches Trainieren, wie man es auch bei anderen Sportarten wiederfindet. Das DVR-Qualitätssiegel macht keine Vorgaben darüber, was genau in einem Motorradtraining trainiert werden sollte, also welche speziellen Übungen unbedingt vorhanden sein müssten, sondern liefert beispielsweise in der Qualitätsdimension „Inhalt“ Qualitätskategorien zu den Themenkomplexen:

- Realitätsbezug,
- Wahrnehmen und Erkennen,
- Einstellungen, Motive und Emotionen,
- Risikobewusstsein und Vermeiden,
- Notmanöver und vorausschauendes Fahren,
- Arbeits- und Gesundheitsschutz.

Die Qualitätskriterien in den oben aufgeführten Kategorien beziehen sich darauf, ob und wie die besonderen Themen im Training aufgegriffen werden. Bei Übungen auf dem Trainingsplatz (z.B. Bremsen) würde es folglich allein nicht ausreichen, die Teilnehmer Bremsungen durchführen zu lassen bis zumindest die Grobform im sensomotorischen Lernprozess oder gar die Feinform erreicht ist. Darüber hinaus und für die Qualität eines Trainings wichtiger, sollte beispielsweise thematisiert werden:

- inwiefern ein trainiertes Fahrmanöver 1:1 im Straßenverkehr umgesetzt werden kann,
- wie sich der psycho-physische Zustand (z.B. Ärger, Freude) des Fahrers auf Wahrnehmung und Verhalten auswirkt,
- die Funktion von Extra-Motiven sowie der Zusammenhang von Geschwindigkeit und Risiko,
- der Zusammenhang zwischen Geschwindigkeit in km/h und der dabei zurückgelegten Wegstrecke in Metern pro Sekunde,
- …

Motorradfahren ist per se eine emotionale Angelegenheit. Die Motivationslage spielt eine große Rolle vor allem bei Allein- bzw. Geschwindigkeitsunfällen. So sollte die bewusste Auseinandersetzung mit dem eigenen „Wollen“ und dem emotionalen Erleben gefördert werden, welche das Geschwindigkeitsverhalten determinieren.

- Der Zusammenhang zwischen den angestrebten emotionalen Erlebnissen und den damit einhergehenden Risiken sollte zukünftig in den Motorradtrainings intensiver behandelt werden.

Methode

Das traditionelle methodische Verfahren der Instruktion (deduktiver Lehrweg) ist dadurch geprägt dass:

- es die zu erlernende Fertigkeit in den Mittelpunkt stellt,
- sich die Teilnehmer eher passiv als Informationsempfänger verhalten,
- der Lernweg rationell und ökonomisch konzipiert ist.
- der Trainer dominiert (es besteht die Tendenz zur Vernachlässigung sozial-affektiver Verhaltensbereiche).

Der Trainer macht etwas vor, erklärt und beschreibt, gibt Anweisungen und korrigiert. Einige Trainingsanteile werden häufiger mit dieser Methode verknüpft sein, weil sie schneller zum „Erfolg“ führt.

Ein qualitativ hochwertiges Training sollte aber auch Lernumwege in Kauf nehmen, um den Teilnehmern mehr Freiraum zur Äußerung von Meinungen und Verhaltensweisen geben zu können. Die induktive oder moderierende Vorgehensweise zeichnet sich in der Regel durch eine höhere Teilnehmerorientierung aus. Mit dieser Methode wird die selbsttätige Auseinandersetzung mit Fahrproblemen gefördert. Die Teilnehmer sind mehr in den (Selbst-)Lernprozess integriert und somit aktiver als bei der deduktiven Vorgehensweise. Die Teilnehmer erhalten die Möglichkeit, Fahrprobleme zu benennen, eigene Lösungsstrategien vorzuschlagen und auszuprobieren, um dann die beste Strategie herauszufinden.

- Es sollte zukünftig in den Trainings mehr teilnehmer- bzw. problemorientiert gearbeitet werden.
    - An den Erfahrungen der Teilnehmer anknüpfen („Wer musste denn schon einmal eine Notbremsung durchführen?“.)
    - Es sollten Fahrprobleme oder Fragen formuliert werden („Wie bremse ich in einer Gefahrensituation optimal?“. „Was mache ich in der Kurve wenn ich zu schnell bin?“).
- Die Teilnehmer sollten häufiger die Möglichkeit erhalten, eigene Lösungsstrategien für definierte Fahrprobleme zu erproben.
    - Zum Beispiel: Erproben unterschiedlicher Lenk- und Blicktechniken.
- Es sollten mehr Aufträge zur Selbstbeobachtung bei der Durchführung eines Fahrmanövers gegeben werden („Beobachte Dich selbst. Was machst Du genau, wenn Du hart bremsen musst?“).

Erfahrungen mit Begutachtungen auf der Basis des DVR-Qualitätssiegels in den Qualitätsdimensionen Aus- und Fortbildungssystem für Trainer und Qualitätssicherung

Die Erfahrungen zu diesen Qualitätsdimensionen zeigen, dass es vor allem bei den großen deutschen Trainingsanbietern ausgereifte Aus- und Fortbildungssysteme gibt. Dort werden in der Regel hohe Punktwerte erzielt. Das gilt eingeschränkt auch für die Dimension Qualitätssicherung. Bezüglich der Qualitätskategorie „Wirkung / Nachhaltigkeit“ wird manchmal nicht ganz deutlich, inwiefern es eine „echte“ Nachbetreuung von Teilnehmern gibt, die über eine Kundenbindungsmaßnahme, im Sinne weiterer Trainingsteilnahmen, hinausgeht. Hiermit ist ein gezieltes Nachfragen zur Wirkungsnachhaltigkeit gemeint. Z. B.:

- Was haben Sie weitergegeben?
- An was denken Sie heute noch?
- Was haben Sie persönlich mitgenommen?
- Was wenden Sie heute noch an?
- Was hat Sie beeindruckt, überrascht?

Dieses „Feedback-System“ sollte dann genutzt werden, um das Training weiterzuentwickeln. Dazu müsste mit wissenschaftlich fundierten Methoden (z.B. schriftliche Befragung) Erhebungen durchgeführt werden, die in einem fest umrissenen Zeitrahmen (z. B. 1 Jahr) zu ausreichenden Datengrundlagen (mehr als N = 100 Rückmeldungen) führen sollten. Diese sollten dann analysiert und angemessen aufbereitet werden. Auch sollte darüber nachgedacht werden, das Motorradtraining einer umfassenden, wissenschaftlich fundierten Evaluation zu unterziehen.

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Long-term effects of a one-day advanced rider training

Langfristige Auswirkungen eines eintägigen Motorradsicherheitstrainings

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Abstract

There is an on-going search for safety measures to improve road safety for motorcyclists. One popular measure is motorcycle training. Although often considered an effective road safety measure, there are only few thorough studies on rider training and they seldom show a positive safety effect. This study aims to assess – in compliance with scientific standards - the safety effects of the advanced rider training 'Risk' by KNMV (Royal Dutch Motorcycle Association).

In 2012 the short term effects of this one-day training were evaluated (Boele & De Craen, submitted). Motorcyclists were randomly assigned to an experimental condition (n=137 followed the 'Risk' training) and control condition (n=85). In 2013 and 2014 the long term effects, 1 to 1,5 year after the 'Risk' training, were evaluated with an extra post-test of the experimental group (n=77) and the control group (n=34) . At pre- and both post-tests, participants completed a questionnaire and their traffic behaviour was assessed in an on-road ride. A selection of participants took a hazard perception test at the post-tests. Results of the short term evaluation showed that trained participants were rated higher on safe riding than the control group in the on-road riding assessment. This effect was still present in the long term post-test. Overall the trained riders performed better on the hazard perception test at the short term post-test, but this difference between control and experimental group was not significant at the long term post-test. At none of the test moments trained riders were more positive about their own riding skills than the control group.

This study is a step forward to demonstrate that motorcyclists' traffic behaviour can be positively influenced by the right training. Crucial for this training is that it did not lead to overconfidence, while it quantifiably improved traffic behaviour even for the long-term.

Long-term effects of a one-day advanced rider training

1 Introduction

Motorcyclists are vulnerable in traffic. In comparison with drivers of motorised four-wheeled vehicles, a motorcyclist has a high risk of death or serious injury as a result of a crash (SWOV, 2010). A popular measure to reduce crash risk is motorcycle training. As is the case with driver training it is commonly believed that motorcycle training improves riding skills, and it therefore improves traffic safety. However, there are only few thorough studies on rider training and they seldom show a positive safety effect (Elvik, Høye, Vaa & Sørensen, 2009).

Kardamanidis et al. (2010) aimed to quantify the effectiveness of motorcycle training, both pre- and post-licence (i.e. advanced training) and included a total of 23 studies in their review. More than half of the studies were conducted 20 years or more ago. Only three studies were from the present century. The authors were unable to draw any conclusions regarding the effectiveness of motorcycle training due to poor design, quality and reporting of the studies. The review of Daniello, Gabler & Mehta (2009) has a similar conclusion; many studies suffer from methodological weaknesses (e.g. lack of randomisation) which makes the outcomes of the studies doubtful.

When a study is carried out with high scientific standards, there are usually no effects of the advanced training found. The content of these trainings might be responsible for this lack of proven effect (Chesham, Rutter & Quine, 1993; Haworth, Smith & Kowadlo, 2000). As demonstrated by Daniello et al. (2009) and Kardamanidis et al. (2010) many studies give very limited information about the form of motorcycle training and the way it is carried out (Elvik et al., 2009). However, we do know from studies on advanced driver training that there is concern that it might lead to overconfidence and consequently to increased risk taking (Gregersen, 1996). In some cases advanced driver training even led to a higher crash risk (Glad, 1988; Jonah, 1986; Siegrist & Ramseier, 1992). Until 1990 advanced driver training was aimed at teaching complex skills, such as how to recover from skid or emergency braking. Around the nineties a new generation of advanced driver training was developed with the main aim to train higher order skills, focusing on anticipating and avoiding hazardous situations (Bartl, Baughan, Fougère & Gregersen, 2002). Unfortunately, this new generation of advanced driver training did not guarantee positive effects either. For example, Sanders and Keskinen (2004) evaluated advanced driver training for young novice drivers in six European countries. The results showed that this new generation advanced driver training can still lead to overestimation of skills. The results of a recent questionnaire survey (Mynttinen, Gatscha, Koivukoski, Hakuli & Keskinen, 2010) of the advanced driver training in Finland and Austria showed a negative effect on driver safety of young drivers. The risk awareness of the Finnish young drivers was even lower after taking the advanced driver training. The researchers stated that the content and the goals of the training did not match. It is possible that motorcycle training, just like driver training, encourages dangerous riding, due to overconfidence, without actually improving skills (Williams, Preusser & Ledingham, 2009).

Taking the results of previous studies into account the Royal Dutch Motorcyclist Association (KNMV) developed a new advanced rider training in the Netherlands. This advanced rider training 'Risk' is based on the underlying processes of hazard perception. More information about the training can be found on the KNMV website[1]. In 2012 the short term effects of the training were evaluated (Boele & De Craen, submitted). Results showed that trained participants were rated higher on safe riding than the control group and performed better on a hazard perception test. This paper reports the long term evaluation of the advanced rider training 'Risk' (i.e. effects 1 to 1.5 years after the training).

Ideally we would analyse the effect on crashes. However, because crashes are rare this was not possible within the scope of this study. Therefore we assessed the effects of training in terms of intermediate safety indicators. First, the actual on-road riding behaviour was observed. Second, we also monitored self-assessed riding behaviour. As discussed earlier, previous evaluations of advanced driver training show that training could lead to overestimation of skills. And, as a result, positive effects of the training may be compromised. Finally, as the 'Risk' training deals with risk anticipation, we also included a hazard perception test. This results in the following research questions:

1. What is the long term effect of training on observed riding behaviour?

2. What is the long term effect of training on self-assessed riding behaviour?

3. What is the long term effect of training on hazard perception?

2 Method

2.1 Design

This evaluation is a randomized controlled study with a pre-test and two post-tests. The complete study took place in the period February 2012 (recruitment of participants) until April 2014 (long term post-test); see Table 1. After completion of pre-test (questionnaire and on-road ride) participants were invited to draw an envelope which assigned them to either the experimental or the control condition. Participants in the experimental condition followed the 'Risk' training between pre- and post-test.

[1] KNMV (2014). Description of vro 'risk' training [in Dutch]. Accessed 10 July 2014 on http://www.knmv.nl/opleidingen/Cursusaanbod-KNMV/VRO-Risico/.

Table 1. Timeline of long-term evaluation

	2012			2013	2014
	March – April	May – July	Sept. – Oct.	Sept. – Oct.	Mar. – Apr.
	Pre-test	Training	Short term PT	Long term PT	
	Questionnaire On-road assess-ment		Questionnaire On-road assessment (Hazard perception)	Questionnaire On-road assessment (Hazard perception)	
Experimental condi-tion (training)	158	156	137 (65)	77 (42)	
Control condition (no training)	117		85 (33)	34 (27)	
Total	275	156	222 (98)	111 (69)	
The number of participants who completed the hazard perception test at either the short term post-test (Short term PT) or long term post-test (Long term PT) are displayed between brackets					

2.2 Participants

Participants in this study were recruited at the annual Dutch Motorcycle Fair in Utrecht in February 2012. Around 500 visitors were approached, 275 motorcyclists accepted our invitation to participate in our study (Response rate of 55%). Participants were randomly assigned to either the experimental or the control condition. Participants in the experimental group did not differ from participants in the control group with respect to age, years of motorcycle licence, cylinder capacity, motor use, gender, previous post licence courses, ABS, and use of safety equipment.

Table 1 shows that a number of participants dropped out in the course of the study. From pre- to short term post-test 43 participants (19 experimental, 24 control group) stopped due to time constraints or motorcycle problems. An additional eight participants in the control group followed an advanced training on their own expenses and two participants in the experimental group cancelled the appointment for the training. These 10 participants were excluded from the analyses[2]. For the long term post-test, originally only half of the participants were invited in September and October 2013. Because of the small number of available participants we decided to add another post-test in March and April 2014[3]. A total of 113 participants completed the long term post-test; 64 in the autumn of 2013 (1 year after training), 49 in the springtime of 2014 (1.5 year after training). Nineteen participants (15 from the experimental and 4 from the control group) took an advanced rider training focused on skills (i.e. riding curves, riding in the mountains, skid training etc.) between the short and the long term post-test. Two participants (1 from the experimental and 1 from the control group) who took the ‘Risk’ training at KNMV were excluded from the analyses[2].

[2] Repeating the analyses with inclusion of these participants did not change results.

[3] Because many motorcyclists in the Netherlands do not ride during winter time, we waited until spring for the additional post-test

The percentage of participants that dropped out in the course of the study was substantial (60%); this drop-out was larger in the control group (71%) than the experimental group (51%). However, Table 2 shows that this selective drop-out did not cause a difference between experimental and control group in the recorded variables.

Table 2. Differences between experimental group (with 'Risk' training) and control group (without 'Risk' training) at the long term post-test

Characteristic	Experimental group (with 'Risk' training; n=77)		Control group (no training; n=34)		Significance
	Mean	SD	Mean	SD	
Age	44.3	14.21	48.2	13.85	n.s.
Number of years motorcycle licence	15.5	14.98	17.1	13.33	n.s.
CC motor	859.86	305.42	907.8	317.47	n.s.
Use of motorcycle in days per week…					
During motor season	4.6	1.80	4.3	1.84	n.s.
Outside motor season	2.9	1.97	2.9	2.12	n.s.
	Experimental group (with 'Risk' training; n=77)		Control group (no training; n=34)		Significance
	Number (n=77)	Share (%)	Number (n=34)	Share (%)	
Gender					
Male	66	86%	31	91%	No test possible
Female	11	14%	3	9%	
Followed previous advanced training focussing on:					
Insight	7	9%	4	12%	No test possible
Skills	33	43%	12	35%	n.s.
Motor with ABS?	30	40%	15	44%	n.s.
Use of motorcycle…					
Commuting	9	12%	2	6%	n.s.
Other / recreational	41	56%	21	62%	
Both	23	32%	11	32%	
Use of measures to improve visibility?					
Daytime running lights	74	96%	34	100%	No test possible
Reflective clothing	52	68%	16	47%	n.s.
Yellow (fluorescent) vest	16	22%	7	23%	n.s.
Use of safety equipment?					
Jacket	77	100%	34	100%	n.s.
Trousers	76	99%	31	91%	n.s.
Back protector	34	45%	16	47%	n.s.
Gloves	76	99%	33	97%	n.s.
Safety shoes	75	97%	32	94%	No test possible
NB: for some variables Chi-square test was not possible due to low numbers in some categories					

2.3 Procedure

Participants were invited to come to one of four test locations, located in different parts of the Netherlands for the pre-test and both post-tests. After a short introduction participants signed an informed consent form and were instructed about the procedure of testing. They completed a questionnaire and their traffic behaviour was assessed in a 20 minute ride on public roads by KNMV instructors. Each ride in traffic was recorded on film. At the short term post-tests a random selection of the participants took a hazard perception test. Due to high testing costs it was not possible to test all participants. At the long term post-test all participants who had not taken the test previously took the hazard perception test.

2.4 Training

The ‘Risk’ training is a one day training with a theoretical and a practical part and focuses on timely perception and recognition of traffic hazards. As opposed to many other training programmes, this training does not focus on acquiring (vehicle control) skills. The motorcyclist is taught that it is better to prevent hazardous situations, rather than how to act in these situations once they have occurred. The training is based on the underlying processes of hazard perception and goes through five steps with the following objectives: 1) insight in one’s own limitations, 2) perceiving possible hazards, 3) judging whether riding behaviour should be adapted, 4) choosing riding behaviour, and 5) performing riding behaviour. To provide insight in possible (unnoticed) traffic hazards and to be able to discuss and learn, the on-the-road rides are recorded. Groups are small with a maximum of nine participants, guided by three KNMV certified ‘Risk’ instructors. In the morning steps 1 to 3 are dealt with, followed by a ride on the public road. Participants are asked to carry out their usual riding behaviour. During this ride risk awareness is central. In the afternoon steps 4 and 5 are discussed. After this part a second ride on the public roads follows. During this ride the execution of riding behaviour is central.

2.5 Instruments

2.5.1 Checklist instructors

After each ride in traffic, the instructors completed a checklist to rate traffic behaviour of the participants. The instructors graded the participants on a scale from 0 to 10 on Fluent, Skilful and Safe riding. They also assessed speed choice and position on the road with regard to 1) creating extra space ahead for a timely reaction, 2) ensuring that other road users see the motorcyclist (conspicuity), and 3) enabling a constructive reaction to potential hazard.

2.5.2 Validity and reliability of the instructors' assessment

As the KNMV instructors were both trainer of the 'Risk' training and assessor of the on-road ride we made some precautions:

- The instructors who assessed the on-road ride were kept "blind" with respect to whether the participant was assigned to the experimental or the control group. In other words they did not know whether the participant was trained or not;
- Participants who followed the training were never assigned to an instructor who was present at his or her training;
- Both participants and instructors were asked not to discuss any driving experience or training results before the post-tests.

To be able to check for the reliability of the instructors' assessment, part of the participants were assessed by two instructors. Table 3 shows that there is a moderate to high degree of inter-rater reliability between the instructors. We therefore conclude that the instructor's assessment was reliable.

Table 3. Pearson correlation scores for inter-rater accordance of two instructors for the same assessments in pre- and both post-tests

	Pre-test (n=43)	Short term Post-test (n=49)	Long term Post-test (n=36)
Fluent riding	.679 **	.427 **	.530 **
Skilful riding	.537 **	.612 **	.707 **
Safe riding	.465 **	.656 **	.698 **
** p<.01: two sided test			

2.5.3 Questionnaire participants

The participant questionnaires at pre- and post-tests were similar, except for questions regarding training and riding experience during the motorcycle season that were only included in the post-tests. Participants assessed (on a scale from 0 to 10) their own riding skills by grading their ability on Fluent, Skilful and Safe riding.

2.5.4 Hazard perception test

The hazard perception test in this study was based on a hazard perception test for car drivers (Vlakveld, 2011). This test was altered (car dashboard replaced by motorcycle steer) and motorcycle specific hazards were identified. The final test comprises of 10 animated films of approximately 40 seconds 'taken' from the motorcyclist's perspective. On the bottom of the computer screen the motorcycle steer is visible. Films consist of both covert (7) and overt (6) latent hazards. Covert latent hazards are possible other road users who are hidden from the view, but may suddenly appear. Overt latent hazards are visible other road users who in the given circumstances may start to act dangerously. The animated films were shown on a 19”screen (1280x1024) in a fixed order. Before the test started participants listened to a 5 minute verbal instruction on headphones. The text of the instruction was also presented on the screen. After instruction they practiced with one film. Participants were told to imagine riding the motorcycle in the film and instructed to watch for situations that could develop into a hazardous situation in which a crash is likely to occur. Directly after each film (and the screen had turned black) the interviewer posed the following questions:

- What drew your attention in the film?
- Were there moments that you thought: “Whew, I hope that this will not happen”? If so, what was it that you were worried about?
- Were there moments that the developing situation could have ended in a crash? If so, describe this development?

Participants could talk aloud about things that drew their attention while watching the films. What participants said during the presentation of the video films as well as the verbal responses to the questions were recorded. In total 13 points could be scored, one for each correctly mentioned overt or covert latent hazard (NB: three films contained two hazards for which a point could be scored).

2.5.5 Validity and reliability of the hazard perception test

The hazard perception test was executed by one of four interviewers during the short term post-test; and by one of two interviewers during the long term post-test. Like the instructors, the interviewers were kept ‘blind’ with respect to the participant’s condition, and were instructed not to discuss previous riding and training experience.

To be able to test for reliability we checked the inter-rater reliability (Cohen’s Kappa) per film. The responses of 50 participants (short term post-test) and 40 participants (long term post-test) were played back and scored again by a second interviewer. For the long term post-test the two original interviewers (from the short term post-test) re-scored the responses.

Table 4 shows that the inter-reliability Cohen’s Kappa scores per film, for the short term post-test and long term post-test, range from average to excellent.

Table 4. Inter-rater reliability per film in Cohen's Kappa at short term post-test and long term post-test

	Film												
	1-1	1-2	2	3	4	5	6-1	6-2	7	8	9	10-1	10-2
Short term post-test	.72	.77	.69	.88	.81	.73	.75	.96	.92	.96	.92	1.00	.94
Long term post-test	.88	.85	.90	.94	.90	.70	.84	.80	.56	.90	.84	.85	1.00

During re-scoring of the long term post-test the interviewers noticed a considerable difference in interview style. One interviewer asked more questions about each film than was regulated by the protocol. All these audio records were rescored; whenever too much questions were asked, the audio record was stopped and possible correct answers were not recorded anymore. The analyses were based on these re-scored responses to the hazard perception test[4].

2.5.6 Data analysis

Preliminary analysis revealed that the instructor's grades for Fluent and Skilful riding were highly correlated at pre-test ($r(220) = .726$, p = .000), short term post-test ($r(220) = .801$), p = .000) and long term post-test ($r(111) = .807$; p = .000). Therefore, these grades were combined and the mean of both grades was analysed further. To investigate if training had an effect on the instructor's and self-assessed grades a repeated measures analysis of variance was carried out with Grade and Time (pre-test / ST post-test / LT post-test) as within-subject variables and Group (experimental / control) as between-subject factor (α=.05). Between group ANOVA was used to investigate if training had an effect on the hazard perception test (α=.05). Besides significance of the results, the effect size (Partial èta squared, η_p^2) is also considered with $\eta_p^2 = .01$ as small, $\eta_p^2 = .06$ as medium, and $\eta_p^2 = .14$ as a large effect size (Cohen, 1988). Chi square analysis was used to investigate the differences in the observed speed choice and position on the road at post-test (α = .05), with Cramer's V to assess effect size. To calculate correlation coefficients, Spearman's Rho (r_s) was used for ordinal data and Pearson for interval data (α = .05). Finally, Cohen's Kappa was calculated to assess inter-rater reliability of the hazard perception test.

3 Results

3.1 Effect of training on observed riding behaviour

Repeated measures analysis of variance of the grade on Safe riding shows a significant main effect of Time ($F(1,109) = 15.83$, p = .000, $\eta_p^2 = .13$) and a small, but significant, interaction effect of training

[4] An analysis of the original response to the hazard perception test did not change the results of the test.

(F(1,109) = 3.43, p = .034, η_p^2 = .03), indicating that the training had an effect on the instructor's grade on Safe riding. Contrast analysis shows a significant interaction of training from pre-test to short term post-test (F(1,109)= 4,83, *r*=0,21), and from pre-test to long term post-test (F(1,109)=4,17, *r*=0,19). Instructors scored trained riders at long term post-test significantly higher (*M*=6.87, *SE*=.12), than the control group (*M*=6.10, *SE*=.18; Figure 1).

The analysis of variance of the grade on Fluent/Skilful riding showed a significant main effect of Time (F(1,109) = 16.54, p = .000, η_p^2 = .132). This combined grade improved for all participants at (long term) post-test. There is no interaction effect of training for this grade, indicating that the training did not have an effect on Fluent and Skilful riding.

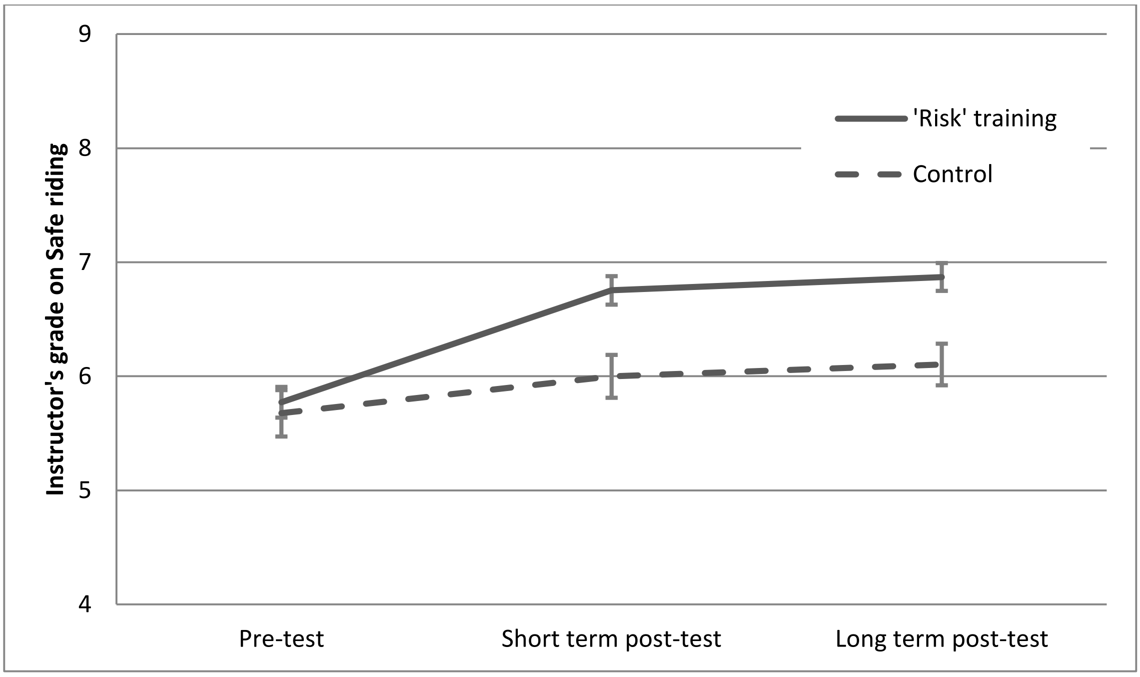

Figure 1. Means and 95%-confidence intervals of instructor's grade on Safe riding

Table 5 shows that during the long term post-test, according to the instructors, trained riders adapt their position on the road more often than the control group in order to react in time (preventive), to ensure to be seen by others (conspicuity) and as a constructive reaction to potential hazard. In addition they reduce speed more often in reaction to potential hazard than the control group. These results are similar to the results at the short term post-test. An exception was the reduction of speed to ensure to be seen by others; trained riders did this more often in the short term post-test than the control group. In the long term post-test the difference had disappeared.

Table 5. Assessment of motorcyclists' speed choice, distance and position on the road in order to 1) react in time (preventive), 2) to ensure to be seen by others (conspicuity) and 3) as a constructive reaction to potential hazard during the long term post-test

		'Risk' training		Control group		Total	Significance
		n	%	n	%	n	
… in order to react in time (preventive)							
Speed	Much too low + low	6	8%	4	12%	10	No test possible
	Correct	64	83%	23	68%	87	
	High + much too high	7	9%	7	21%	14	
Distance keep-ing	Correct	34	44%	13	38%	47	n.s.
	Too little + much too little	43	56%	21	62%	64	
	Correct	26	34%	3	9%	29	
Adapt position on the road	Too few	42	55%	23	68%	65	χ^2(2,111)=8.47,*p*=.015, Cramer's *V*=.276
	Much too few	9	12%	8	24%	17	
	Much too low + low	6	8%	4	12%	10	
… ensure to be seen by others (conspicuity)							
Increase speed	Never	31	40%	15	44%	46	n.s.
	Sometimes	34	44%	13	38%	47	
	Often + Always	12	16%	6	18%	18	
Reduce speed	Never	4	5%	5	15%	9	n.s. (was significant at short term post-test)
	Sometimes	31	41%	18	53%	49	
	Often + Always	41	54%	11	32%	52	
Adapt position on the road	Never	13	17%	7	21%	20	χ^2(2,111)=9.36, *p*=.009; Cramer's *V*=.290
	Sometimes	25	33%	20	59%	45	
	Often + Always	39	51%	7	21%	46	
As constructive reaction to potential hazard…							
Increase speed	Never	30	39%	13	38%	43	n.s.
	Sometimes	31	40%	16	47%	47	
	Often + Always	16	21%	5	15%	21	
Reduce speed	Never	4	5%	6	18%	10	χ^2(2,111)=10.28,*p*=.006; Cramer's *V*=.304
	Sometimes	32	42%	20	59%	52	
	Often + Always	41	53%	8	24%	49	
Adapt position on the road	Never	12	16%	11	32%	23	χ^2(2,110)=7.08,*p*=.029; Cramer's *V*=.254
	Sometimes	30	40%	16	47%	46	
	Often + Always	34	45%	7	21%	41	

3.2 Effect of training on self-assessed riding behaviour

To study if the training led to overconfidence, the participants graded themselves on a scale from 0 to 10 on Fluent, Skilful and Safe riding. Figure 2 shows that overall participants rated themselves somewhat lower on Skilful riding than on Fluent and Safe riding. There was a significant main effect of time on Fluent riding ($F(1,107) = 6.01$, $p = .003$, $\eta_p^2 = .053$) and Skilful riding ($F(1,51) = 10.48$, p = .0030, η_p^2 = .089). Both trained riders and the control group graded themselves slightly, but significantly, higher at post-tests compared to the pre-test for fluent and skilful riding. There was no significant main effect of time on safe riding. Also, there was no significant difference between the trained riders and the control group, at pre- and post-tests, indicating that the training did not have an effect on self-assessed riding behaviour.

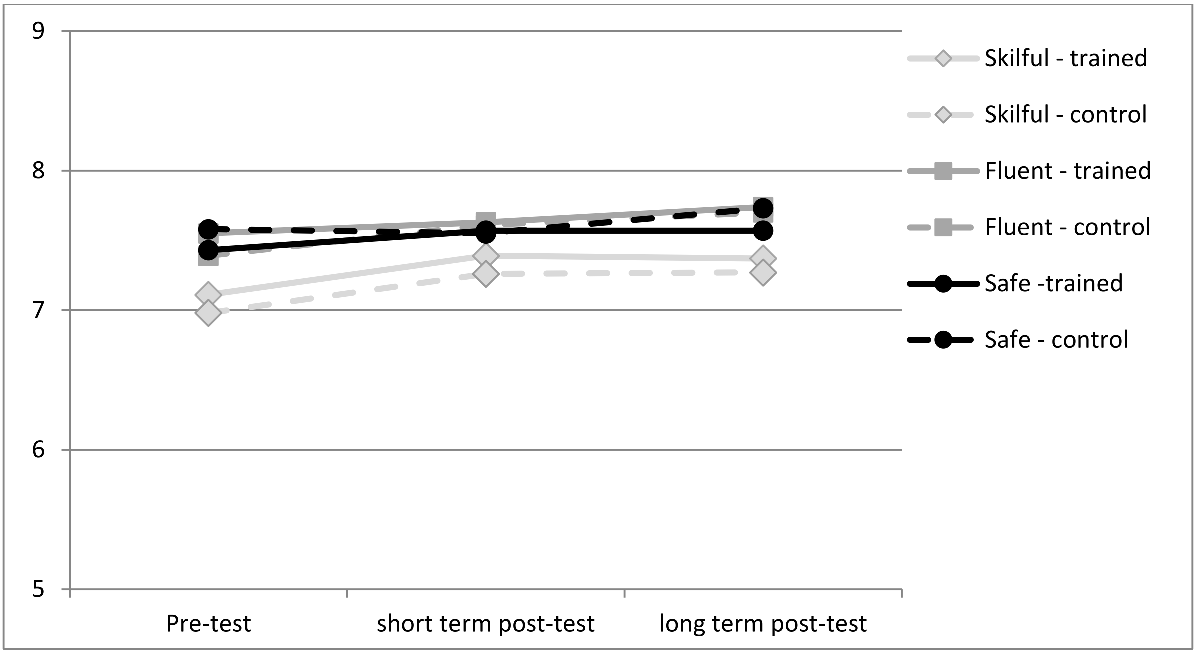

Figure 2. Riders self-assessment of Skilful, Fluent and Safe riding at pre-test, short term post-test and long term post-test

3.3 Effect of training on hazard perception

Figure 3 shows that at both post-tests trained riders performed better on the hazard perception test than riders from the control group. During short term post-test, this difference was significant ($F(1,96)=8.98$, $p=.003$, $\eta_p^2=.09$); trained riders had a significant higher score ($M=7.3$; $SD=1.94$) than the control group ($M=6.1$; $SD=1.95$). During long term post-test this difference between trained riders ($M=6.9$; $SD=2.69$) and control group ($M=5.9$; $SD=2.83$) was not significant.

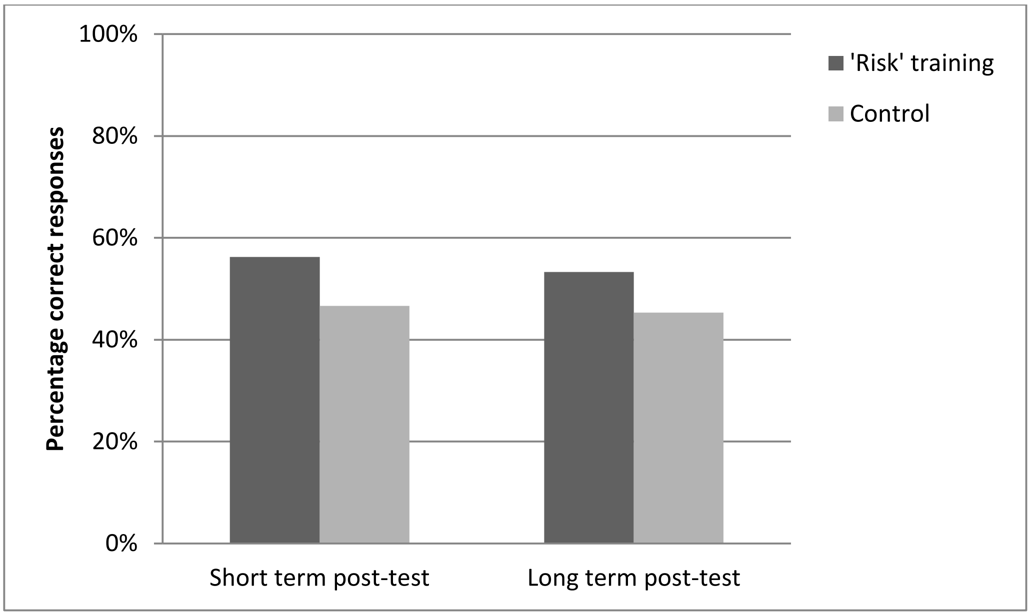

Figure 3. Percentages of correct responses in the hazard perception test at short term and long term post-test

4 Discussion

This paper reports the long term evaluation of the advanced rider training 'Risk' (i.e. effects 1 to 1.5 years after the training); the short term effects were reported by Boele and De Craen (submitted). The study used random assignment of participants into the experimental and control group. The experimental group followed the 'Risk' training. Three research questions were formulated in this study:

1. What is the long term effect of training on observed riding behaviour?
2. What is the long term effect of training on self-assessed riding behaviour?
3. What is the long term effect of training on hazard perception?

With respect to the first question, results show that the 'Risk' training has a positive effect on safe riding, both on the short term (3-5 months after training) and on the long term (1 to 1.5 years after the training). Trained riders received a higher grade for Safe riding than riders from the control group. Furthermore, the training has a positive, short and long term, effect on speed choice and position on the road. After 1.5 years the trained riders still show an improved position on the road in order to react in time (preventive), to ensure to be seen by others (conspicuity) and as a constructive reaction to potential hazard. In addition the training causes riders to reduce speed more often in reaction to potential hazard. The training did not affect fluent and skilful riding; not in the short term nor in the long term.

The second research question concerns the effect of training on self-assessed riding behaviour. There is no indication that that the ‘Risk’ training influences self-assessed riding behaviour. This averts the risk of overconfidence of trained motorcyclists.

With respect to the third research question, the hazard perception test did not show a significant long-term improvement of hazard perception skills. Although the trained riders scored better on the hazard perception test on both short term and long term post-test, this difference was only significant at short term post-test. At long term post-test trained riders scored, on average, 1 point (out of 13) higher than the control group. But this difference was not consistent, as indicated by the large standard deviation ($SD \approx 3$), and can therefore not be attributed as an effect of the training.

As discussed in the introduction there are only few thorough and recent studies that show a positive effect of an advanced rider training (Daniello et al., 2009; Kardamanidis et al., 2010). In the present study the utmost was done to carry out the evaluation according to scientific standards. An important plus in this study is that participants were randomly assigned to the experimental and control condition and consequently did not differ beforehand on relevant aspects (i.e. age, years of motorcycle licence, cylinder capacity, motor use, gender, previous post licence courses, ABS, and use of safety equipment). In many evaluation studies effects of the training are measured with participants who voluntarily participate in the training. This could easily lead to a self-selection bias, since it cannot be excluded that motorcyclists who choose to participate in a safety training are more concerned with safety and ride more safely than those who do not. This self-selectivity creates a problem in determining the effectiveness of the training. In the present study, this kind of alternative explanations were excluded due to random assignment. It is also an advantage that, as opposed to many other studies, the effects of the training was measured with multiple instruments. In addition to the self-assessed riding behaviour – which is not always a reliable predictor of actual behaviour (De Craen, Twisk, Hagenzieker, Elffers & Brookhuis, 2008) – the actual riding behaviour of the participants was assessed during the on-the-road rides. Furthermore, the effects of the training were measured with a hazard perception test.

Unfortunately we do not know if the training actually reduces crash risk. Previous research (Senserrick & Haworth, 2005) questioned the relationship between passing a driving test and crash risk. Likewise, young male drivers - despite passing the driving test more easily than young females - have a higher crash risk in most countries (Crinson & Grayson, 2005; Maycock, 2002). In other words, driving or riding safely in a practical driving/riding test, does not automatically imply lower crash risk. In addition, the results of this study may be biased towards the (KNMV) instructor’s viewpoint on safe riding. A participant can be rated as a safe rider, while this actually means that he or she is a safe rider according to instructors (KNMV) standards. There is no objective information indicating that riding according the KNMV standards is associated with a lower risk of being involved in a crash. Because of practical limitations (i.e. costs) it was not possible to invite as much participants, and randomly assign them to the training and control condition, that is needed to make reliable statements about the effects on crash risk.

Despite this limitation, the results of the hazard perception test show that trained riders, at least in short-term, benefited from the ‘Risk’ training and performed better on the hazard perception test. This is important, because this result indicates a transfer of training. The knowledge acquired at the ‘Risk’ training has an effect on the performance on the (non-trained task of the) hazard perception test. The design of this test did not have any similarities with the assessment of the instructors (and their view-point on safe riding) as it was developed outside the scope of this study. Moreover, hazard perception has previously been described as the only higher order skill that can predict crash liability. There are strong indications that test performance on the hazard perception test correlates with crash involvement (e.g. Horswill & McKenna, 2004; Vlakveld, 2011). Unfortunately, this transfer of training to the objective hazard perception test did not sustain 1 to 1.5 years after the training.

Based on previous studies on advanced driver or rider training, we have some ideas why this training contrary to many others, does show an effect on observed riding skills. As discussed in the introduction concern has been expressed about the possible counterproductive effects of overconfidence following an advanced rider training (Williams et al., 2009). Results indicate that this training does not lead to overconfidence, while it quantifiably improves traffic behaviour (i.e. safer riding sustaining 1 to 1.5 years after training and better hazard perception). An important training objective is that motorcyclists get a more realistic idea of their own capacities and vulnerability. This is accomplished by watching the video recordings of their own on-the-road ride which may make them realise which risks they have been exposed to. A study of McKenna & Crick (1997) showed similar results. The participants in their study watched videos from the driver’s perspective together with a driving instructor. The instructor stopped the video at the moment that hazards started to develop. The participant was asked to make predictions about the development of the possible hazards. Participants of this training had significantly shorter reaction times than untrained drivers. Another explanation might be that riders learn more from their own mistakes than from other people’s mistakes. This effect has also been demonstrated by Ivancic & Hesketh (2000). They exposed drivers in a simulator drive to situations that elicited errors. Drivers who crashed or nearly crashed drove slower and had significantly fewer crashes in similar situations in consecutives simulator drives than drivers who did not crash.

The practical part of the ‘Risk’ training takes place on public roads, and not on a closed off circuit. Training on public roads confronts the motorcyclists with the risks involved in ordinary traffic situations. Moreover, it reduces the illusion of safety (Horswill, Waylen & Tofield, 2004) and closed off circuits training can still be perceived as a skills training (e.g. skid training; De Craen, Vissers, Houtenbos & Twisk, 2005) although it is not the aim of the training.

4.1 Final conclusion

Motorcyclists are, compared to for example car drivers, vulnerable in traffic. The short-term evaluation the 'Risk' training (Boele & De Craen, submitted) shows a positive effect on riding behaviour and hazard perception 3-5 months after the training. The improvement in riding behaviour is still present 1 to 1.5 years after training, whereas the improvement in hazard perceptions skills had disappeared. Essential for this advanced rider training, no indications were found that the training influenced the motorcyclists' assessment of their own riding skills (with the risk of creating overconfidence). These findings are important as there are only few thorough studies that show a positive, let alone long term, effect of advanced driver and rider training.

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Conceptual Architecture of Motorcycle Simulators for the Training of Novice Riders

Konzeptionelle Architektur von Motorrad-Simulatoren für die Ausbildung von Anfängern

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Abstract

Brazilian traffic presents alarming rates of accidents and deaths. There are over 42,000 deaths per year in a country with 202 million inhabitants. These indexes have been growing in recent years, particularly among motorcyclists, and studies show that most of these accidents are determined by human error. Thus, a better traffic education constitutes a social need for security and public health in Brazil. In this context, training in vehicular simulators emerged as an alternative for improving the traffic quality. This article's main objective is to present the study conducted by the authors on motorcycle simulators for training of novice drivers. It also aims to evaluate three models of motorcycle simulators: a commercial one, the "Honda Riding Trainer", a modified version of this and a prototype developed for the study. The study is based on a literature review of motorcycle simulator solutions all around the world. This review was followed by observations of the use of the 3 models, involving 60 students of a Driving School from a Brazilian suburb. As a result, the paper gives a revision of requirements of motorcycle simulators and an optimized architecture proposal of these systems to the Brazilian context, in order to provide better driving training for safer traffic.

Keywords: Motorcycle Simulators; Training for Motorcyclists; Traffic Safety.

Conceptual Architecture of Motorcycle Simulators for the Training of Novice Riders

1 Introduction

In face of the very high accident rates and a total death rate of 6 motorcyclists per 100,000 inhabitants in Brazil per year, there is a great beneficial potential for a widespread technology, such as a motorcycle simulator, to help training the young and inexperienced drivers which constitute a large number of the population. The established solutions of simulators for aircraft and space training, as well as truck and car show an important alternative to the training of motorcycle riders.

The research's central issue reported in this paper is to establish requirements for suitable motorcycle simulators to the Brazilian reality. This research has a primary goal to present a proposal in motorcycle simulators for coherent traffic education according to the social and economic diversity conditions in Brazil. Still listed as secondary objectives: to correlate vehicular simulators and education for traffic safety; and present the results of usability testing with 60 users conducted in 3 different configurations of simulators.

The present work aims to evaluate the use of simulators as a means of promoting improvements in drivers' education process, which has emergency social implications, given the alarming accident rates on Brazilian roads.

The survey based on usability testing reported in this paper is delimited as a small-scale experimental study.

It does not presume to dictate definitive quality standards throughout Brazil, but to establish reference marks of a simulator with efficient educational performance as well as to serve as a basis for future studies on a larger scale conducted in different regions of Brazil.

2 Development

2.1 Motorcyclists and Safety in Brazilian Traffic

Brazil has 42,000 traffic deaths per year, with a population just over 202 million people, and such indexes have shown an increasing trend of 3.7% per year [1]. While in some developed countries such as Canada, Japan and Sweden, the traffic accident rates are decreasing [2], these rates are increasing in underdeveloped countries, where 90% of traffic fatalities [3] occur. In this context the Brazilian traffic, in terms of deaths per 100,000 population, ranked 57th in a list of 192 countries [4]. Surveys point to several causes such as: roads' infrastructure problems, lack of public transportation options, etc. But the Brazilian driver behavior emerges as the determinant factor in these numbers, marked by recklessness and carelessness [5].

The problem is aggravated by motorcycle drivers. Studies show an alarming increase of 932.1% in the deaths of motorcyclists from 1996 to 2011, which already represent 33% of total traffic deaths in Brazil [1]. In part this increase is explained by the boom of motorcycles in Brazil, i.e., an increase of 4,000,000 to 18,400,000 motorcycles in circulation between 2000 and 2011. According to the "*Mapa da Violência*" (2013), this increase in the percentage of motorcycles in the vehicle fleet in Brazil was followed by changes in the motorcyclists' profile. It's now of a younger person who does not want to rely on public transport because of the disabilities of this service and still spend less time in traffic when using a two-wheels vehicle that is faster and less vulnerable to traffic jams. In other words, the new Brazilian motorcyclist, besides being inexperienced, is more likely to have a dangerous conduct in traffic, ignoring risks.

The Brazilian government initiatives to solve this problem have been, historically, awareness campaigns spread through communications media, as well as the formulation of more stringent laws to regulate the traffic, and the New Traffic Code from 1997. However the motorcyclists preparation conducted at Drivers' Education Centers, small private driving schools named in Portuguese "Centros de Formação de Condutores" **CFC's**. With limited resources this Centers have a need of investment and evolution. Currently, the process involves 45 hours of theoretical classes and 20 hours of practical classes. There are no practical lessons on the streets during the training and the drivers perform an evaluation exam in a closed runway [6]. Unlike many countries, there are no different qualification categories according to the size/power of the bike.

In 2009, the Brazilian National Department of Transit (DENATRAN), along with the National Traffic Council (CONTRAN), commissioned a study to UFSC on the feasibility of car simulators in order to get technical requirements for a device better suited to the Brazilian reality in terms of costs and benefits [7]. This study substantiated the federal ordinance 808-2011 [8] which regulates the use of car simulators as a teaching tool in CFCs, specifying a minimum acceptable configuration.

After facing the CFCs' strong resistance in adopting simulators in compulsory scheme, in July 2014 CONTRAN made this equipment optional with the possibility of replacing up to 30% of the practical classes hourly load, currently 25 hours to qualify small-car drivers. Such resistance can be explained by the following factors:

a) Resistance to its use due to the lack of human resources for proper operation of the equipment;

b) With the prospect of compulsory regulation, the prices of the driver's training course raised disproportionately at the start of the program;

c) Additional costs and lack of space for installation of equipment, mainly in CFCs located in urban centers.

d) Existence of few certification agencies and a long approval process, resulting in few models available in time (1 year) to supply the market;

e) Basic infrastructure problems in some Brazilian states (eg, internet), given the lack of homogeneity between regional conditions resulting in some technical impossibilities;

The current project is also commissioned by DENATRAN and can be seen as the continuation of the evaluation process of simulators as a training tool for new drivers, this time applied to motorcycles. Based on previous experience including the problems of large-scale implementation, the research aims to establish a foundation for future regulation of motorcycle simulators throughout the Brazilian territory.

2.2 Motorcycle Simulators

"Driving Simulator" means any device which performs the function of playing conditions of use of a vehicle in a virtual environment [9]. Considering this, a simulator is an artifact able to offer a virtual environment that keeps reliability when playing a real environment, to the point that learning obtained in simulations builds skills applicable in real situations.

A driving simulator must reproduce the reality of traffic in a variety of scenarios that enable performance gains while driving a vehicle in such environments. Every simulator objectifies the users' learning skills in a virtual environment, and such gains in learning are to be transferred, at another time, to real environments. Some simulators are developed in order to train users in basic vehicle controls, thereby emphasizing gain in driving skills. Other simulators emphasize gains in perception and risk control in traffic.

About a simulator focused on perception and risk management instead of a focused in fine driving control [10], says that the artifact *"improves the novice riders' ability of recognizing hazard situations and reacting in such a way as to avoid risks"*.

Specifically, about the two-wheeled vehicle simulators there is a greater range of technical challenges to ensure the realism and immersion in the virtual environment experience. These challenges are related to the difficulty of playing in a simulation artifact the kinesthetic sensations of driving a two-wheeler:

> *Driving simulators were used extensively in aeronautical and automotive fields. It remains a secure, low cost and ecological tool for training future drivers and developing new techno-*

logical features. This situation is much more complicated for two-wheeled vehicles, minimization of risk and the lack of visibility leads to fatal consequences, knowing that the power to mass ratio is higher than that in the case of automobile... [11].

Because of such technological restrictions or limitations for realistic simulation, despite studies indicating benefits and efficiency in teaching driving skills, simulators of two-wheeled vehicles sometimes have questionable or difficult to measure results. The use of simulators without kinesthetic feedback, however, may be a low-cost solution effective for risk perception development [12].

The challenge in designing simulations for two-wheelers lies in providing balance between ensuring an immersive and realistic experience and, on the other hand, developing an artifact affordable and technologically capable of reproducing the conditions of use of a vehicle. Because of the engineering and design challenges, motorcycle simulators are even less used than car simulators worldwide [11].

2.3 Bibliographical Review on Motorcycle Simulators

The early development of motorcycle simulators occurred in Japan, organized by Honda Motor Co., in the late '80s. The first prototype, developed in 1988 [13], was a model composed by a platform with 4 degrees of freedom and front projection system, large sized, and had the objective of studying the motorcycles response in maneuvers and assessing the equipment viability for safe driving training [40]. The second prototype (1991) was basically a compression compared to the first.

It had larger screens, motion platform with 2 degrees of freedom and steering with force feedback. The design of these models has been patented in Europe and the United States [30], [31]. After a continuous effort to reduce costs and develop technology, in 1996 the first model was launched on a commercial scale in the Japanese market. In the same year the use of simulators in motorcyclists training was set as a requirement for obtaining a driver’s license for large motorcycles in Japan (over 400 cc) [32]. The training sessions with simulators became mandatory training for motorcyclists of all categories in 1998 [23]. Since then, three hours in simulators are required for motorcycle license.

Although there aren't many studies available correlating simulators with a decrease in accidents in Western languages [23], accident statistics [33] show that comparing to the years before 1996, when accidents of motorcyclists were among the leading causes of deaths among young people, there was a significant reduction in the number of motorcycle accidents in the first 2 years after qualification. For the approval of simulators in Japan a set of requirements has to be fulfilled in hardware / software and content of the lessons that are designated by the Japanese National Police Agency [34] and measured by the Japan Traffic Management Technology Association [35].

From the 2000s there has been a greater emphasis on developing simulators motorcycle out of Japan in cooperation projects, particularly in Europe, whether in national initiatives. Among these we can cite the cases of European cooperation projects 2BESAFE [34] and SAFERIDER [35] as national programs as PREDIT/SIMACOM in France. These projects supported the development of some simulators for research, in particular: simulators from the University of Padova [19], [20], [21], [22], simulators developed at INRETS / Evry University [15] [16] [17] [18]. Initially the development of these simulators gave more attention to problems of the dynamics of many physical phenomena and complexity of mechatronics and computational part of the equipment to simulate them as well as their objective and subjective evaluation with experienced motorcyclists.

In parallel, Honda developed in 2005 [29] a low-cost version of a commercial simulator for greater international diffusion of technology in their training centers all around the world. This is the Honda Riding Trainer (HRT) or Smart Trainer (Safe Motorcyclist Awareness and Recognition Trainer) in some markets such as the USA. A feature of HRT compared to previous simulators developed by Honda is how simple the equipment is, composed by a transportable tubular chassis with static base and the ergonomics related to a typical Scooter and controls (handlebars, brakes and automatic or manual gear) connected via USB to a computer and a monitor. Its emphasis is on the software and training content for risk perception and prevention of accidents in situations of mixed traffic (bikes, cars, trucks, pedestrians, etc.). HRT has been developed considering Honda´s experience with simulators, including the analysis of 921 accidents for the generation of hazardous situations [28]. On version 4, HRT contains, as its whole, a package of 17 scenarios divided into 2 modules: Module for Beginners Training (2 classes) and Defensive Driving Module (15 lessons). The classes involve practical driving in city (11) and on the road (4). These scenarios can be configured in three modes: daily, nocturne and foggy. In total 82 different combinations of scenarios can be created.

To promote and evaluate the effectiveness of HRT, Honda sponsored exchange programs with universities such as Nihon University, Japan [29] and the Department of Psychology at the Padova University, Italy [26], where studies were carried out with target audience. These studies demonstrated its effectiveness as a pedagogical tool for novice drivers [10] [27].

A recent project with the purpose of developing cognitive skills in motorcyclists is the SIM2CO + (2011-2014), developed in France. The SIM2CO + has an emphasis on developing training modules on simulators to improve the perception of risk for novice motorcyclists and was developed by a consortium of research institutions and companies led by IFSSTAR Institute (ex-INRETS). This project involved a naturalistic study [24] [25] with 24 motorcyclists and subsequent data analysis for characterization of risk situations and development of simulation scenarios. About 20 typical accident scenarios were identified and software/content for 3 versions of simulators have been developed:

- An online multimedia tool (to be distributed via Website);
- A low-cost simulator based on the product ECA FAROS EF-Scooter;
- High-performance simulator with motion platform and higher cost.

However until now further details about the simulators and contents developed are yet to be published.

2.4 Diffusion of Motorcycle Simulators around the World

Regarding the spreading of technology in the international market the number of manufacturers and suppliers of motorcycle simulators for training is still small compared to the supply of car driving simulators for training. Due to its pioneering, the Japanese market is the one with greater variety of models, having these equipments use already been regulated. In the other countries the French company ECA-FAROS stands out with some models of equipment available for this purpose.

We classify the products into two classes: kinesthetic simulators that have some level of movement (expressed in "degree of freedom" or DoF) usually roll and pitch; and equipment with fixed base, static, with emphasis on the software/content. Table 1 shows motorcycle simulators of the first class.

Table 1. Commercial Simulators with kinesthetic (Motion Platform)

Manufacturer/Model	Features	Figure
ECA -FAROS Cruise Bike (France)	- 2 DoF + steering with force feedback; - 3 Screens 42", 120 degrees FOV; - Commands/Ergonomics/Body of Motorcycle; -Real Instrument Panel.	
Honda Riding Simulator (Japan)	- 2 DoF + steering with force feedback; 1 Screens 52" + 1 Instructor's Screen; -Commands/Ergonomics/Body of Motorcycle; -Flexible Seat configuration (Motorcycle/Scooter); -Real Instrument Panel.	

Manufacturer/Model	Features	Figure
Mitsubishi RS-6000 (Japan)	-1 DoF steering with force feedback;- Commands/Ergonomics/Body of Motorcycle; - Flexible Seat configuration(Motorcycle / Scooter); - Real Instrument Panel; -1 Screen 50" + 1 Instructor's Screen; - Real Panel.	

A few examples of the second class of simulator are presented in Table 2:

Table 2. Commercial Simulators (Fixed Base)

Manufacturer/Model	Features	Figure
Honda Rider Training/ HRT/Smart Trainer (Japan)	-1 monitor 19"; -Tubular Chassis; -PC + USB Handlebar ; - Software.	
ECA Faros EF-SCOOT (France)	-Portable Chassis (2 Pieces;) – USB Steering Handlebar steering with force feedback); - Software; -Not supplied with PC/ Display.	
Mitsubishi DS-30 (Japan)	-Seat and Base Table; -USB Handlebar; - Software.	
Shangai Infrared (China)	- Chassi/Seat(Scooter type); - Instrument Panel. - Monitor 22"; - Software.	

Manufacturer/Model	Features	Figure
Simulcar SIMUSCOOTER II (France)	- Chassi/Seat(Scooter type) Notebook base; -USB Handlebar; - Software (ROAD STAR) Optional: 3 screens.	

Although some providers didn't inform the costs when consulted, usually kinesthetic simulators could cost more 10x than static base simulators, which is certainly a restriction on their distribution in major scales despite possible pedagogical benefits. The Honda Riding Simulator model, according to Honda's website, is sold in Japan for ¥ 6.09 million (approximately US$ 60,000.00) with maintenance fee of ¥ 210,000 (US$ 2,000.00)/year. Such values are not feasible for the reality of the Driving Schools in emerging countries like Brazil.

2.5 Research Questions

Analyzing the development of simulators in Japan and Europe, it was found that there was a simplification in the devices architecture with less emphasis on obtaining fidelity in movements and reproduction of existing physical phenomena while driving a motorcycle for more simplified versions for training focused on cognitive development for risk perception. Thus, much of the efforts to implement motorcycle simulators migrated from hardware to software and audiovisual content.

This effort consists in collecting existing dangerous situations in the motorcyclists' everyday life, analyzing existing statistics or naturalistic studies, and implementing them as scenarios in content to run while training.

Unfortunately in Brazil there are no statistical records with sufficient quality to allow the generation of located content or naturalistic studies of this order in progress, therefore the use of content script applied internationally such as in HRT can't be discarded at first, although it is necessary to adapt it to the traffic rules in use in the country. However studies for better understanding the specificities of the accident situations in Brazil are necessary in the future to improve the solution.

Despite the substantial costs involved in developing software and content, on a large-scale implementation that effort is diluted cost wise by the number of units produced. In Brazil the market would demand tens of thousands of units. Alternative business models can be used in dissemination to make it more accessible (such as rent or even government subsidy) enabling its diffusion.

The hardware complexity level implies directly on the equipment cost per unit even more because unlike the software, hardware importation is taxed in Brazil and many imported components are needed. Therefore any effort for the wide mass diffusion of simulation technology aims to make the hardware costs affordable.

Table 3 summarizes the relationship between the simulator features and their implications for the equipment cost.

Table 3. Sensitivity to a simulator's resources cost

Feature	Result in the Simulation	Sensitivity to Cost	Notes/Comments
Image Generation System (resolution, distance and angle of horizontal and vertical field of view).	Direct effects on the peripheral vision development.	Medium	The projectors and large TV costs decrease every year VR glasses may prove to be the future solution?
Motion Platform with degrees of freedom (DOF).	Plays movements and increases the immersion	High	Are there alternative non motorized solutions?
Commands' Ergonomics	Direct effects on the transfer to the real vehicle	Low	Maximun use of motorcycles components made in Brazil
Computational System	Direct effects on the simulation execution	Low	Prices constantly declining relative to performance increasingly offered
Software/Content	Sets the training quality	High	Scale Factor Need of content updating/adapting

As most widespread and tested product in the international market, HRT could be nominated as a candidate to be the reference basis to an initial specification. However, apart the fixed base, some restrictions may be enumerated on the equipment even compared to the Japanese regulation:

- The image generation system provided (17" monitor) presents a narrow vision field (FOV FOV 21.7° 27.2° H x V). The vision field isn't compatible even with the Japanese minimum legal requirements that are 58.° H x 35.° V. Studies as Wade Allen et al[38] in driving simulators show that the narrowing of the vision field can affect the efficiency of training in driving simulators. To this is added the panel that is projected on the screen, while the Japanese regulation requires the panel to be placed in the actual position.
- Ergonomics are similar to scooter model than to a traditional motorcycle model where the motorcyclist sits mounted to drive. In Brazil, Scooters have a very small representation in the market.
- The quality of the controls could be improved, including the handlebar position and ergonomics aren't as realistic as desired.

- Sound system has low quality, with built-in speakers in the computer, without sufficient volume mainly for low frequencies and poor spatial disposition.

Due to these factors, the following questions have been formulated, to be answered by this study:

3 Research Procedures

This research is based on test use of simulators. As such, it consists of a qualitative research based on observations of the users' behavior under controlled use conditions, but it also involves measurements and statistical treatments of these behaviors.

The experiments were performed in two units of a CFC in the suburbs from Florianopolis, SC. All the volunteers were drivers in training for motorcycle driver's license qualification and signed a Consent Form Document, and therefore were instructed about the exploratory aspect of the study. They were also aware that this study wasn't valid to replace any lesson in the driving training, theoretical or practical, and many other items in order to ensure the ethics in this research.

The sample standard is very similar to the Brazilian population profile in terms of schooling, gender, age, etc. The group consisted of 29 men and 30 women, with the average age of 25 (4.5 standard deviation). From these, 39 were residents of neighboring districts to the CFCs. In terms of education, 26 testers didn't complete high school, 29 did and 4 were attending higher education. From the 59 testers, 32 declared already having some experience in driving motorcycles. Additional 10 testers didn't conclude the program and are not considered in the study.

3 simulators with different features were used in the research. The Simulator 1 (SIM1) is the original version of the HRT provided for testing by ABRACICLO (Brazilian Association of Manufacturers of Motorcycles). Simulator 2 (SIM2) is a version of HRT with improved display and sound systems, we used a 46" LCD TV which is quite close to Japanese law requirement. The simulator 3 (SIM3) is a prototype developed by CERTI/UFSC. In addition to this research, the purpose of building this simulator was to meet the technological challenges and gain experience in technology development.

Table 4 details the 3 simulators tested:

Table 4. Simulators' Settings in the Research

Setting	Simulator 1 (SIM1)	Simulator 2 (SIM2)	Simulator 2 (SIM3)
Model	HRT	HRT Plus	P3UFSC
Chassis/Body	Tubular e Seat (Scooter)	Tubular e Seat	Titan 150 Motorcycle
Handlebar	USB Handlebar	USB Handlebar	Titan 150' original instrumented handlebar
Steering	With spring return	With spring return	With force feedback
Levers	Accel/Clutch/Fr Break	Accel/Clutch/Fr Break	Accel/Clutch/Fr Break
Pedals	Selector/Rear Brake Mech Transm 5 Gears	Selector/Rear Brake Mech Transm 5 Gears	Selector/Rear Brake Mech Transm 5 Gears
Keys	Headlight/Contact/Start /Horn/Indicators	Headlight/Contact/Start/ Horn/Indicadors	Headlight/Contact/Start/Horn /Indicadors
Panel	On the Screen	On the Screen	Emulated by Tablet (Placed on the Handlebars)
Protection System	Monitor 19 " 4:3	TV 46" 16:9	3 Projectors 4:3 with Curved Screen
Resolution (pixels)	1024 x 768	1024 x 768	2400 x600
Angle of Field of Vision - FoV (H xV in degrees)	27.2° x 21.7°	55,° x 32,1°	131.2° x 30.1°
Distance from the Eye (mm)	700	1000	1950
Sound System	Estereo	Estereo 2.1 (with SW)	Surround 5.1(SW)
Degrees of Freedom (DoF)	None(Fixed)	None(Fixed)	4 - roll, pitch, Y and Z axes
Dimensions (LxWxH)	594x568x923	594x568x923(*)	2200x2300x1125(*)

(*) Disregarding TVs, projectors and screens.

The original idea was to use the same software existing in the HRT in the 3 prototypes, though it wasn't technically possible in a timely manner because of technical constraints and lack of further integration with developer in Japan. Therefore, on the third prototype the Software Scanner Studio was used, which is a modular solution for simulating vehicles. To make the contents homogeneous, the scenarios were developed to replicate the existing situations in the scenarios used in HRT sessions. The simulated motorcycle behavior was also set to be similar to HRT including its direct steering feature.

Figure 1. from left to right: HRT1, HRT2 and P3 5DOF tests

The tests were performed by a program of lectures produced by two specialized in traffic education pedagogues, from scenarios and resources available in SIM1 and SIM2, replicated in SIM3. The program included 5 lessons of 30 minutes each, arranged as shown in Table 5:

Table 5. Classes Program in the Simulator

Class	Goals	Scenario
1 - Habituation with the motorcycle	– Learn basic commands; – Turn on the motorcycle; – Put the motorcycle in motion; – Change gears; – Control the speed; – Stop the vehicle.	Infinite line. Without difficulty.
2 – Basic Commands and Intermediary Traffic	– Repeat the same goals from lesson 1; – Conduct respecting the rules fo the way; – Close the route without collisions, or disrespecting any traffic laws.	Empty town. Town with intermediate traffic.
3 – Heavy Traffic	Close the route without collisions, respecting rules and traffic laws.	Several scenarios on urban roads with heavy traffic.
4- Highway	Close the route without collisions, respecting rules and traffic laws.	Highway.
5 - Review	Recap the main skills learned, with emphasis on the gaining of skills in risk perception.	All the scenarios.

Each student's performance was measured from 19 success indicators and 14 fault indicators that evaluate by counting the observed responses, the acquisition of skills while driving motorcycles. These indicators were set from the CFC's teaching and assessment materials and DENATRAN's teaching normative. Table 6 shows the indicators used to measure driving skills on the simulator:

Table 6. The 19 success indicators categorized by skills

Class of Competence	Success Indicators
Control of the basic commands	1. Two pedals; 2. Handlebars; 3. Accelerator; 4. Clutch; 5. Indicators; 6. Horns; 7. Lights
Start Engine	8. Shifts to neutral gear and start the engine, start moving in first gear smoothly.
Transit on the motorcycle	9. Moves with precision through the track in straights and curves; 10. Uses the indicators correctly (on then off); 11. Has good reflexes and response time; 12.Maintains the speed under the limit; 13. Drives in the proper gear; 14. Watches the mirrors; 15. When fails, is able to explain why and offer alternatives; 16. Shifts gears correctly (without accelerating); 17. Stops putting the left foot on the floor for support.
Stopping the motorcycle	18. Brakes correctly (slow down, back brake, press the clutch and put left foot on the floor); 19.Turns off the motorcycle at the right time (stopped, shift to N, off the key).

Table 7 shows the indicators used to measure the failures:

Table 7. The 14 fault indicators ranked by severity

Fault's Severity	Fault Indicators
Mild / Moderate	1. Lets the engine turn off; 2. Shifts gears incorrectly (engine time, not press the clutch, accelerate while shifting gears, etc.); 3.Forgets the indicators on; 4. Misses the path; 5. Comess close to getting involved in an accident, but can avoid it; 6.Ignores risk situations.
Severe	7. Crosses the red light; 8.Drives in high speed; 9.Doesn't give preference to pedestrians; 10. Invades other vehicles' space 11.Uses the indicators incorrectly; 12. Passes other cars by the wrong side
Extremely Severe	13. Crashes 14.Can not explain the cause of the crash.

Before and after each lesson each student was interviewed about the experience in the simulator, being encouraged to report expectations, inadequacies, suggestions for improvements, etc.. Each tester also responded to the System Usability Scale questionnaire [39], with responses in scale from 1 to 5 for 10 items: I think I would use this system frequently; I found the system unnecessarily complex; I found the system easy to use; I think I would need help from a technician to be able to use the system; I found that the system's functions were well integrated; I found that there were many inconsistencies in the system; I think most people would learn how to use this system quickly; I felt very uncomfortable using the system; I felt very confident using the system; I had to learn many things before being able to use the system.

Weeks after the end of the classes in the simulator they were interviewed again on subsequent reflections and conclusions about that experience, especially how experience in the simulator affected their practical classes in the CFC.

Besides being experienced by students, simulators were tested by experienced motorcyclists who already had their licenses, and also 8 CFC instructors. They observed some of the classes with students and commented regarding the equipment and its use in CFCs.

In a separate test, conducted in parallel to the simulators tests, more affordable versions of the type HMD (Head Mounted Display) were tried, as an alternative to the image projection. About 10 testers used the HMD systems during the lessons on the simulator to evaluate this feature for immersion.

4 Results

The results of the use of simulators 3 tests are presented, focusing on aspects concerning the delimitation of technical requirements:

4.1 Environment of use

Table 8 presents recommendations about the physical environment for the simulators use, based on the evaluation experience conducted in this research:

Table 8. Recommendations in terms of the Physical Environment

Discretion	Recommendations
Thermal Comfort	Demand for air-conditioned environment. Especially when the simulator is used with helmet.
Lighting	Moderate light, to highlight the visual stimulation from the projection system.
Space	Demand for an environment of at least 3 by 4 meters to accommodate 1 instructor and 1 student at a time, and possibly 1 or 2 observers.
Sound and Noise	Requires an environment with little noise and isolated enough so the simulator itself doesn´t become a noise generator in the CFC.

Although these parameters seem obvious they have a profound impact on the outcome in a large-scale implementation, since these factors are restrictive in many cases. In ergonomic terms, the simulator physical environment is presented as a workplace for the instructor, who will act as the device operator, teaching students. The simulator operator will be responsible for configuring the device before its use and giving instructions to student in real time, while he's using it, which makes it necessary to consider the environment around the simulator in terms of space and furniture, such as a workplace for the CFC instructor.

4.2 Evaluating the 3 Simulators

The SUS questionnaire applied [39] to the 3 groups of testers resulted the following averages presented in Table 9:

Table 9. SUS rating on the 3 simulators

	SIM1	SIM2	SIM3
1. I think I will use this system frequently.	4,65	4,15	4,45
2. I found the system unnecessarily complex.	2	2,65	3,5
3. I found the system easy to use.	4,65	4,75	4,45
4. I think I would need help from a technician to be able to use the system.	3	3,2	4,55
5. I found that the system's functions were well integrated.	4	4,2	3,5
6. I found that there were many inconsistencies in the system.	1	1,25	1,5
7. I think most people would learn how to use this system quickly.	4,45	4,75	4,65
8. I felt very uncomfortable using the system.	1,5	1,25	1,5
9. I felt very confident using the system.	4	4,25	4,5
10. I had to learn many things before being able to use the system.	2,5	2,75	2,45

Starting from the table above, it is inferred that the SIM1 was presented as a simple and consistent simulator, being also comfortable and easy to use and learn. SIM2 has a very similar score to SIM1. SIM3 stands out just as more voted in apparent complexity and operation, but similar in all other aspects of usability.

Performance indicators in the 3 simulators are presented in Table 10, which expresses the average of scored points:

Table 10. Performance on the 3 simulators

Type of Indicators	Class	SIM1	SIM2	SIM3
Successes	Control of the basic commands	31	34	33
	Starts Engine	4,5	4,7	4,4
	Transits on the motorcycle	38	37	39
	Stops the motorcycle	6,7	7	7,1
Faults	Mild / Moderate	23,5	21,4	16,7
	Severe	13,2	12,1	8,7
	Extremely Severe	9,2	10,6	7,2

Table 10 shows how the correct answers in the 3 simulators were equivalent; as well as the failures showed a mild decrease in SIM3. In summary, in the 3 simulators the learning was very similar in terms of measured performance indicators, with only SIM3 taking a slight advantage.

With the SIM1 tests, it was observed that the lack of kinesthetic was initially perceived as a problem by the user, as well as the different visual appearance from that of a motorcycle .The greatest problem, however, was on having only one screen (which limits the user's vision field with respect to the virtual scenario by decreasing the peripheral vision), and small and very close to the user, being positioned in such a way that caused the user to look at an angle slightly below normal. When driving the motorcycle, the driver looks ahead and away, reflecting practical classes and real road conditions. Performance indicators, among 19 on success and 14 on failures, confirm these testimonials from students about the vision field restricted by the single screen. About 60% of collisions occurred because of the student's poor side visibility, especially in crossing intersections.

Also the lack of space between the pedal and the floor is highlighted, as reported by 15% of the testers (all those taller than 1.8 meter). With regard to the complain about the pedals being low, providing too little space between the feet and the floor, it was found that the same space, at a Honda Bis (a scooter model vehicle that the SIM1 cowling simulates) is 19cm, while it is 10cm in HRT. Another point discussed in the interviews was that SIM1 has the scooter format, where the motorcyclist pilots sitting, and most of the motorcycle fleet has low potency, between 125 and 150 cc where motorcyclists drive mounted.

While testing the SIM2, it was found that with a larger and better positioned screen in terms of height and distance improved the user immersion, providing the user a higher-impact experience. But the new screen has improved only 8% performance indicators relating to lateral collisions, suggesting that a display provides a very restricted vision field, regardless of its size. Another factor that contributed to a better immersion in the simulation was the sound system used, more powerful. The simulator's sounding outcome proved to be important to the realism of the experience, being much required by the testers.

Regarding the SIM3's use it was seconded by users' greater sensory realism because of the actual bike chassis, with commands similar to a motorcycle (eg, handlebars). The 3 screens increased the user's angle of view, which had a decrease of 33% in the failure rate on the side collisions. This model's kinesthetic, formed by 4 degrees of freedom over the handlebars with force feedback, brought more sensorimotor realism, in the testers' own words. But such extra realism was not reflected in terms of performance indicators. In other words, the success and failure rates were similar to the SIM1 and SIM2.

4.3 Requirements for a Conceptual Architecture

Based on 3 models of simulators evaluation, the authors developed Table 11, which summarizes a conceptual architecture for a simulator better adapted to the Brazilian reality:

Table 11. Summary of the Simulators' Evaluation

Feature	Recommendations	Notes/Comments
Chassis	Similar to a small national motorcycle 125cc Mounted driving position.	Testers complained a lot about HRT to shape as a scooter instead of a common motorcycle
Commands (handlebars, buttons on the panel, pedals)	Complete accelerator/clutch/front brake set and transmission/back brake pedals with force specification and consistent courses with a small national motorcycle (125-150cc). Mechanical transmission 5 gears Keys Headlights/contact/start/horn/indicators Handlebars with steering with force feedback	Preferentially use a serie I motorcycle components.
Panel	Physical or emulated but at the actual position with the instruments and lights.	Panel on screen is not recommended
Mirrors	Left and right mirrors emulated on the projection screen with proper size according to the projection distance.	
Image Projection System	Angle of field of view of at least 120 degrees horizontally and 30 degrees vertically. Minimum distance between the projection and the conductor of 1 meter. Resolution exceeding 20 pixel/degree	HMD projection system with low cost aren't recommended because of the high incidence of "Simulation Sickness". Recommended using projectors instead of composition of TVs.
Sound / Vibration	Surround 5.1 Minimum 15W RMS /channel + 30W RMS from the subwoofer.	A vibration system that simulates the motorcycle engine behavior. "In helmet sound system" is not recommend as it is forbidden in Brazilian legislation
Motion platform with degrees of freedom	Optional	Raises the cost significantly without measured gain

Comparing this proposition with the specification in use in Japan, the differential is in the image projection system with a greater vision angle. This is justified by the considerable cheapening of image projection technologies (televisions, projectors) in the last decade. Besides, the use of larger angles of field of vision has become a common practice in driving simulators for cars, including already in use in Brazil.

The use of the motion platform raises costs and equipment's operating complexity, including installation and maintenance. For that, innovative motion solutions that demand less use of expensive mechatronics parts should be investigated to achieve a greater level of immersion with affordable costs which allows greater diffusion.

5 Final considerations

This study started from the primary goal of presenting a proposal for a Brazilian solution in motorcycle simulators for traffic education. As secondary objectives are included: to correlate vehicular simulators and education in road safety; and demonstrate the study that investigated requirements for motorcycle simulators in Brazil. These purposes were fulfilled as the use tests in Brazil were performed and presented, and with them the possibility to suggest general features for a proper simulator for the national reality.

The research reported in this paper is the first systematic study of criteria for the use and development of simulators for Brazilian CFCs, having produced the first technical guidance on such simulators in terms of requirements. The present study didn't, however, stipulate the ideal simulator, but only defined the basic features of a model with characteristics of cost and performance that is supposed to be compatible with the Brazilian reality.

For future studies, the authors suggest:

a) Continuing study on a simulator with the proposed architecture, and large trials in CFCs from different regions of Brazil;

b) Definition of the didactic program of simulators including the proposition of study of situations of risk and specific causes of accidents in Brazilian traffic for inclusion in the simulators' content;

c) Creating a training program for instructors to use the simulation tool.

Regarding simulation technology there are always new technologies being developed, which brings the need for constant specification review according to the availability of these and the declining of associated costs, allowing its use on a larger scale.

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In-depth study of rider trainees and novices: impacts for a renovation of licensing test and the design of motorcycle training modules in France

Tiefenstudie über Führerscheinanwärter und Fahranfänger: Ergebnisse für eine Überarbeitung der Führerscheinausbildung und Motorradtrainingseinheiten in Frankreich

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Abstract

The risks associated with riding powered two-wheelers for novices (who have held a licence for less than two years) are a major public health issue in France and in Europe. However, scientific attempts to achieve a better understanding of their behaviours are limited although its potential value both with regard to research and public policies. This is why we conducted two in-depth researches focussing on 1) the initial training in motor-school, 2) the problem faced by just licensed novices on road.

In both study we used an innovative (for PTW) methodology called in-depth naturalistic riding study (iNRS) that combine objective data (sensors) but also subjective data (face-to-face interviews conducted by psychologist). The interviews allow to identify the contextual clues gathered by the rider and the motives that underlie his/her decision making process.

Six novice motorcyclists and 20 trainees were studied. A systematic monitoring of all the daily trips made by the novices for more than two months and during training sessions for the trainees was carried out. This paper deals with the novices' study.

The collected data permit to identify 248 risky events, to specify their dynamics and context of occurrence. These situations were then grouped together to form clusters of typical incident scenarios on the basis of their similarities.

In our presentation we will detail the methodology used (iNRS), and the results we acquired that lead to a change in the French licensing test (applied since January 2013) and for the design of new training modules (on-going). The discussion will insist on (1) the benefit of this approach for improving training and licensing systems and gaining a better understanding on PTW riding, and (2) some guidelines for optimizing future naturalistic riding studies.

In-depth study of rider trainees and novices: impacts for a renovation of licensing test and the design of motorcycle training modules in France

Introduction

This paper focusing on the behaviour of novice riders in order to improve the French licensing and training system (prior 2013). The following paragraphs present the testing and training process in France, and its main limitations. But it is very difficult to follow a logic to describe the training and licensing systems, as the training is often adjusted to the testing exercises... the aim being unfortunately to train the novices to get the license, and so to succeed to the test... not to be properly trained...

Testing

The motorcycle initial training in France is mandatory composed of a minimum of 8 hours training on tracks and 12 hours training on open roads (apart of the highway code learning). In a synthetic way, the training on tracks aims at teaching novices to master the vehicle, while the training on roads aims at teaching the novices to control the vehicle in traffic conditions and to behave appropriately.

The licence test is composed (apart the highway code test) of a test on track and a test on open roads. The test on track consists mainly in two parts: a test at low speed (slalom in first gear, engine at idle power), where the capacity of the trainee to keep its equilibrium is judged; and a test at "normal speed" (~50 kph, slalom, emergency breaking and avoidance). The time is measured for the slalom at "normal speed", and as to be below a certain threshold to be accepted.

Training

To be trained in a motorcycle school is not mandatory, but fairly all the novices use them. It is up to the motorcycle schools to choose their pedagogy and there is a large spectrum of practises. However, the PhD work sponsored by MAIF foundation (insurance) and conducted by Aupetit (Aupetit et al., 2013) showed several dysfunctions. The main one was a strong focus on the training on tracks, to the detriment of the training on open roads. This was induced by the complexity of the timed "normal speed" slalom test. For some novices succeeding this exercise required more than 35 hours training. In this late case the training on roads was reduced to only 2 hours... Aupetit et al. (2013) showed also that the pedagogy used to train the novices was often very poor and not efficient... the pedagogy consisted in reproducing exactly the license test again and again, sometimes more than 500 times for the slalom.

Context limitations and rational of the project

Novice riders (those who have held a licence for less than two years) are overrepresented in accidents data, i.e. one in five crash-involved motorcycles in France has been registered for under one year (ONISR, 2009). These figures seem to show a dysfunction in the training/licensing system. This system is however quite complex to change as it involve social-economic issues. However, the strong focus on motor skills (with complex and non-ecologic exercises), to the detriment of driving skills lead to inappropriate behaviors... in fact we tend train "pilots" and not "riders" and many novices will ride like pilots... but on open roads... Moreover, Aupetit et al. (2013) has suggested that complex motor skills tend to be loosed when they are not regularly retrained, and if not will lead to over confidence. From a safety perspective over confidence is critical.

As stressed above, an improvement of the initial training of motorcyclists is clearly of potential value both with regard to public policies and research. Moreover, a better knowledge of novices, and the problem they face on road will help to identify the failure in the training/licensing system, and to design counter measures. These questions were the rational for a collaborative research program in France, called SIM2CO+ and started in 2010.

1 Approach and procedure

1.1 Literature on novice riders

Novice car drivers have been studied for a long time, and studies mainly focus on the origins of the over-involvement of young people in accidents (Brown and Groeger, 1988). Three main axes are investigated: psychological and personal factors, such as sensation seeking (Engströme et al., 2003), risk perception (Underwood, 2007), and contextual factors such as the use of alcohol or drugs (Gregersen, 1996).

The literature dedicated to novice riders is poorer, as well as the research projects. Chapman, King and Underwood (2001) suggest that novices do not seek for the most relevant information: If they do not ignore the problem, they cannot recognize it because of their poor hazard perception. Novice riders are slower than experienced rider in hazard detection for Haworth and Mulvihill (2005). The EU IRT project (2007) stress the difficulty for the novices to share their attention between the vehicle control, the perception of the road context and the reactions to risky events. This can be explained by problems in scanning right in front of the motorbike and at the same time far ahead for Cheng, Ng and Lee (2011).

1.2 Conceptual framework

This study refers to the “French cognitive ergonomics approach” (Leplat, 1990). Such an approach has been used to study the activity of car drivers and the potential use of ITS (Ciaccabue and Saad, 2008). It has more recently been used to study motorcyclists activity (Aupetit et al., 2013). Compare to the researches based on accident data (e.g. EU 2BESAFE project, 2009-2011), such an approach allows to catch unsafe situations that may lead to accidents, including nearmisses. The rational for using such a methodology is to try to identify the environmental elements that have been taken by riders in consideration to avoid the situations to become critical. The study of accident data is not considered as sufficient to 1) detect unsafe situations, 2) explain the context of the unsafe situation, 3) explain the contextual clues gathered by the riders, and 4) explain the rider's decision making process.

The approach we propose, that can be called “in-depth” naturalistic study, consists in a systematic monitoring of all the riders’ trips for a significant period of time, and in collecting and combining objective data (about the rider’s actions) and subjective data (about the rider’s experience). Compare to "classical" naturalistic study, it aims at answering the items described just above, and particularly items 3 and 4.

It is the motorcyclists themselves who decide whether a situation is risky or not. Taking into account the rider's point of view is essential to study what has meaning for him (De Keyser, 1991).

1.3 Procedure

Based on considerations describe above, we decided to conduct an “in-depth” naturalistic riding study (iNRS) with novice riders. For insurance reason, it is not possible to provide instrumented motorbikes to novices (at least in France). Thus, and thanks to previous work and experience acquired in various projects (e.g. French DAMOTO project, 2007-2011; EU 2BESAFE project, 2009-2011), we designed a "low cost", "reversible" instrumentation for the top sold motorbike to novices in 2010 (Kawasaki ER6n, cf. Figure 1). This instrumentation allowed us to conduct our iNRS. Thanks to Kawasaki, our participants got a specific discount when purchasing their motorbike. Figures 2 & 3 show the cameras viewpoints and the cameras coverage.

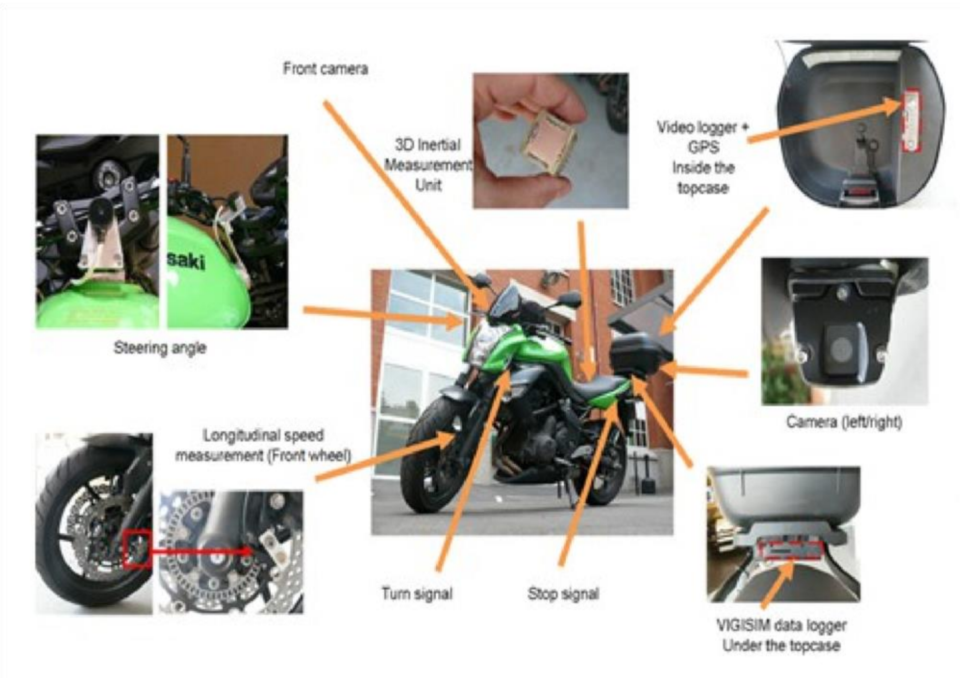


Figure 1. reversible instrumentation, Kawasaki ER6n

Figure 2. cameras viewpoint

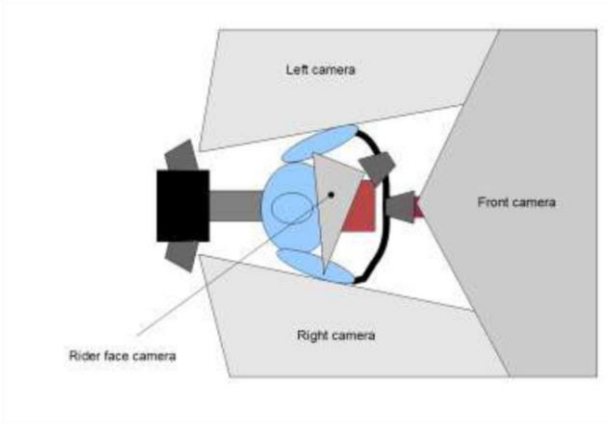


Figure 3. cameras coverage

The iNRS (Work Package 3) was the core of the SIM2CO+ collaborative project that aims to: 1) fill the existing knowledge gap in term of novices' riding activity, 2) identify unsafe situations encountered by novice riders, 3) design training / retraining modules usable on Web and/or low cost riding simulators (Work Packages 4, 6, 7), and 4) improve existing Web based training tools, and riding simulators (Work Package 5) (cf. Figure 4).

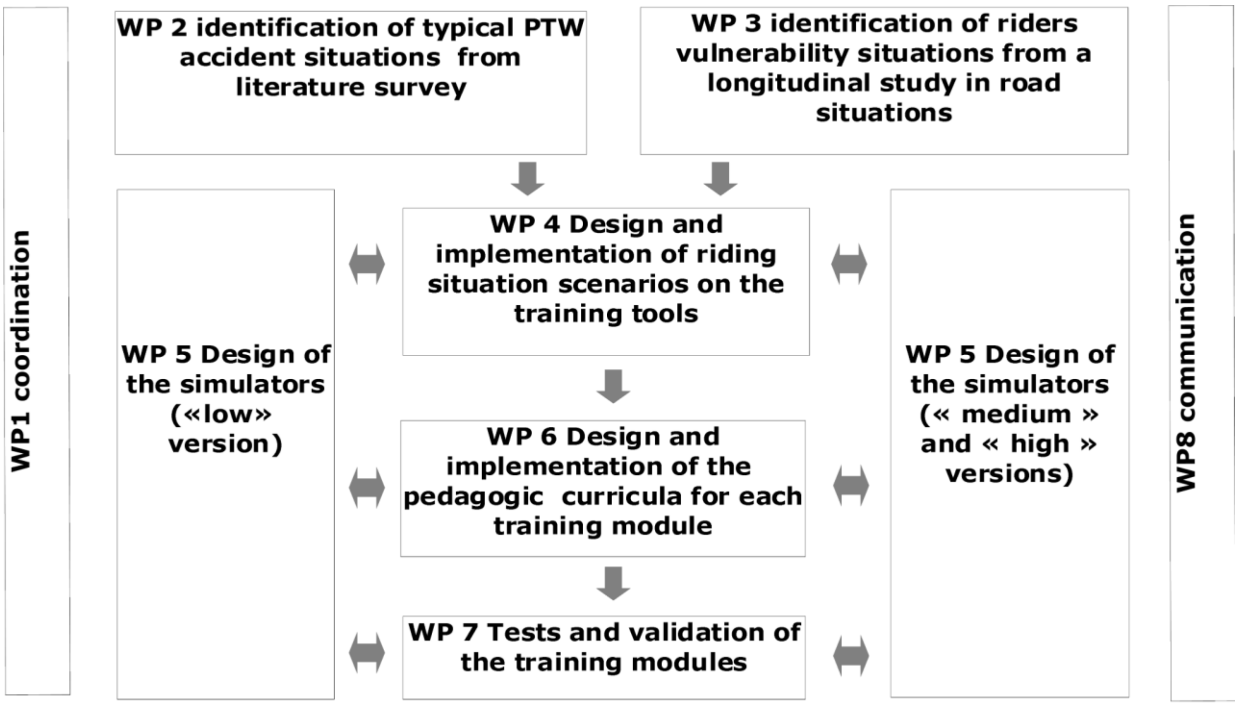


Figure 4. schematic of the SIM2CO+ project

Six trainees were recruited, thanks to the motorcyclist press. They never drove a "heavy" motorbike (>= 125cc) before, and all of them were considering the acquisition of a Kawasaki ER6n. Riders were selected with the objective to have the most diverse population in terms of age and riding experience (Table 1).

Table 1. Details of the studied motorcyclists

	Age	Distance to place of work (km)	Car driving license
	24..33	9..32	1996..2006
mean	28	16	2002

One of our subjects was a woman (in France about 10% of the trainee is a woman). One of our participants already drove a 125cc motorcycle while 2 other already drove 50cc scooters. All our participants except one were in Paris region, the last one was in a middle city (Orléans) in country side.

The procedure was the following: when a trainee gets the license, he/she orders its motorbike at the reseller but doesn't get it immediately, we instrumented the motorbike before. So, we observed our novices since their first experiences of riding after passing the test. We conducted a systematic monitoring of all their trips for more than two months each. In total, we achieved 64 weeks of monitoring (distance of more than 14,000 km travelled) (Table 2).

Table 2. duration of the monitoring and distance travelled

	Duration of the monitoring (weeks)	Distance travelled within the experiment (km)
	8..12 weeks	(350) 1600..4100 km
total	64 weeks	14430 km

RQ one of our subject (male) was not fair play (he drove only 350km within the monitoring period), and profited from the discount on the motorbike price without participating too much to the experiment...

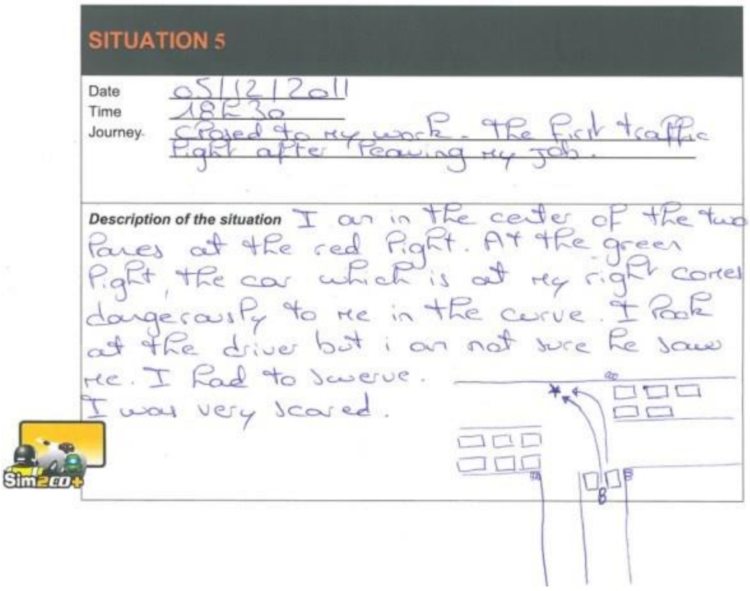
At the end of the monitoring period, we removed the instrumentation and putted back the motorbike in its original state. Thanks to the reversibility of the designed instrumentation, that step was inexpensive from both time and money standpoint.

1.4 Data collection

We use three methods to collect data: logbook, self-confrontation interview based on the videos of the journeys recorded by embedded cameras, and embedded sensors (accelerometer/gyrometers, wheels rotation, handlebar angle, turn and break signals, GPS). However, in this particular analysis based on verbalization, we didn't use the data recorded by the embedded sensors.

Logbook

All along the experiment, our novices filled in a logbook which was specifically designed for the study. The instructions for them were to note down all the situations they faced and they considered as unsafe for them during their journeys (cf. figure 5).


SITUATION 5

Date 05/12/2011
Time 18h30
Journey Closed to my work. The first traffic light after leaving my job.

Description of the situation I am in the center of the two lanes at the red light. At the green light, the car which is at my right comes dangerously to me in the curve. I look at the driver but i am not sure he saw me. I had to swerve. I was very scared.

Figure 5. Extract from participant 6's logbook (translated from the French)

Before starting the experiment we train them to describe situations using the logbook.

This method permitted to identify 248 risky situations.

Self-confrontation interviews

The novices' motorbikes were equipped with 4 video cameras. The installation and operation was designed to be as unobtrusive as possible. The recording start/stop automatically when the motorcycle started and stopped. Two cameras were mounted on each side of the motorcycle's rear top case, covering about 160 degrees of the front visual field (Figure 2). Two others were mounted on a specific wind deflector, one pointing towards the scene to the front and another pointing towards the rider's face. The recorder was housed in the top case of each motorcycle. In total, 110 hours of video were recorded.

Each week, a face-to-face interview was conducted at the participant's home or place of work. The interview lasted about 30 minutes on average. This interview was divided in two parts: (1) a brief description of the risky situations reported in the logbook, and (2) a self-confrontation interview based on the video footage of the identified situations. The interview itself was recorded using three cameras (cf. Figure 6). We have achieved 49 interviews, which represent 23 hours.

The self-confrontation interview allows to obtain a step-by-step description of the actor's actions and intentions (Macquet and Fleurance, 2007). The researcher's input is systematically related to what the participant has just said or done during the interview or the situation on the screen, and playback of the video footage is interrupted from time to time to give the participant time to speak (Theureau, 2003).

Figure 6. self-confrontation interview showing the equipment and the positions of the actors

1.5 Data processing and analysis

The collected data were loaded into processing tables that were based on the verbal protocols developed by Theureau (2003). The objective is to obtain the most detailed description of the situation by combining the different data levels. The tables are divided in three sections (cf. Figure 7). The first contains a full transcription of the data collected using the logbooks. The second lists the remarks based on the videos concerning the context. The third section contains the verbatim transcription of the face-to-face interview.

Diary	Observations		Interview		
	Time	Videos	Time	Speaker	Verbal data
Date: 10.28.2011 Time: 10h30 Journey: Home to Paris. I have the priority and I see a car approaching from the right at a stop mark. Suddenly he restarts and stops in the center of the road. I avoid him.	10h28	The situation takes place in urban areas in an intersection in "X". The rider avoided the vehicle by the left side of his lane. Cars were present in the opposite direction.	1'12	Rider 2	I saw the driver turned his head in my direction at the stop line. I thought I had detected me. And suddenly I was surprised to see the car ahead. The driver notices me and brakes suddenly
			1'35	**Researcher**	**What are you doing at this time?**
			1'42	Rider 2	I think I started to slow down but I realized that this will not be enough to stop, so I released the brakes and decided to avoid the car by the left. Fortunately there was a little place in the lane. I was relieved to be out without falling!

Figure 7. Extract of a table for processing the collected data for week 2 of the participant 2

The data analysis aims at characterizing the risky situations encountered by the novices. We applied both a "*top-down*" model (deductive reasoning) and a "*bottom-up*" model (inductive reasoning) to categorize the situations.

2 Results

2.1 About risky situations

The analyses on the collected data allowed us to count the number of risky situations faced by our novices, and the dynamics of occurrence of these risky situations (cf. Figure 8).

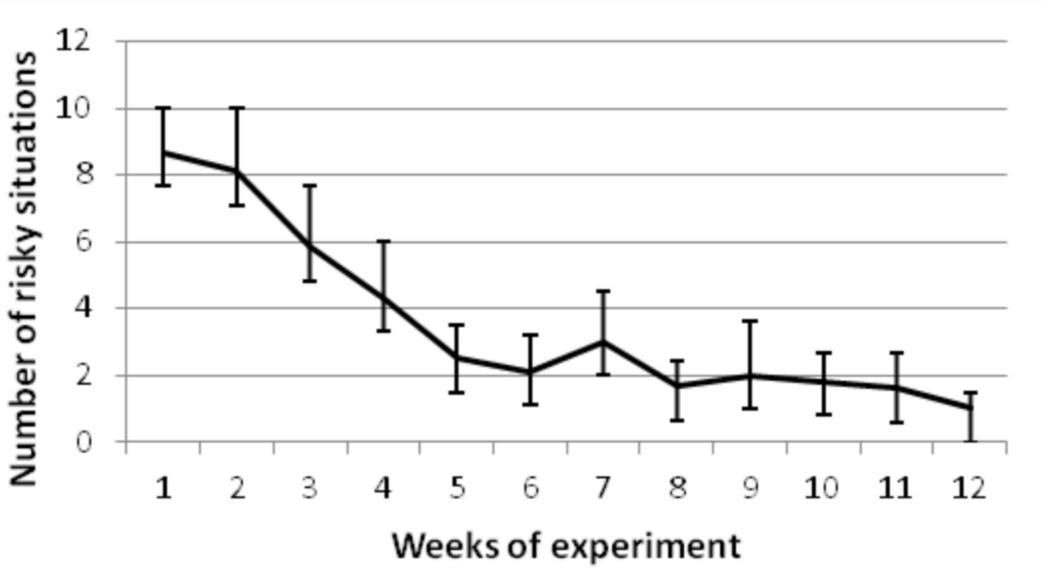


Figure 8. Number of risky situations reported in the logbooks during the experiment process

The analyses gave us also the context of the risky situations and their categories.

The risky situations occurred more during a leisure journey (52%) than during a commuting trip (48%). They occurred mainly on usual roads (68%) (cf. Figures 9 & 10).

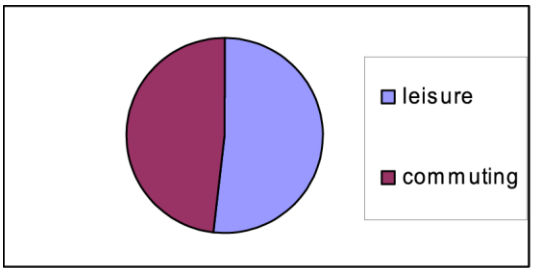


Figure 9. type of journey

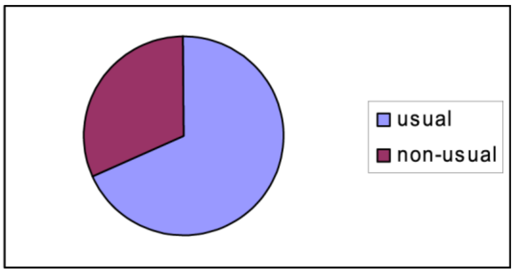


Figure 10. type of trip

The risky situations occurred largely in built-up area (44%). It is more shared for the infrastructure: 21% happened on an intersection, 15% at road entrance or exit, 14% in a curve, and 11% on a roundabout (cf. Figures 11 & 12).

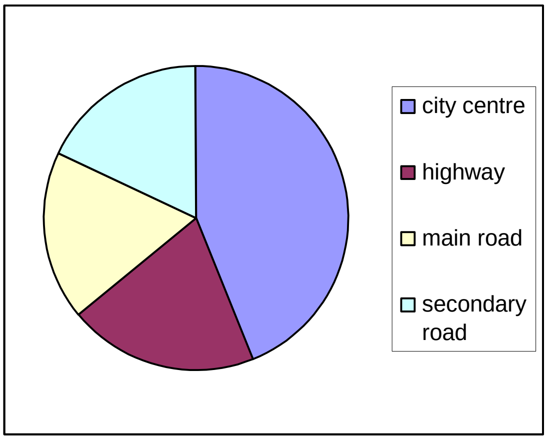


Figure 11. type of road

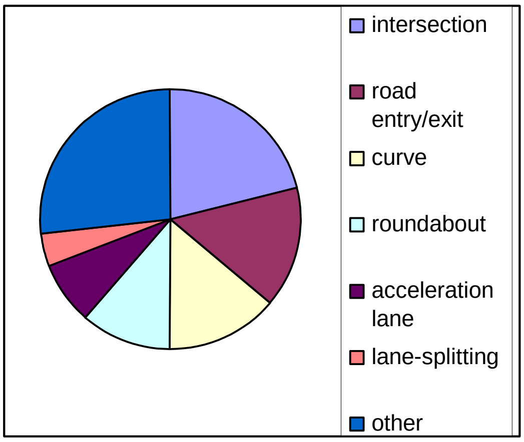


Figure 12. infrastructure

Almost all the risky events occurred with a car driver (77%). Data show the weather conditions associated to the risky situations (this item was noted only when the rider reported that the weather conditions have an impact on the triggering of the risky event). 15% of the risky events occurred on wet roads (cf. Figures 13 & 14).

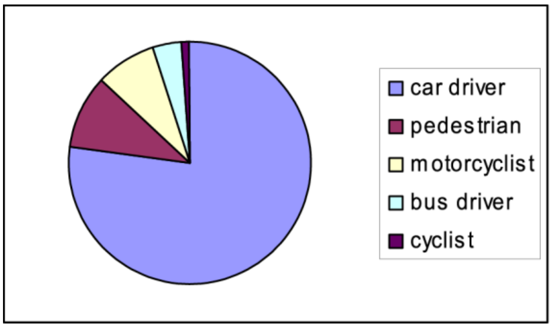


Figure 13. type of conflict

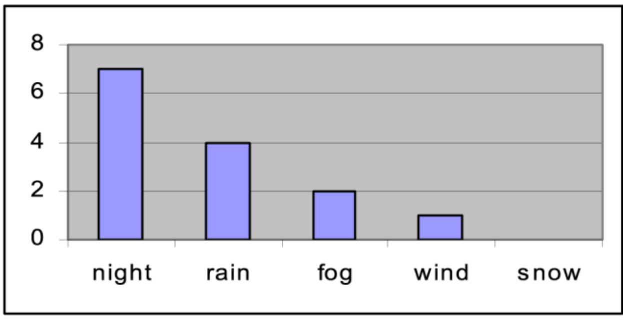


Figure 14. weather condition

The social factor is very limited; the factor “riding with a pillion” interferes in 3% of the risky situations and “riding with a group of riders” only in 2%. Last, the within risky situations the motorcyclist reported various feeling, the most of the case afraid or surprised.

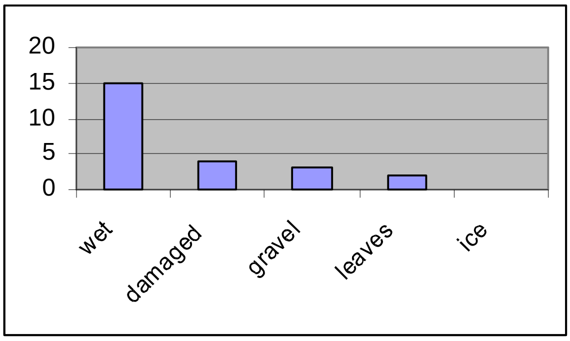


Figure 15. road surface

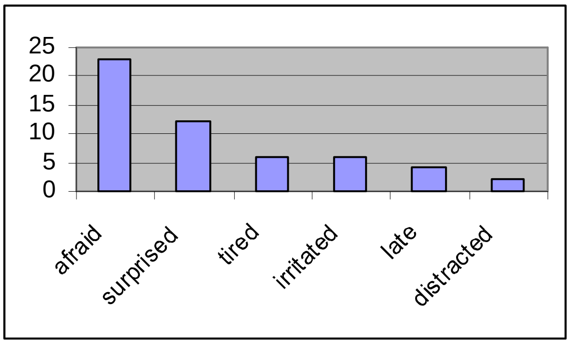


Figure 16. novice's feeling

2.2 The typical scenarios of incident

We inspired from the concept of typical scenarios of accident from Clabaux and Brenac (2010). We considered as a typical scenario of incident a prototypical sequence of risky situation. Thanks to the field study data, we identified 248 risky situations. During our analyses we aggregated these risky situations in 13 typical scenarios (Table 3). In this table the proportion of risky situations that can be found for each scenario is indicated in terms of percentage and occurrences (e.g. situations associated with the scenario number 1 represent 15% of all the risky situations, i.e. 38 occurrences among the 248 situations).

Table 3. The 13 typical scenarios of incident identified with the field data

Scenario number	Title of the scenario	Proportion	
		Occurences	**Percentage**
1	Near-miss during lane changing in case of dense traffic	38	15%
2	Near-miss when another user does not give the right of way at an intersection	32	13%
3	Loss of control in sharp bend	27	11%
4	Loss of control on slippery road	25	10%
5	Near-miss after an unanticipated lane changing of a user in front of the rider	23	9%
6	Near-miss after an unanticipated slowdown of the traffic	20	8%
7	Near-miss during an overtaking maneuver achieved by the rider	18	8%
8	Near-miss when the rider does not give the right of way at an intersection	17	7%
9	Near-miss during filtering when a user desires to turn left	17	7%
10	Near-miss while looking for an itinerary in case of dense traffic	12	5%
11	Loss of control when turning after starting	7	3%
12	Near-miss when another user overtakes the rider on the wrong side	6	2%
13	Loss of control due to wind	6	2%
Total		**248**	**100%**

3 Discussion

The SIM2CO+ iNRS highlighted the fact that a large number of riding situations can lead to problems, sometimes significant, for the (novice) motorcyclists. One can note also the diversity of the risky events in terms of infrastructure (highways, urban roads... roundabout, intersection...) and road users (car drivers, motorcyclists, pedestrians...). The skills involved in these situations are also different, e.g. perception, recognition of risky situations, combination of vehicle handling and observation of the environment, etc.

One can note, however, that almost all the identified risky situations are linked to perceptual and/or cognitive shortcomings. The interviews showed that a number of these situations have not been tested during training (Aupetit et al., 2013), they are discovered by novices after licensing.

3.1 Use of the results to design new training modules

Thanks to the iNRS we succeeded to identify specific skills not mastered by the novices. We aggregated the lacks in 3 classes: 3.1.1 no or bad anticipation on the behaviour of the other road users, 3.1.2 difficulties to combine vehicle handling and observation of the environment, and 3.1.3 no or bad reading of the infrastructure.

In each of these classes we defined sub-classes that refine the missing skills, and for each of them we proposed situations in which incidents may occur. Note that the proposed situations are a sub-set of the quasi infinite case where the missing skill may lead to unsafe situations.

It also appears to us that one of the limits of simulated situations is that they are often unrelated to current life. So we propose to propose everyday life situations, with a goal (to reach a destination), with time constraints. For instance, the trainee has to reach a train station to catch somebody 5 minutes after it starts. Note that, in several simulated situations, the trainee has to manage his/her path to reach his/her destination.

Last, we choose to limit each simulated situations to 5 up to 8 minutes riding. Each situation starts with a "safe" situation, and continue with a potentially risky situation (depending on the novice choices).

3.1.1 No or bad anticipation on the behaviour of the other road users

The anticipation of the behaviour of other road users is based on various indices (e.g. children playing with a ball on a side-walk may lead to a ball and just after... children(s) crossing the road). Experienced riders learn often by their own errors (and fortunately only near-misses) to anticipate on such situations. It appears to us relevant to design simulation scenarios that help to train novices to recognise hazardous situations. We sub divided these classes in 3 main problems: inappropriate evaluation of the front traffic situation, bad anticipation of a changing lane manoeuvre by another road user in the same direction, no or bad anticipation of the appearance of another road user cutting its lane.

a) Inappropriate evaluation of the front traffic situation.

In this sub-set we propose common situations encountered in everyday journeys by riders (note that some of these situations occur due to local (French) practices). These situations aim at acquiring various knowledge, among them to understand the poor conspicuity of the motorbike, and to understand that behaviours are more important that highway code (the understanding of this notion is critical for vulnerable road users like motorcyclists that often have a too strict confidence in the infrastructure based priorities, it addresses in particular the very common accident case where a car driver without priority cut the way of the motorcyclist). In the proposed situations the trainee has the choice to do or not potentially unsafe manoeuvres, for instance he/she may (or not) chose to filter in specific situations. The five situations we propose are:

- filtering (with visual mask (e.g. truck or van) in the vehicles queue)
- filtering between opposite traffic lanes, with car coming in opposite direction
- sequence of green traffic lights with one passing to yellow, the car in front of the trainee breaks abruptly
- left turn (right hand driving) by the novice at an intersection (with traffic)
- entering a highway using an entry ramp (with traffic on the ramp and on the highway)

b) Bad anticipation of a changing lane manoeuvre by another road user in thesame direction.

One more time, the situations proposed in this sub-set are common ones. The knowledge that can be acquired in these situations are for instance: to choose an appropriate speed regarding the traffic, to choose an appropriate lateral position on its lane, to choose an appropriate time headway, to search for eye contact with the other road users, to recognise indices that may indicate abrupt changing lane manoeuvre (speed slowdown, approach of intersection...),... The five situations we propose are:

- lane sharing practice close to an entry ramp
- traffic slowdown
- approaching a motorway splitting
- approaching a vehicle driving (without traffic) on the central lane of a 3 lanes motorway
- riding on the slow lane on a motorway while passing an entry ramp

c) No or bad anticipation of the appearance of another road user cutting its lane.

The situations proposed in this sub-set are also very common ones... required competencies are more or less the same as for the previous situations: to recognise indices (e.g. an "abnormal gap" in a cars queue), to search for eye (visual?) contact, to adapt its speed...

- cut in by a vehicle without priority
  - intersections in residential area
  - in a very dense traffic (continuous queue), while the novice filter, a car coming from the right (secondary road) suddenly appear and cut the way of the trainee
- cut in by a pedestrian
  - a pedestrian cross the road when the traffic light is red for him
  - a pedestrian cross the road outside a pedestrian crossing
  - a pedestrian cross a road using a pedestrian crossing, but truck or a van is stopped and the pedestrian is not visible

3.1.2 Difficulties to combine vehicle handling and observation of the environment

Here the aim is to train the novice to properly handle the vehicle while adapting his/her behaviour to the traffic situation. The understanding of the differences in the dynamics of a car and a motorbike is also important as the difference may lead to incompatible behaviours in some circumstances (e.g. roundabout, narrow tunnel...). We also propose to train novices to prepare and manage their itinerary.

Two sub-sets are defined: vehicle handling, search for itinerary, and sequences of lane changing, vehicle handling, and start for entering a curve or a roundabout with dense traffic.

a) Vehicle handling, search for itinerary, and sequences of lane changing

- search for an unknown destination, using urban motorways
- search for an unknown destination in urban area with dense traffic

b) Vehicle handling, and start for entering a curve or a roundabout with dense traffic

- start at a traffic light and turn right in dense traffic
- entering a roundabout with dense traffic
- using an entry ramp (in a slope), with traffic
- sequence of roundabout with traffic and pedestrian crossing

3.1.3 No or bad reading of the infrastructure

This last class addresses default in the infrastructure as well as rules to safely take bends. The novices we monitored faced difficulties to anticipate the impact of local pavement default, and to determine the appropriate speed for taking a bend. Last, they all have serious problem with clutching. They stall very often when restarting at traffic lights. This particular skill was clearly not acquired.

Because we propose to train novices using simulators, we focus on the visual part of the decision making process. Two situations are proposed: pavement default and bends.

a) Pavement default

A set of default and their potential impact on the vehicle handling are proposed:

- oil or diesel leakage, in particular in roundabouts
- default in the hot bitumen connection between two lanes (particularly important in case of lane sharing practice)
- sand, oil, leaves in bends
- wet roads, snow, icy portions

b) Bends

Several situations are problematic for novices. As already stated we do not consider feasible train the motor skills using simulators. Thus, we propose to focus on recognition, anticipation and decision making process. The following topics are proposed:

- bend sequences with various radius
- trajectories in bends with poor visibility

3.2 Impact for the license test

The situations proposed aim to train novices to hazard detection. Simulation is not real life... but we hope that the on-going designed scenarios will help to train new motorcyclists to appropriately identify indices that may help them to avoid facing risky situations. From a pedagogy stand point, the remaining question is to avoid to create an over confidence. Within SIM2CO+ we also worked on this issue, and the industrial training tools that will appear on the market will address this issue.

The results of our iNRS focusing on novices have already been used to modify the French license test. Two major points were taken in consideration: lack of clutching skill, and over-concentration on motor skills (in particular with the timed "normal speed" slalom). Despite the numerous constraints to change the test, and thus the training in motor-schools, we succeeded to modify several items:

1) The "normal speed" slalom is now timed any more, and the configuration ofthe slalom is closer to actual situations (sequence of bends). The expected benefit of this measure is to mitigate the number of training hours on track... giving more time for the training on road

2) The "low speed" slalom is now timed... trainees have to play with the clutch,the breaks and the equilibrium to achieve the slalom in more than a specific duration. The expected benefit is to introduce clutching technique in the training.

3) The U-turn that exists in the test is now with a stop. The idea here is toaddress the problem faced by novices when stopping/starting in curve (or close to curves).

Conclusion

Novice riders those who have held a licence for less than two years) are overrepresented in accidentology, one in five crash-involved motorcycles in France has been registered for under one year (ONISR, 2009). These figures show a dysfunction in the training/licensing system.

The strong focus on motor skills in the French training/licensing system (with complex and non-ecologic exercises), to the detriment of driving skills leaded to inappropriate behaviours on roads. The system may be considered as counterproductive as it prepared trainees to feel themselves as "pilots" rather than "riders" and that can lead to inappropriate behaviours on road. Moreover, 1) the time spent to train novices to slalom at "normal speed" reduced the time potentially spent on roads, and 2) motor-skills are loosed when they are not regularly retrained, and if not will lead to over confidence which is worse than nothing. From a safety perspective over confidence is critical.

The SIM2CO+ collaborative project ended in June 2014. It aimed at improving of the initial training of motorcyclists in France... but the founding are probably much generic. The iNRS designed and used in SIM2CO+ is a methodology that have proved to be a powerful means of studying the activity of car drivers or motorcyclists. Within SIM2CO+ it allowed us to identify 248 risky situations faced by novice riders, and to understand the motives, the context and the dynamics that lead to these situations. Thanks to the acquired knowledge, two results have been reached: changes in the licensing test in France, and design of new training modules dealing with hazard detection. It is of course too early to stress if the impacts of these results are positive in term novice behaviours and road safety... we hope that they will contribute to motorcyclists safety improvement. We are conscious of the importance of a further evaluation of the impact of the changes in the licensing test on the motors-school training... but this will be the topic a future study...

Last, iNRS is an experimental tool, fairly complex to use on motorcycles due to 1) the limits in term of size, width and power consumption for embedded systems, 2) the huge number of collected data and thus the time and cost required for the treatments and analyses. However, one have to consider that asking the riders to explain situations, manipulated indices, motives of their decision making, feelings... is the only way of understanding why situations occurs... an, we believe, the only way to design relevant and accepted safety counter measures: relevant because based on scientific background... not expectations, accepted because addressing real issues.

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Development of a method for analysis and effectiveness evaluation of driving safety functions in powered two-wheelers

Entwicklung einer Methode zur Analyse und Wirksamkeitsbewertung von Fahrsicherheitsfunktionen in motorisierten Einspurfahrzeugen

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Abstract

The present study deals with an analysis for sphere of action for especially active safety systems in powered two-wheelers. The aim was to analyse objectively the effectiveness of advanced driver assistance systems (ADAS), vehicle dynamics control systems (VDCS) and other auxiliary functions to increase road safety of motorcycles, based on real accident data. According to a detailed descriptive analysis of accident data using the GIDAS- database, the entirety of accidents of motorcycles was summarized in a multistage process into 11 accident scenarios out of 135 individual accident types. It succeeded to categorise nearly 1600 motorcycle accidents out of GIDAS.

Continuing, the accident emergence phase of the respective accident scenarios has been described in detail to derive specific requirements of ADAS and VDCS according to the particular accident scenario. Furthermore, existing driver assistance systems and control systems have been analysed for basic functionality and transferred into a function-based scheme. Therefrom causal loops and signal flow diagrams were derived. Together with the specific requirements this helped to carry out the weighted evaluations of the effectiveness of individual functions based on the particular accident.

In order to simulate the mentioned accident situations realistically and to study the potential to increase active Safety of assistant systems in simulative researches, it is to model the motorcycle as a dynamic system in the accident simulation environment. Previously, the Matlab/SIMULINK-based simulation environment of "Verkehrsunfallforschung an der TU Dresden GmbH" did not include dynamic motorcycle models. In the cooperation project, the environment has been extended, so that a MBS-motorcycle model can be included in the simulation of accident scenarios. Therefore a code-export-interface was used in the SIMPACK-simulation environment.

The MBS-models are set up in SIMPACK with a motorcycle kit developed at TU Dresden, which allows simple configuration of two-wheeled models from pre-defined and fully parameterised assembly models. During the cooperation project, the functionality of the kit has been extended, especially to represent the bottom contact of an overturned motorcycle and the slide of the overthrown two-wheeler on a road surface.

The driver behavior is taken into account by means of a co-simulation with a Matlab-modeled driver controller. This can be extended by functions of assistance systems. In the project the effect of ABS in a typical accident situation was studied exemplarily.

Entwicklung einer Methode zur Analyse und Wirksamkeitsbewertung von Fahrsicherheitsfunktionen in motorisierten Einspurfahrzeugen

1 Fragestellung

Mit der Einführung von Fahrerassistenzsystemen in Kraftfahrzeugen konnte in den letzten zwei Jahrzehnten ein deutlicher Rückgang der im Straßenverkehr getöteten Personen verzeichnet werden. Dies beschränkt sich jedoch im Wesentlichen auf Insassen von PKW, LKW und Omnibussen. Fahrer motorisierter Zweiräder sind nach wie vor sehr gefährdet. Dies begründet sich zum einen in der fehlenden oder im Verhältnis zum PKW nur sehr rudimentär ausgeführten passiven Sicherheit und zum anderen in bisher fehlenden Möglichkeiten zur Unfallvermeidung. Tritt ein Unfall ein, so lassen sich meist trotz massiver Anstrengungen für eine gute Schutzausrüstung schwerere Folgen als beim PKW-Insassen nicht vermeiden.

Zur Erhöhung der Verkehrssicherheit von Motorrädern sollte eine Methode entwickelt werden, die es ermöglicht, die Wirksamkeit von Fahrerassistenzsystem bezogen auf reale Unfallarten und deren statistische Relevanz zu bewerten. Beginnend mit einer umfassenden Unfallanalyse sollten Szenarien ausgewählt und beschrieben werden, die statistisch relevante Handlungsfelder der Motorradsicherheit aufzeigen. Parallel dazu sollte ein Screening bekannter und in Entwicklung befindlicher Assistenzfunktionen erarbeitet werden. Weiterhin sollte damit das Gerüst einer Wirkungsfeldmatrix erstellt werden, die im weiteren Projektverlauf Basis der Methodenentwicklung zur Quantifizierung der ermittelten Wirkungsfelder war.

Als wesentliches Entwicklungswerkzeug wurde bereits bei Projektbeginn die virtuelle Auslegung in verschiedenen Simulationswerkzeugen definiert. Der Aufbau einer für die Entwicklung zukünftiger Assistenzfunktionen nutzbaren Simulationsumgebung wurde daher bereits begonnen und sollte die Verbindung zweier Simulationsumgebungen, präziser einer Abbildung fahrdynamischer Zusammenhänge und einer Simulation des Unfallgeschehens, zum Ziel haben.

2 Methodenentwicklung

2.1 Kurzzusammenfassung

Beginnend mit einer ausführlichen Literaturrecherche zum allgemeinen Unfallgeschehen motorisierter Zweiräder auf dem deutschen Straßennetz auf Basis von Veröffentlichungen der BAST, der FGSV, DESTATIS und anderen verfügbaren Quellen (Vgl.: [1], [2], [3] und [4]) wurden zunächst Stoffsammlungen angelegt. Darüber hinaus wurde eine durch die Verkehrsunfallforschung an der TU Dresden GmbH (VUFO) innerhalb dieses Projektes angefertigte GIDAS-basierte Unfalldatenanalyse für motorisierte Zweiräder der hier vorliegenden Arbeit zugrunde gelegt. Parallel dazu wurden Recherchen zu bestehenden und zukünftigen Fahrerassistenzsystemen (FAS) sowohl im Gebiet der Motorradtechnik als auch in den Gebieten der allgemeinen Kraftfahrzeugtechnik und Luftfahrt durchgeführt. Die Erkenntnisse dieser Recherche wurden in detaillierten Funktionsmustern abgelegt, die in späteren Projekten Grundlagen für eine eventuell erforderliche Modellerstellung sein könnten. In dieser funktionalen Beschreibung der Fahrerassistenzsysteme wurde nach dem zeitlichen Ablauf ein Flussdiagramm erzeugt.

Weiterhin wurden auf Basis des vorliegenden allgemeinen Unfallgeschehens mögliche Erweiterungen in Form von Übernahmen aus anderen Anwendungsgebieten und neuen Ideen in die o.g. Darstellung der Fahrerassistenzsysteme aufgenommen und deren Funktionsprinzip dokumentiert. Zur Erstellung der Wirkungsfeldmatrix wurden die Wirkungsweisen der FAS in ihre physikalischen Basisfunktionen zerlegt.

Aus den gemeinsam mit der VUFO entwickelten Unfallszenarien wurden szenarienspezifische Anforderungen an FAS abgeleitet. Diese wurden dann in einem hier entwickelten Bewertungsschema mit den o.g. Basisfunktionen bestehender und zukünftiger Fahrerassistenzsysteme verglichen. Entsprechend der durch die VUFO bestimmten Relevanzen der Unfallszenarien wurde eine Wichtung vorgenommen und die Ergebnisse entsprechen interpretiert. [5]

In einem weiteren Schritt wurden den Wirkfeldern potenziell umsetzbare Methoden zur weiteren Objektivierung und technischen Machbarkeit zugeordnet.

Abb. 2.1 zeigt schematisch das Vorgehen bei der Wirkungsfelduntersuchung.

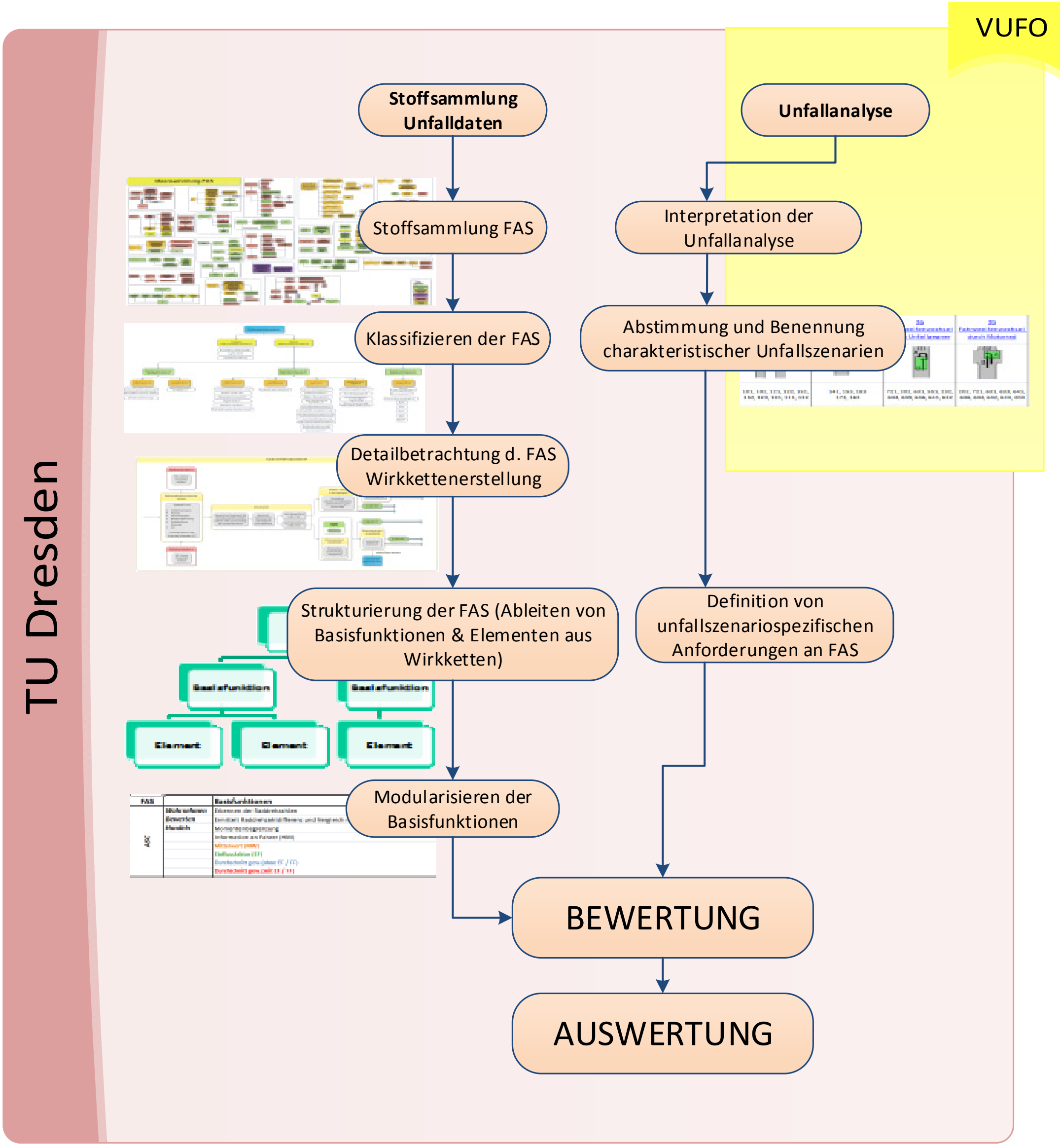


Abb. 2.1. Vorgehensweise zur Erstellung der Wirkfeldmatrix Vgl.: [5]

2.2 Bestimmung charakteristischer Unfallszenarien

Auf Basis der in der deskriptiven Unfallanalyse entwickelten Häufigkeitsverteilung der Unfalltypen (Vgl. [6] und [7]) wurden Unfallszenarien definiert. Darin wurden die nach gemeinsamen Charakteristika sortierten Unfalltypen zusammengefasst. Die gemeinsam mit der VUFO definierten Unfallszenarien wurden zunächst hinsichtlich ihrer spezifischen Unfallursachen untersucht. Dabei sollte ein detailliertes Verständnis der Unfallszenarien erzeugt werden, dass später zur subjektiven Beurteilung der Wirkung der Fahrerassistenzsysteme erforderlich sein wird.

2.2.1 Hauptunfallursachen der jeweiligen Unfallszenarien

Zur Generierung der für Bewertung erforderlichen spezifischen Anforderungen an Fahrerassistenzsysteme wurden in diesem Schritt der Bearbeitung die Hauptunfallursachen zu den Unfallszenarien untersucht. Dies erfolgte auf Basis der von der VUFO zur Verfügung gestellten Daten der Unfallanalyse. Ziel war es hier, ein detailliertes Bild des jeweiligen Unfallszenarios zu gewinnen, ohne dabei auf die getroffenen Vereinfachungen und Zusammenfassungen zu verzichten.

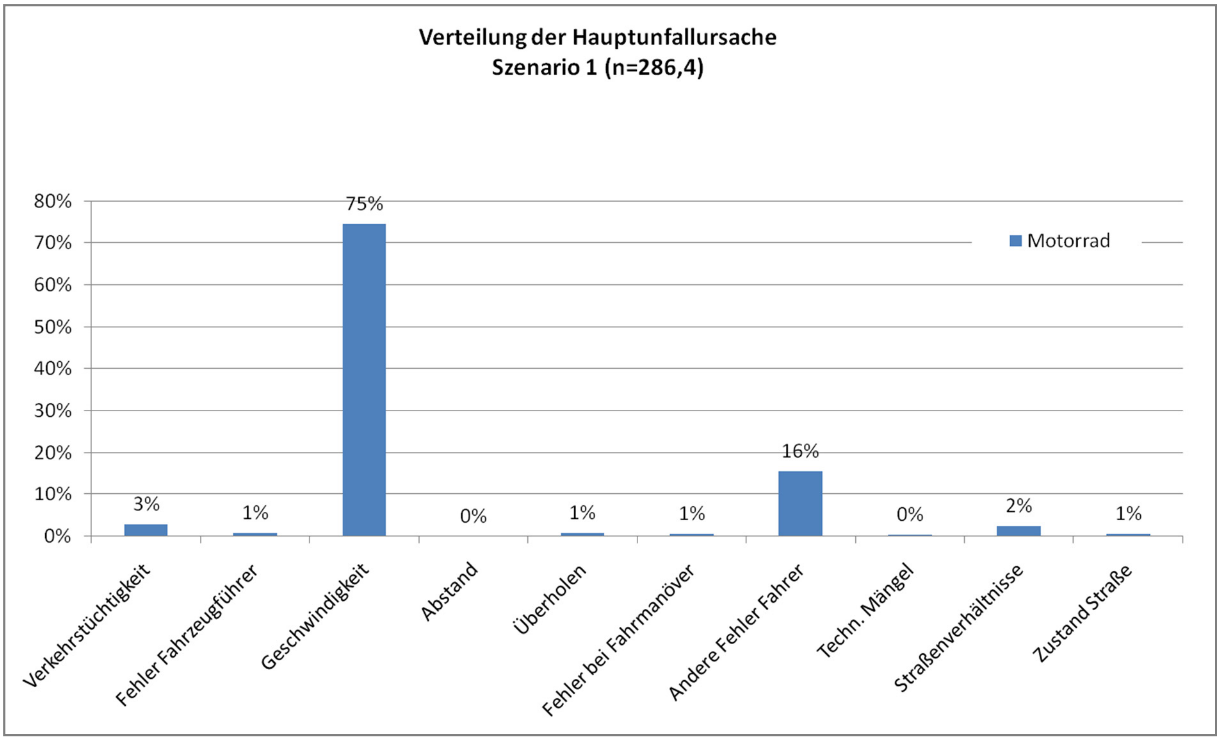


Abb. 2.2. Hauptunfallursachen Szenario 1 [7]

2.2.2 Definition unfallszenarienspezifischer Anforderungen an FAS

Die Unfallszenarien wurden im vorangegangenen Kapitel auf ihre spezifischen Unfallursachen untersucht. Darauf aufbauend wurden dann unfallszenarienspezifische Anforderungen an die zu bewertenden Fahrerassistenzsysteme abgeleitet, anhand derer die spätere Bewertung nachvollziehbar gemacht werden soll. Ziel war es hier, die Anforderung möglichst ohne strukturelle Ansprüche an zukünftige oder bestehende Systeme zu formulieren und dabei alle Unfallursachen des jeweiligen Szenarios zu erreichen. Es wurde dabei gezeigt, welchen funktionalen Umfang ein Fahrerassistenzsystem abdecken muss um alle denkbaren Unfälle, die zu diesem Szenario gehören, zu verhindern oder zumindest deren Folgen zu mildern. Anhand des Unfallszenarios 1 „Fahrunfälle in Kurven" soll dies exemplarisch gezeigt werden.

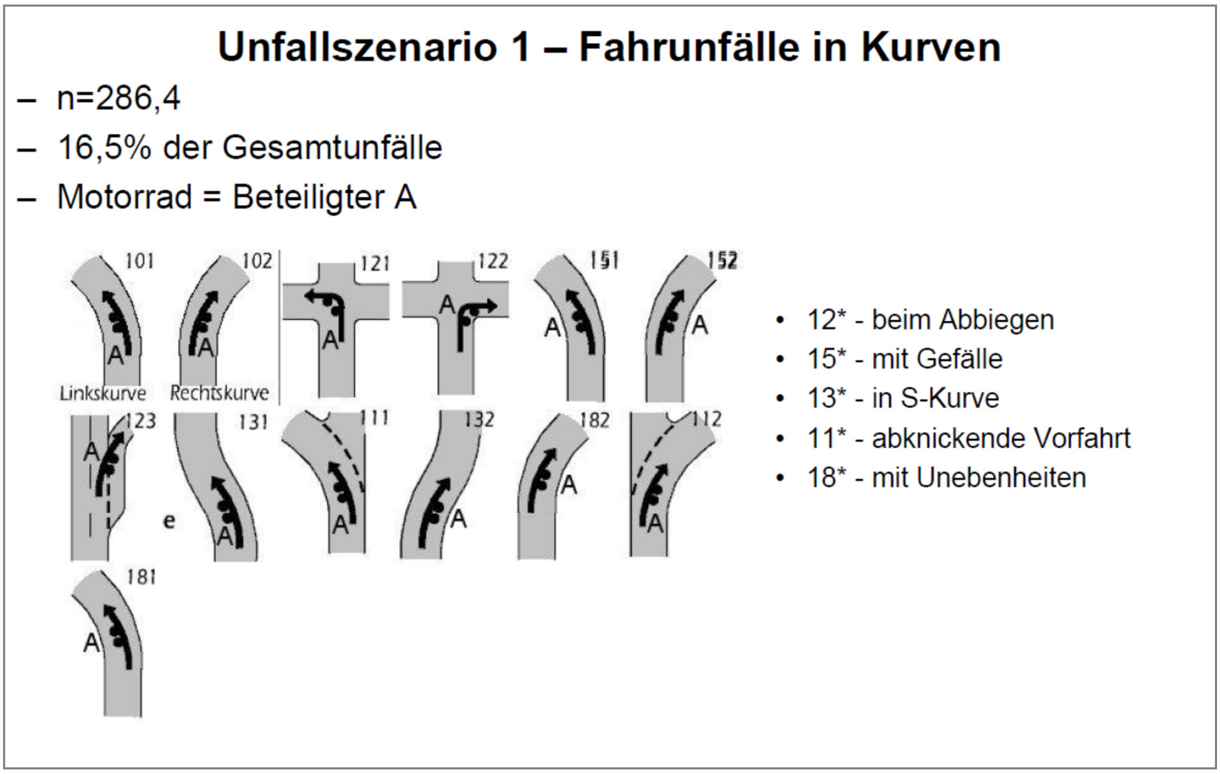


Abb. 2.3. Unfallszenario 1 - Fahrunfälle in Kurven [5]

Erfassen:

- Geschwindigkeit
- Beladungszustand
- Betriebspunkt
- Kurvenradius
- Schräglage
- Eigene Position auf Fahrbahn
- Straßenbreite
- Straßenaufteilung (Anzahl der Fahrstreifen)
- Gefälle
- Fahrbahneigenschaften
- Raddrehzahlen
- Radmomente
- Routenplanung / Fahrerwunsch
- Vorfahrtsituation
- Fahrerzustand (Aufmerksamkeit, Müdigkeit, Gesundheit, Fahrtüchtigkeit)

Bewerten:

- Sturzrisiko
- Risiko, die Fahrbahn zu verlassen
- Fahrtüchtigkeit

Agieren:

- vor Gefahrensituation warnen
- Geschwindigkeit verringern
- Sonstiger Eingriff in Gefahrensituation und dadurch das Unfallrisiko oder dessen Folgen vermindern

2.3 Untersuchung der Fahrerassistenzsysteme

Nach der Betrachtung der Unfallszenarien werden in diesem Kapitel die Arbeitsschritte des linken Astes der in Abb. 2.1 gezeigten Vorgehensweise beschrieben. Um die hohe Komplexität des Themengebietes und die damit einhergehende Fülle an Fachbegriffen durchgehend beibehalten zu können, wurde eine einheitliche Struktur der technischen Systeme angestrebt. Diese sollte zudem die ohnehin vorhandene Subjektivität einer Wirkungsfeldabschätzung mit den zur Bearbeitung vorliegenden Informationen und Werkzeugen herabsetzen und damit zur Nachvollziehbarkeit der einzelnen Bewertungsschritte beitragen. Zur Einführung in die hier angewendete Strukturierung wird zunächst eine Begriffsdefinition gegeben. Darauf aufbauend wurden die benannten Fahrerassistenzsysteme in Ihrer Funktion näher beschrieben und ihrer Wirkketten abgeleitet. Anhand der Wirkketten wurde die Einteilung in die Struktur vorgenommen. Mit Hilfe dieser Struktur sollte dann die in Kap. 2.4 beschriebene Wirkfeldanalyse vorgenommen werden.

2.3.1 Begriffsdefinition

Einleitend soll hier eine kurze Übersicht über die im Projekt betrachteten Fahrerassistenzsysteme gegeben werden. Für die Entwicklung einer funktionsbasierten Struktur ist es erforderlich, eine grundlegende Einteilung bezogen auf den jeweiligen Einsatz- bzw. Unterstützungsbereich des FAS vorzunehmen. Eine erste Unterscheidung erfolgte hier in aktive und passive Systeme. Da passive Systeme in der vorliegenden Studie eine untergeordnete Rolle spielen, werden weiterführend nur aktive Systeme unterteilt. In Anlehnung an [8] erfolgt eine weitere Gliederung nach dem 3-Ebenen-Modell der Fahrzeugführung von Donges.

Die oberste Ebene des 3-Ebenen-Modells der Fahrzeugführung wird als „Navigationsebene“ bezeichnet. Sie umfasst sämtliche Prozesse, welche die eigentliche Planung der Fahrt betreffen. Dazu zählen die Auswahl von Transportmittel und geeigneter Fahrtroute sowie die Abschätzung des Zeitbedarfs. Die Auswahl erfolgt nach persönlichen Kriterien wie Kosten, Zeitbedarf und Streckenbekanntheit. Das Verhalten auf der Navigationsebene bildet somit den motivationalen Hauptanteil der Fahraufgabe, wobei es regelungstechnisch im Grunde kaum an der eigentlichen Fahrzeugführung beteiligt ist, da diese Prozesse entweder vor Fahrtantritt bereits abgeschlossen sind, oder während der Fahrt nur bei Änderung der Fahrtroute oder Navigation durch unbekanntes Gebiet erfolgen. Gleichzeitig erzeugen Handlungen auf Navigationsebene die höchste kognitive Beanspruchung.

Die eigentliche Umsetzung der auf Navigationsebene bestimmten Fahrtroute in Form einzelner Fahrmanöver erfolgt auf der mittleren Modellebene, welche als „Bahnführungsebene“ bezeichnet wird. Diese umfasst Prozesse wie die vorausschauende Wahrnehmung der Verkehrssituation und die Ableitung von Führungsgrößen der Fahrzeugbewegung (Soll-Spur, Soll-Geschwindigkeit). Des Weiteren obliegt dieser Ebene auch die Ausführung der notwendigen Fahrmanöver in Form antizipatorischer Eingriffe in die Fahrzeugbewegung im Sinne einer Steuerung (Open-Loop). Die Antizipation besteht hierbei darin, dass der Fahrer ein gewisses Systemverständnis über die Dynamik seines Fahrzeugs besitzt, welches er nutzt, um beispielsweise für eine gewünschte Bahnkrümmung einen passenden Lenkwinkel bzw. ein Lenkmoment und die dazu erforderliche Schräglage (Rollwinkel) einzustellen. Der Prozess der Steuerung läuft dabei kontinuierlich ab, die Planung der Fahrmanöver selbst in diskreten Zeitschritten von einigen Sekunden. Die kognitive Beanspruchung bei der Ausführung dieser Handlungen ist im Normalfall wesentlich geringer als auf Navigationsebene.

Die unterste Modellebene wird als „Stabilisierungsebene“ bezeichnet. Auf ihr werden die eventuellen Abweichungen des aktuellen Bewegungszustandes des Egofahrzeugs von der Soll-Trajektorie bzw. des Rollwinkels der Bahnführungsebene erfasst und im Sinne einer kompensatorischen Regelung ausgeglichen. Dies ist notwendig, da das Systemverständnis des Fahrers über sein eigenes Fahrzeug auf Bahnführungsebene i.d.R. nur bedingt genau ist und auch Störgrößen nicht hinreichend berücksichtigen kann. Ein einfaches Beispiel stellt in diesem Zusammenhang das Auftreten von Seitenwind auf einer geraden Strecke dar. Der Verlauf der Soll-Trajektorie erfordert keinerlei Lenkwinkel bzw. -moment, welcher durch Antizipation eingestellt werden könnte. Die Störgröße „Seitenwind“ hat jedoch eine Abweichung zwischen Soll- und Ist-Spur zur Folge, welche durch einen zusätzlichen Lenkwinkel bzw. -moment auszuregeln ist. Sowohl die Erfassung der Regelabweichungen als auch die Regeleingriffe laufen nahezu kontinuierlich ab und erzeugen nur minimale kognitive Beanspruchung.

Für die Erfüllung der jeweiligen Aspekte der Fahraufgabe sind spezielle Fähigkeiten des Fahrers erforderlich. Diese Fähigkeiten müssen in geeigneter Weise angesprochen werden (Vgl.: [9]). Sind die Fahraufgabe, die anzusprechenden Fähigkeiten und die dazugehörigen Schnittstellen bekannt, kann der Fahrer besser unterstützt werden. Als weiterführende Literatur sei hier auf [8], [9], [10] und [11] verwiesen.

In Abb. 2.4 ist eine schematische Gliederung der hier betrachteten Fahrerassistenzsysteme dargestellt.

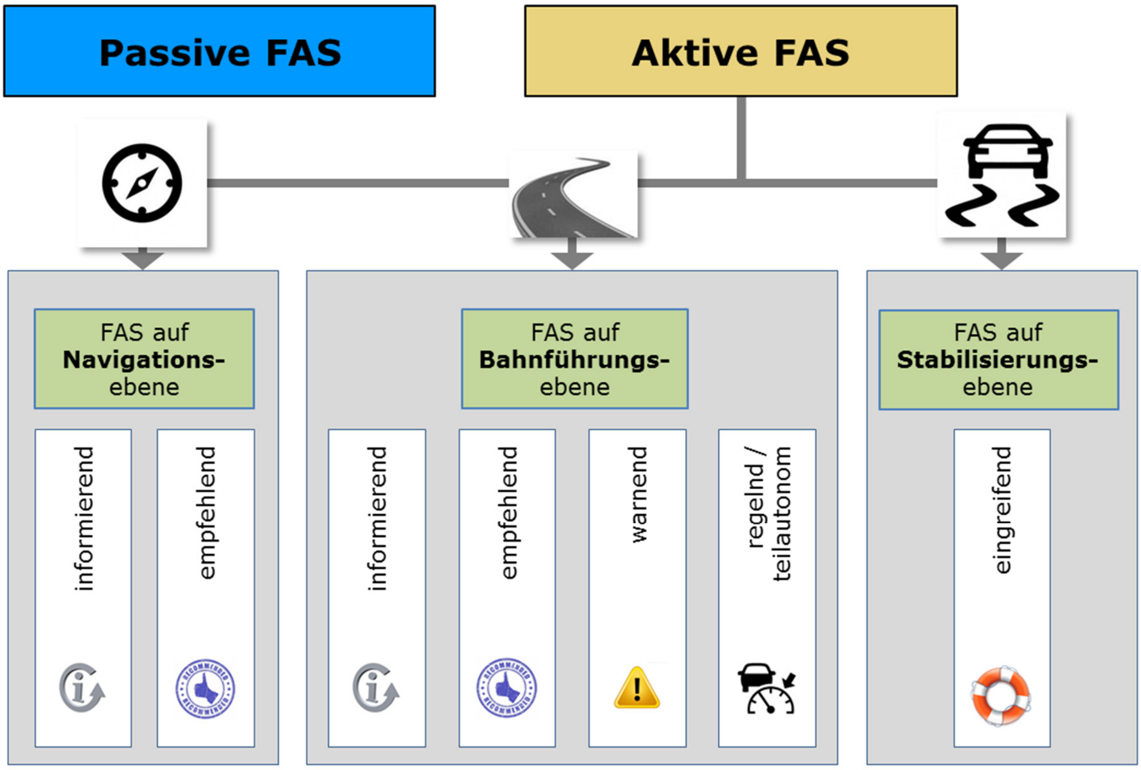


Abb. 2.4. Einteilung Fahrerassistenzsysteme

Fahrerassistenzsystem (FAS)

Zitat: „Fahrerassistenzsysteme sind *Systeme*, die geeignet sind, den Fahrer in seiner Fahraufgabe hinsichtlich Wahrnehmung, Fahrplanung und Bedienung zu unterstützen – sie wirken damit bei der Navigation, der Fahrzeugführung und der Fahrzeugstabilisierung. Sie können signifikant zur Unfallvermeidung und Unfallfolgenminderung beitragen. Dazu gehören zum Beispiel Systeme der Bereiche Fahrdynamik, Licht, Umfeldinformation und die intelligente Vernetzung mit Systemen der passiven Sicherheit.“ – Deutscher Verkehrssicherheitsrat, 2006

System

Ein System ist die Gesamtheit von *Elementen*, die zueinander in Beziehung stehen, sodass sie als eine Einheit angesehen werden können, die einem Zweck bzw. einer Aufgabe dient und sich in dieser Hinsicht von der sie umgebenden Umwelt abgrenzt.

Elemente = Systemkomponenten

Elemente sind Komponenten eines Systems, die so aufeinander abgestimmt sind bzw. in Wechselwirkung zueinander stehen, sodass sie einen Beitrag zu den *Basisfunktionen* des Gesamtsystems leisten. Ohne die Elemente ist das System nicht in der Lage, die ihm zugedachte Aufgabe zu erfüllen. Elemente von Fahrerassistenzsystemen sind z.B. Sensoren, Steuergeräte, Blinker, Bildschirm etc.

Basisfunktion

Als Basisfunktion wird eine Aufgabe bezeichnet, die das Fahrerassistenzsystem zu erfüllen hat, um eine *Gefahrensituation* zu erfassen, zu bewerten oder positiv zu beeinflussen, sodass der PONR (point of no return) nicht erreicht, oder Unfallfolgen minimiert werden. Erfüllt das FAS die geforderte Aufgabe, wird von "Funktionalität" gesprochen. Ist ein Fahrerassistenzsystem dazu in der Lage mehrere Funktionen zu erfüllen, so wird dies als "Multifunktionalität" bezeichnet. Bei der Ausübung der Funktion bedient sich das System der Elemente und lässt diese miteinander interagieren.

Gefahrensituation

In der vorliegenden Arbeit ist die Gefahrensituation eine kritische Situation, die ein hohes Risiko birgt einen Schaden zu erleiden und beschreibt die unfallauslösenden Gegebenheiten.

Risiko

Unter Risiko wird hier die Kombination aus der Wahrscheinlichkeit einen Schaden zu erleiden und dem Schweregrad des Schadens verstanden.

2.3.2 Erstellung einer funktionsbasierten Struktur der Fahrerassistenzsysteme

Zu Beginn der Untersuchung des Wirkfeldes von Fahrerassistenzsystemen für motorisierte Zweiräder erfolgte zunächst eine Stoffsammlung zu bereits bestehenden und sich in Entwicklung befindenden Fahrerassistenzsystemen auf Basis einer Literaturrecherche. Es wurde jeweils eine funktionsbasierte Struktur dieser Systeme erstellt. In Abb. 2.5 ist ein Ausschnitt der Grafik zu sehen. Durch farbliche Kennzeichnung wurden Unterscheidungen zum Reifegrad vorgenommen, die jedoch für die Darstellung des methodischen Vorgehens nicht von Bedeutung sind. Die Darstellung der Fahrerassistenzsysteme erfolgte größtenteils wirk- und funktionsbasiert. Zur Erstellung wurden u.a. Fahrerassistenzsysteme aus dem Automobilbau übernommen und Vorschläge sowie Anforderungen zur Anpassung an das Motorrad definiert. Die unterbreiteten Vorschläge stellen keine endgültigen Lösungen für die Systeme dar. Sie sollen zum einen Anregungen zu einer möglichen Gestaltung geben und zum anderen war es wichtig, eine möglichst genaue Festlegung aller Funktionalitäten für eine darauf aufbauende Bewertung zu treffen. Auf den Hintergrund der Funktionsdarstellung wird im Folgenden noch näher eingegangen. Auf Grundlage der Ergebnisse der Unfallstatistik erfolgten zudem Funktionserweiterungen zu sowohl bestehenden als auch zukünftigen Assistenzsystemen.

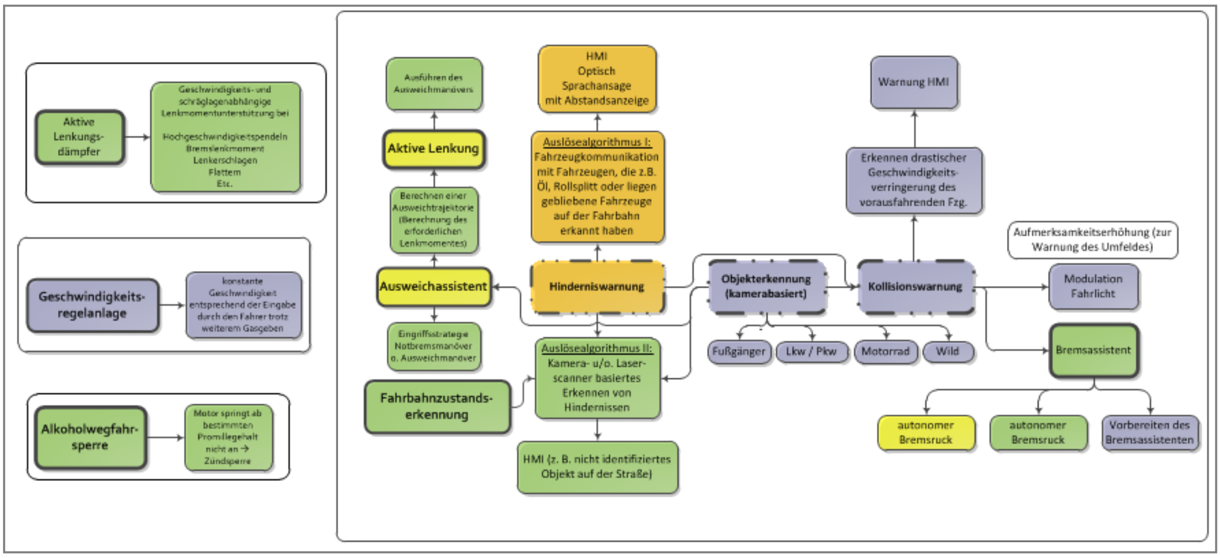


Abb. 2.5. Ausschnitt aus der funktionsbasierten Struktur von Fahrerassistenzsystemen

Auf die Stoffsammlung aufbauend erfolgte eine Detailbetrachtung der Fahrerassistenzsysteme mittels Wirkkettenplänen. In den Wirkketten wird der zeitliche Verlauf der Wirkungsweise jedes einzelnen Fahrerassistenzsystems dargestellt. Der Signalfluss zwischen den Systemkomponenten ist in seiner allgemeinen Struktur in Abb. 2.6 dargestellt.

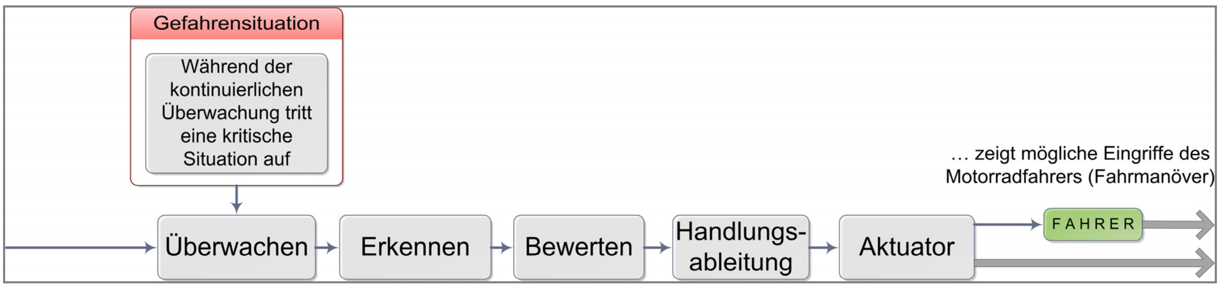


Abb. 2.6. Allg. Struktur des Signalflussplans eines Fahrerassistenzsystems

Die Aktivierung des Systems durch Betätigen des Zündschalters, einer Fahrerhandlung (z.B. Bremsen) oder durch Fahrerwunsch (z.B. Knopfdruck) wird durch einen Pfeil auf der linken Seite der Wirkkette gekennzeichnet. Nachdem das Assistenzsystem aktiviert wurde, erfolgt je nach System mittels Sensoren eine permanente Überwachung des Fahrzeugzustandes und/oder des Fahrzeugumfeldes bzw. eine Überwachung des Fahrers. Damit ist es zu jedem Zeitpunkt möglich, die Gefahrensituation zu erkennen. Die sensorisch ermittelten Daten werden an eine elektronische Steuereinheit weitergeleitet und mit einem geeigneten Auswertealgorithmus bewertet. Dabei werden die gemessenen Werte bzw. daraus berechneten Parameter z.B. mit Referenzwerten verglichen und je nach Ergebnis des Vergleichs entsprechende Handlungen abgeleitet und Stellgrößen berechnet. Die Stellgrößen werden an Aktuatoren weitergeleitet, die Handlungen, wie z.B. Fahrlichtmodulation oder „Informationen an den Fahrer", ausführen.

Bei den passiven Systemen Tagfahrlicht und Schutzausrüstung ist diese Struktur der Wirkkette nicht möglich. Hier erfolgte daher eine nicht vernetzte Darstellung der Basisfunktionen.

In Abb. 2.7 ist als Beispiel die Wirkkette des Linksabbiegeassistenten dargestellt. Weitere Wirkketten der o.g. Fahrerassistenzsysteme sind dem Anhang zu entnehmen.

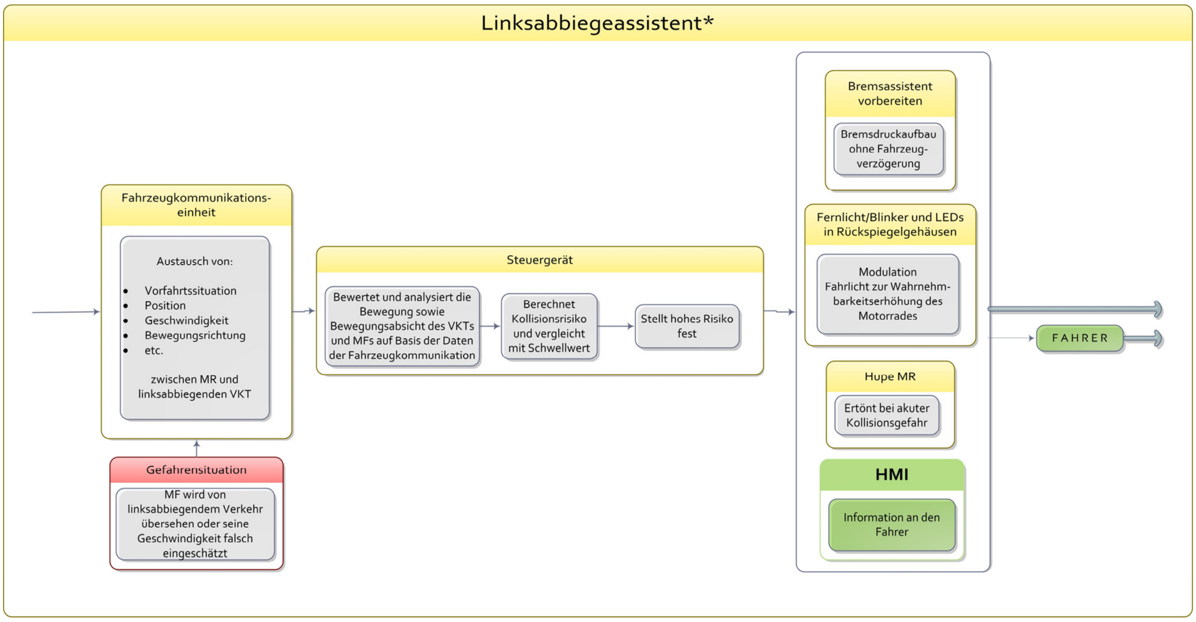


Abb. 2.7. Wirkkette am Beispiel eines Linksabbiegeassistenten

In Abb. 2.7 sind die Module Überwachen und Erkennen (Fahrzeugkommunikationseinheit), Bewerten und Handlungsableitung (Steuergerät) sowie Aktuator (Fahrlichtmodulation, Mensch-Maschine-Schnittstelle etc.) zu erkennen. Jedes Element ist durch eine gelbe Box gekennzeichnet, in der die jeweils ausgeführte Basisfunktion steht. Die Gefahrensituation wird durch eine rote Box gekennzeichnet, in der die kritische Situation konkret beschrieben wird. Insbesondere bei warnenden, informierenden und empfehlenden Assistenzsystemen wird der Fahrer in die Wirkkette einbezogen. Darauf soll später noch genauer eingegangen werden. Bei autark eingreifenden Assistenzsystemen, wie dem ABS, wird davon ausgegangen, dass ein Fahrereinfluss nicht gegeben ist, da diese Systeme deutlich schneller eine kritische Situation erfassen und gezielt eingreifen können. Besteht dennoch ein Einfluss des Fahrers auf den

Unfallablauf, so wird dieser durch eine grüne, ovale Box gekennzeichnet. In Abhängigkeit der Form der Arbeitsteilung zwischen Mensch und Maschine übernimmt der Fahrer dabei zeitlich unterschiedliche Aufgaben. Bei der seriellen Form der Arbeitsteilung werden von Fahrer und System verschiedene Aufgaben abwechselnd nacheinander ausgeführt. Bei der parallelen Form führen System und Fahrer parallel ablaufende Aufgaben aus. In der dritten Form der Arbeitsteilung, die auch als „Assistenzfunktion" bezeichnet wird, werden von Fahrer und System die gleichen Aufgaben redundant- parallel ausgeführt. In Abhängigkeit der Arbeitsform erfolgt der zeitliche Einfluss des Fahrers auf den Unfallablauf unterschiedlich. Bei informierenden, empfehlenden und warnenden Systemen ist es stets möglich, dass Fahrer und Assistenzsystem parallel die gleichen Aufgaben durchführen. Diese Form der Arbeitsteilung wurde zu Gunsten der Übersicht in den Wirkketten vernachlässigt und vereinfacht davon ausgegangen, dass der Fahrer erst nach der Information des Systems mit einer entsprechenden Fahrerhandlung reagiert.

Dies ist z.B. beim dargestellten Linksabbiegeassistenten der Fall. Das System bemerkt, das der entgegenkommende Verkehrsteilnehmer links abbiegen möchte, obwohl eine Kollision mit dem vorfahrtberechtigten Motorradfahrer droht. Durch die Fahrzeugkommunikation werden die relevanten Daten beider Fahrzeuge erfasst und mittels der elektronischen Steuereinheit bewertet. Der Motorradfahrer ist ebenfalls in der Lage, die drohende Kollision zeitnah zu erfassen und falls notwendig, zu reagieren. Somit liegt die dritte Form der Arbeitsteilung vor. Hier wird vereinfacht davon ausgegangen, dass zunächst das Fahrerassistenzsystem agiert und dann der Fahrer durch entsprechende Fahrmanöver eingreift, falls der drohende Kollisionskontrahent nicht entsprechend auf die Warnung reagiert. Die blauen Pfeile am Ende der Wirkkette kennzeichnen den Ausgang der kritischen Situation. Ob die kritische Situation dabei durch den Eingriff des Assistenzsystems oder durch entsprechende Fahrerhandlungen abgewendet werden kann oder nicht, wird in der Wirkkette offen gelassen und erst in der Wirkungsfeldmatrix untersucht. Aus dem geschilderten Sachverhalt des Fahrereinflusses lässt sich bereits an dieser Stelle festhalten, dass bei der Bewertung von Systemen, die den Fahrer in die Wirkkette einbeziehen und somit der Unfallablauf u.U. nur durch eine entsprechende Fahrerhandlung positiv beeinflusst wird, der Fahrer in die Bewertung mit einbezogen werden muss. Ignoriert der Motorradfahrer die Warnung des Systems, so kann der zunächst positive Nutzen des Systems durch die gegebenen Basisfunktionen gering werden. Anderenfalls, bei entsprechender Reaktion und Handlung des Motorradfahrers kann es u.U. möglich sein, die Gefahrensituation noch vor Erreichen des point of no return abzuwenden.

Nach Abschluss der Detailbetrachtungen der Systeme erfolgten Vorüberlegungen für die Potenzialfeldabschätzung der Fahrerassistenzsysteme für motorisierte Zweiräder. Um die Herangehensweise zur Potenzialfeldabschätzung möglichst objektiv und nachvollziehbar zu gestalten, wurden die Fahrerassistenzsysteme in Basisfunktionen und Elemente abstrahiert. Weiterhin wurde eine Bewertungsmethode entwickelt, die ebenfalls das Ziel einer möglichst objektiven Beurteilung der Fahrerassistenzsysteme verfolgt. Auf diese wird in Abschnitt 2.4.2 näher eingegangen. Die Abb. 2.8 zeigt der Bewertung der Systeme zugrundeliegende Struktur.

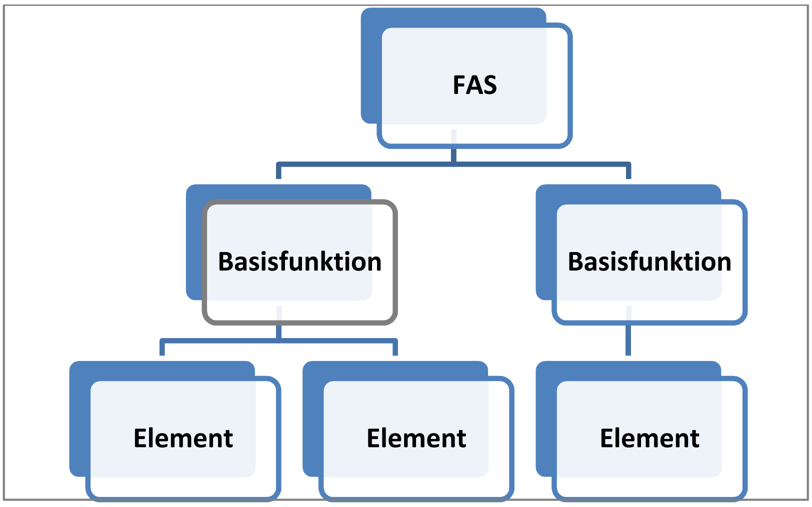


Abb. 2.8. Struktur der Fahrerassistenzsysteme

Eine subjektive Betrachtung und Einschätzung des Wirkfeldes kann zu einer Pauschalisierung der Wirkungsfelder der Fahrerassistenzsysteme führen. Mittels der Abstrahierung in Basisfunktionen und weitere hier beschriebenen Maßnahmen soll dies weitestgehend unterbunden werden.

Als *Basisfunktion* wird daher wie in 2.3.1 definiert eine Aufgabe bezeichnet, die das Fahrerassistenzsystem durch seine gegebenen Komponenten (Elemente) erfüllen kann und somit in Abhängigkeit von weiteren vorhandenen Basisfunktionen in der Lage ist, eine Gefahrensituation zu erkennen, bewerten und entsprechende, den Fahrer unterstützende Maßnahmen einzuleiten. Infolgedessen kann das System durch die gegebenen Basisfunktionen dazu beitragen den Unfallablauf positiv zu beeinflussen, sodass der point of no return u.U. erst gar nicht erreicht wird oder Unfallfolgen gemindert werden können. Bei der Ausübung der Basisfunktionen bedient sich das System der Elemente und lässt diese miteinander agieren. Die Elemente sind dabei Komponenten des Systems, die so aufeinander abgestimmt sind bzw. in Wechselwirkung zueinander stehen, sodass sie einen Beitrag zu den Basisfunktionen des Gesamtsystems leisten. Ohne die Elemente ist das System nicht in der Lage, die ihm zugedachten Aufgaben zu erfüllen. Elemente sind z.B. Sensoren, Steuergeräte, Blinker, Bildschirm etc.

Die Basisfunktionen und Elemente wurden aus den zuvor erstellten Wirkketten abgeleitet. Da die Bewertung der Fahrerassistenzsysteme hinsichtlich ihres Wirkfeldes mittels der Basisfunktionen erfolgt, war es wichtig, bei allen Systemen und hier insbesondere bei den zukünftigen Systemen möglichst alle Funktionalitäten zu definieren.

Für die Bewertung, welche in Kapitel 2.4.2 noch näher beschrieben wird, wurden die Basisfunktionen der Fahrerassistenzsysteme entsprechend Ihrer Wirkketten in die Bereiche Wahrnehmen, Bewerten und Agieren unterteilt. Tab. 2.1 zeigt am Beispiel eines ABS die vorgenommene Einteilung.

Tab. 2.1. Basisfunktionen in Bereiche eingeteilt Bsp. ABS

Wahrnehmen	Erkennen der Raddrehzahlen
	Bremsdruckerkennung
Bewerten	Ermittelt Raddrehzahlgradient und Vergleich mit Schwellwert
	berechnet Ventiltaktzeit
Agieren	Bremse auf Bremse zu (Bremsdruckmodulation)
	aktive Bremsdruckverteilung (ABD) HR/VR
	Bremsschlupf um Reibwertmaximum regeln
	Information an Fahrer (HMI)

2.4 Wirkfeldanalyse

Das Ziel dieses Kapitels ist es, Wirkungsfelder von bestehenden und zukünftigen Fahrerassistenzsystemen für motorisierte Zweiräder, in Bezug auf statistisch ermittelte Unfallszenarien, aufzudecken und Entwicklungstendenzen aufzuzeigen. Hierfür stellt die Wirkungsfeldmatrix das Grundgerüst der Untersuchung dar. Der Aufbau der Matrix wird im nachfolgenden Abschnitt 2.4.1 detailliert erläutert.

Bevor im nächsten Schritt das Schutzpotenzial der 35 Fahrerassistenzsysteme bezüglich der Unfallszenarien in der Wirkungsfeldmatrix beurteilt werden konnte, musste zunächst eine geeignete Bewertungsmethode entwickelt werden. Für eine möglichst objektive Herangehensweise zur Potenzialfeldabschätzung der Assistenzsysteme war es dabei insbesondere wichtig, diese Methode so zu gestalten, dass die Systeme weitestgehend losgelöst von der subjektiven Meinung der Autoren bewertet werden. Im Zusammenhang mit den zuvor in Basisfunktionen abstrahierten Fahrerassistenzsystemen wurde eine Bewertungsmethode entwickelt, die eine weitestgehend objektive Beurteilung des Schutzpotenzials der Systeme erlaubt. Im Abschnitt 2.4.2 wird auf diese Methode ausführlich eingegangen.

2.4.1 Aufbau der Wirkfeldmatrix

Wie bereits in 2.3.2 erwähnt, wurden in der vorliegenden Arbeit bestehende und zukünftige Fahrerassistenzsysteme auf ihr Unfallvermeidungspotenzial bzw. ihr Potenzial hinsichtlich des Verringerns der Unfallfolgen untersucht. Beide Gruppen wurden zunächst getrennt, in zwei Wirkungsfeldmatrizen gleichen Aufbaus betrachtet. Grund dieser getrennten Untersuchung war, aus dem Ergebnis der Bewertung des Potenzials des aktuellen Standes der Technik, ggf. neue Systeme bzw. Funktionen zur Erhöhung der Fahrsicherheit abzuleiten.

Für die Grundstruktur der Matrizen wurde zunächst festgelegt, welche Fahrerassistenzsysteme untersucht werden sollen. Weiterhin wurden mittels einer umfassenden Unfallanalyse der Verkehrsunfallforschung der TU Dresden GmbH statistisch relevante Unfallszenarien von motorisierten Zweirädern bestimmt (Kapitel 2.2). Damit ist zunächst das Grundgerüst für die sich anschließende Potenzialfeldabschätzung geschaffen. In Abb. 2.9 wird ein Ausschnitt der Wirkungsfeldmatrix für bestehende Fahrerassistenzsysteme gezeigt.

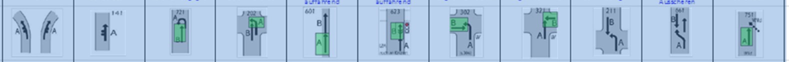
Unfallszenario			1 Fahrunfälle in Kurven	2 Fahrunfälle auf Geraden	3a Fahrstreifenwechsel durch Unfallgegner	3b Fahrstreifenwechsel durch Motorrad	4a Längsverkehr, Motorradfahrer auffahrend	4b Längsverkehr, Unfallgegner auffahrend	5 Kreuzungskonflikt, Gegner von rechts	6 Kreuzungskonflikt, Gegner von links	7 Gegenverkehr beim Abbiegen	8 Gegenverkehr beim Überholen / Ausscheren	9 Hindernisse auf der Straße		
grafische Darstellung des Unfalltyps des jeweiligen Unfallszenarios mit der größten Relevanz (Motorrad)															
TOP 10 der Unfalltypen des Unfallszenarios			101, 102, 121, 122, 151, 152, 123, 131, 111, 132	141, 153, 183 173, 163	721, 202, 631, 351, 232, 644, 649, 646, 641, 632	202, 721, 631, 633, 641, 646, 644, 642, 634, 204	601, 611, 623, 201, 612, 231, 621, 602, 613, 603	623, 601, 611, 201, 621, 612, 231, 602, 624, 613	302, 301, 303, 312, 371, 321, 361, 371, 311, 322	321, 322, 303, 271, 302, 312, 352, 301, 372, 332	211, 722, 723, 351, 343, 215, 281	661, 554, 521, 553	421, 401, 454, 411, 431, 402, 272, 463, 472, 471		
Relevanz gesamt			16,5%	6,6%	15,4%	1,4%	10,0%	3,3%	15,6%	6,2%	12,2%	1,7%	2,6%	91,5%	1,092896175
Relevanz gesamt auf 100% aufgewertet			18,05%	7,21%	16,83%	1,53%	10,95%	3,61%	17,05%	6,78%	13,33%	1,86%	2,84%	100,00%	
FAS 1	*Wahrnehmen*	Erkennen 1	1	1	0	0	0	0	0	0	0	0	0	0,252	
	Bewerten	Ermitteln und Vergleichen	1	1	0	0	0	0	0	0	0	0	0	0,252	
	Handeln	Begrenzen 1	1	1	0	0	0	0	0	0	0	0	0	0,252	
		Information an Fahrer (HMI)													
		Mittelwert (MW)	1,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	2,000 /22	
		Einflussfaktor (EF)	0	0	0	0	0	0	0	0	0	0	0		
		Durchschnitt gew.(ohne EF / FF)	0,180	0,072	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,252 /2,102	
		Durchschnitt gew.(mit EF / FF)												0,000	

Abb. 2.9. Ausschnitt der Wirkungsfeldmatrix bestehender FAS

In der blau unterlegten Zeile sind die elf Unfallszenarien aufgeführt. Jedes Szenario wurde mit einem Dokument verlinkt, das die Darstellung der Einzelunfalltypen beinhaltet. Weiterhin wurde zur Verdeutlichung der vorliegenden kritischen Situation zu jedem Szenario eine Grafik des am häufigsten vorkommenden Unfalltyps abgebildet. Dieser Abbildung folgen die Aufzählung der zehn häufigsten Unfalltypen sowie die Relevanz (Häufigkeit) jedes Szenarios.

In der grün unterlegten Spalte sind die Fahrerassistenzsysteme bzw. deren Basisfunktionen dargestellt. Die Basisfunktionen jedes Systems wurden den drei Modulen „Wahrnehmen", „Bewerten" und „Agieren" zugeordnet. Diese Einteilung folgt aus der zugrundeliegenden Bewertungsmethode und wird neben den farblichen Unterlegungen (orange, grün, gelb) sowie den weißen Feldern innerhalb der Matrix im folgenden Abschnitt 2.4.2 erläutert.

2.4.2 Bewertungsverfahren

Wie bereits in Kapitel 2.3 erwähnt, wird eine möglichst objektive Herangehensweise zur Potenzialfeldabschätzung der Fahrerassistenzsysteme angestrebt. Dazu wurden die Systeme in ihre physikalischen Basisfunktionen zerlegt. Darauf aufbauend wurde eine Bewertungsmethode entwickelt, die die Basisfunktionen in Abhängigkeit ihrer verrichteten „Tätigkeit" den drei Modulen „Wahrnehmen", „Bewerten" und „Agieren" zuordnet. Jedes Modul wurde für sich, unabhängig von den anderen Modulen nach folgenden Fragestellungen bewertet (Abb. 2.10). An das Bewertungsfahren wurden folgende Ansprüche gestellt:

- grafische Auswertung mittels Diagrammen ermöglichen
- objektive Bewertung

- übersichtliche Darstellung für ein schnelles Erkennen von "Hot Spots" (Auffälligkeiten)

Anfängliche Überlegungen beruhten auf einer Kennzeichnung des Unfallvermeidungs- bzw. Folgenminderungspotenzial der Fahrerassistenzsysteme mittels Plus-Minus-Zeichen. Diese Form der Bewertung ermöglicht jedoch keine arithmetische Auswertung, sodass es den gestellten Ansprüchen nicht genügt. Ebenso konnte das von Eichberger angewendete Bewertungsschema [12] mit einer Unterscheidung nach Unfallfolgen und Unfallvermeidung hier keine Anwendung finden. Neben der wie beim erstgenannten Verfahren fehlenden Möglichkeit zur arithmetischen Behandlung, setzt dieses Verfahren tiefgründige Untersuchung vor allem für Aussagen zur Unfallvermeidung voraus. Da diese nicht Gegenstand dieser Untersuchungen waren, wurde das im Folgenden beschriebene Verfahren entwickelt. Grundlage ist eine im weiteren Entwicklungsverlauf austauschbare Definitionstabelle, die den einzigen hier in der Wirkfelduntersuchung verbleibenden subjektiven Arbeitsschritt auflöst. Gelingt es in einem Anschlussprojekt, diesen Arbeitsschritt mit entsprechenden Ansätzen zu objektivieren, ist ein automatisiertes Bewertungsverfahren umsetzbar. Da hierfür jedoch auch Kenntnisse zu Eigenschaften des Fahrers und dessen Interaktionen mit den jeweiligen Fahrerassistenzsystemen erforderlich sind, sind für die Umsetzung dieser Objektivierung verschiedene Vorüberlegungen hinsichtlich der Abbildbarkeit erforderlich. Das hier entwickelte Bewertungsverfahren basiert auf der oben beschriebenen Definitionstabelle, welche als Bewertungsschema in Abb. 2.10 dargestellt ist.

			0	1	2
Wahrnehmung	Wie gut kann die Gefahrensituation unfallspezifisch erkannt werden?		erforderliche Parameter sind nicht erfassbar	grundlegende Parameter erfassbar	alle Parameter für eine gute Regelgüte erfassbar
Bewerten	Wie gut kann anhand der verfügbaren Parameter und des vorliegenden Bewertungsalgorithmus die unfallspezifische Gefahrensituation bewertet werden?		kann nicht bewertet werden	kann grob bewertet werden	kann gut bewertet werden
Agieren	Wie hoch ist der positive Einfluss der abgeleiteten Handlung auf den Unfallablauf bzw. dessen Folgen?		hat keinen Einfluss	hat geringen positiven Einfluss	hat großen positiven Einfluss

Abb. 2.10. Bewertungsschema

Die Absicht hinter dieser entkoppelten Bewertung ist das Erreichen einer vergleichbaren Bewertbarkeit bestehender und zukünftiger Fahrerassistenzsysteme. Somit ist es möglich, die Module mit dem größten Potenzial zum Erfassen, Bewerten und Beeinflussen (Agieren) der Gefahrensituation zu erkennen und Entwicklungstendenzen aufzuzeigen. Agieren die drei Module miteinander, so erhält das System in Abhängigkeit des Zusammenspiels der Module eine entsprechende Bewertung und stellt sich damit z.B.

über die Systeme, die lediglich die Unfallsituation erfassen können, aber keinen passenden Bewertungsalgorithmus oder eine Eingriffsstrategie zur Verfügung stellen. Demzufolge wird sowohl das Schutzpotenzial des gesamten Systems betrachtet, als auch, welchen Beitrag jedes Modul zum Schutzpotenzial des Systems leisten kann.

Nachfolgend wird die Bewertung der Module beschrieben. Zunächst wurden die Einzelunfalltypen jedes Szenarios zusammen mit einer Statistik zu unfallszenarienspezifischen Unfallursachen analysiert. Dies diente der Konstellation von möglichen Gefahrensituationen. Weiterhin wurden die Wirkketten der Fahrerassistenzsysteme und deren Basisfunktionen betrachtet. In Vorarbeit wurde erörtert, welche Anforderungen ein Fahrerassistenzsystem zu erfüllen hat, um möglichst alle Unfälle des jeweils betrachteten Szenarios verhindern zu können. Diese Anforderungen wurden mit den vorhandenen Basisfunktionen jedes Fahrerassistenzsystems verglichen. In Anlehnung an [12] erfolgte eine Einschätzung des Verfassers, inwieweit die gegebenen Basisfunktionen mit den idealen Basisfunktionen übereinstimmen. In Abhängigkeit des Übereinstimmungsgrades und der Wichtigkeit der Basisfunktionen wurden die einzelnen Module bewertet und die Punkte null bis zwei vergeben. Anschließend wurde über die drei Module ein Mittelwert gebildet. Dieser Mittelwert wurde dann mit der jeweiligen Relevanz des Unfallszenarios multipliziert und als gewichteter Mittelwert dargestellt. Er zeigt das Wirkungsfeld des jeweils betrachteten Fahrerassistenzsystems.

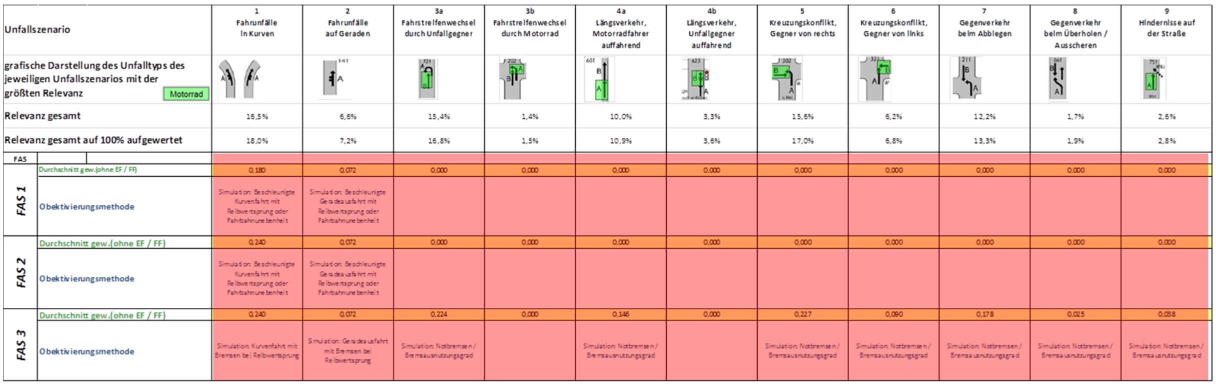
Zwischen dem gewichteten und ungewichteten Durchschnitt wurde der Einflussfaktor des Fahrers eingetragen. Dieser drückt aus, ob der Motorradfahrer in die Wirkkette des Fahrerassistenzsystems einbezogen wird. Der Fahrereinfluss ist insbesondere bei informierenden, empfehlenden und warnenden Systemen gegeben, bei denen die auftretende Gefahrensituation größtenteils nur durch eine der Warnung, Empfehlung oder Information durch das System folgende, entsprechend richtige Fahrerhandlung abgewendet werden kann. Ist ein solcher Einfluss des Fahrers gegeben, dann wurde eine „1“ eingetragen anderenfalls eine „0“, wie z.B. bei der autonom regelnden Stabilitätskontrolle. Der Eintrag des Fahrereinflusses erfolgte in Vorarbeit auf einen vollständigen Einbezug des Fahrers in die Bewertungsmethode, welcher insbesondere bei Systemen, die einen Fahrereingriff bedingen, notwendig ist, um das Schutzpotenzial umfassend bewerten zu können. Dazu wurde die gelbe Zeile als Platzhalter eingefügt. Die Einbeziehung des Fahrers in die Wirkfelduntersuchung kann die Aussagekraft der vorliegenden Matrix bei entsprechender Beschreibung deutlich erhöhen.

Der gewichtete und ungewichtete Mittelwert sowie die gewichteten Module wurden über alle elf Unfallszenarien aufsummiert und normiert. Weiterhin wurden die gewichteten Mittelwerte der bestehenden und zukünftigen Fahrerassistenzsysteme pro Unfallszenario aufsummiert.

2.5 Methoden zur Objektivierung der Wirkungsfelder

2.5.1 Methodenmatrix

In der Methodenmatrix werden die zur weiteren Objektivierung des Wirkungsfeldes erforderlichen Schritte (rot markiert) dargestellt. Dazu wurden anhand der absoluten Häufigkeit spezifischer Unfalltypen je Unfallszenario zum Beispiel konkrete Fahrmanöver in der Simulation oder Untersuchungen zur Wirkung des Fahrers abgeleitet. In dieser ersten Untersuchung wurden besonders die bei den Projektpartnern vorhandenen Möglichkeiten und Erfahrungen berücksichtigt.



Unfallszenario		1 Fahrunfälle in Kurven	2 Fahrunfälle auf Geraden	3a Fahrstreifenwechsel durch Unfallgegner	3b Fahrstreifenwechsel durch Motorrad	4a Längsverkehr, Motorradfahrer auffahrend	4b Längsverkehr, Unfallgegner auffahrend	5 Kreuzungskonflikt, Gegner von rechts	6 Kreuzungskonflikt, Gegner von links	7 Gegenverkehr beim Abbiegen	8 Gegenverkehr beim Überholen / Ausscheren	9 Hindernisse auf der Straße
grafische Darstellung des Unfalltyps des jeweiligen Unfallszenarios mit der größten Relevanz (Motorrad)												
Relevanz gesamt		16,5%	6,6%	15,4%	1,4%	10,0%	3,3%	15,6%	6,2%	12,2%	1,7%	2,6%
Relevanz gesamt auf 100% aufgewertet		18,0%	7,2%	16,8%	1,5%	10,9%	3,6%	17,0%	6,8%	13,3%	1,9%	2,8%
FAS												
FAS 1	Durchschnitt gew.(ohne EF / FF)	0,180	0,072	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Obektivierungsmethode	Simulation: Beschleunigte Kurvenfahrt mit Reibwertsprung oder Fahrbahnunebenheit	Simulation: Beschleunigte Geradeausfahrt mit Reibwertsprung oder Fahrbahnunebenheit									
FAS 2	Durchschnitt gew.(ohne EF / FF)	0,240	0,072	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	Obektivierungsmethode	Simulation: Beschleunigte Kurvenfahrt mit Reibwertsprung oder Fahrbahnunebenheit	Simulation: Beschleunigte Geradeausfahrt mit Reibwertsprung oder Fahrbahnunebenheit									
FAS 3	Durchschnitt gew.(ohne EF / FF)	0,240	0,072	0,224	0,000	0,146	0,000	0,227	0,090	0,178	0,025	0,058
	Obektivierungsmethode	Simulation: Kurvenfahrt mit Bremsen bei Reibwertsprung	Simulation: Geradeausfahrt mit Bremsen bei Reibwertsprung	Simulation: Notbremsen / Bremsausnutzungsgrad		Simulation: Notbremsen / Bremsausnutzungsgrad		Simulation: Notbremsen / Bremsausnutzungsgrad	Simulation: Notbremsen / Bremsausnutzungsgrad	Simulation: Notbremsen / Bremsausnutzungsgrad	Simulation: Notbremsen / Bremsausnutzungsgrad	Simulation: Notbremsen / Bremsausnutzungsgrad

Abb. 2.11. Methodenmatrix

3 Entwicklung der Simulationsumgebung

Die Simulationsumgebung der Verkehrsunfallforschung dient der Rekonstruktion realer Unfallsituationen. Die hierfür benötigten Informationen wie beispielsweise die Unfallskizze und die Einlaufgeschwindigkeiten der am Unfall beteiligten Fahrzeuge sind in einer Datenbank hinterlegt. Die Simulationsumgebung selbst ist in MATLAB/ Simulink programmiert, wobei der Kollisionspartner z.B. mit Hilfe von carSIM® modelliert und in diese Umgebung eingebettet wird. Die Abbildung des Motorrades erfolgte bisher als rheonom geführtes kinematisches Modell, welches keine eigene Dynamik besitzt. Für eine realitätsnahe Simulation des Unfallgeschehens ist allerdings eine dynamische Interaktion beider Fahrzeuge innerhalb der Unfallumgebung unerlässlich. Aus diesem Grund wurde im Rahmen dieses Projektes das Motorrad als MKS Modell codebasiert in die VUFO-Simulationsumgebung integriert. Ein wichtiger sich daraus ergebender Vorteil ist, dass Zustandsgrößen wie Gierrate und Rollwinkel ermittelt werden können, die zur Entwicklung sicherheitsrelevanter Fahrassistenzsysteme notwendig sind.

Beispielhaft wurde dazu ein mit dem von der TU Dresden entwickelten Motorradbaukasten in der Mehrkörpersimulationssoftware SIMPACK erstelltes Fahrdynamikmodell in die VUFO Simulationsumgebung eingebunden. Da diese Simulationsumgebung in MATLAB/Simulink programmiert ist, erfolgte die Integration des Motorradmodells als sog. S-Function mit Hilfe der Code-Export-Funktion von SIMPACK.

Um auch das Aufschlagen des umgekippten Motorrads auf dem Boden sowie das Rutschen über eine Fahrbahnoberfläche simulieren zu können, wurde das Motorradmodell um die erforderlichen Funktionalitäten erweitert.

3.1 Das Simulationsmodell

3.1.1 Modellstruktur

Der Motorradbaukasten ist modular aufgebaut, so dass sich verschiedene Konfigurationen von Motorrädern schnell und unkompliziert erstellen lassen. Für folgende Baugruppen sind voll parametrisierte Substrukturen (Teilmodelle) vorhanden:

- Vorder- und Hinterradführung
- Hauptrahmen
- Räder und Bremsen

Beispielhaft zeigt Abb. 3.1 die implementierten Bauarten der Vorderradführung.

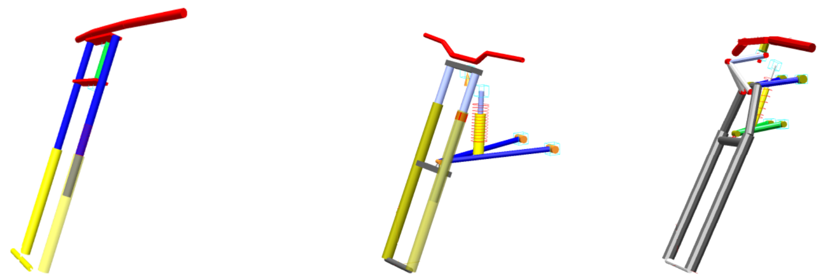


Abb. 3.1. Vorderradführungen (Teleskop-Federgabel, Telelever®, Duolever®)

Die verschiedenen Bauarten sind hierbei als Starrkörpermodelle ausgeführt.

Der Fahrer kann im MKS-Modell auf zwei Arten modelliert werden, wie Abb. 3.6 veranschaulicht. Das MKS-Modell des Fahrers ist eine aus 12 Starrkörpern bestehende, passive Substruktur, das heißt von diesem Modell gehen keinerlei Regeleingriffe zur Fahrzeugführung aus. Vereinfachend können der Massen- und Trägheitseinfluss des Fahrers auch durch einen fest mit dem Rahmen verbundenen Starrkörper berücksichtigt werden. Für die hier vorgestellten Simulationsrechnungen wurde die zweite Variante verwendet.

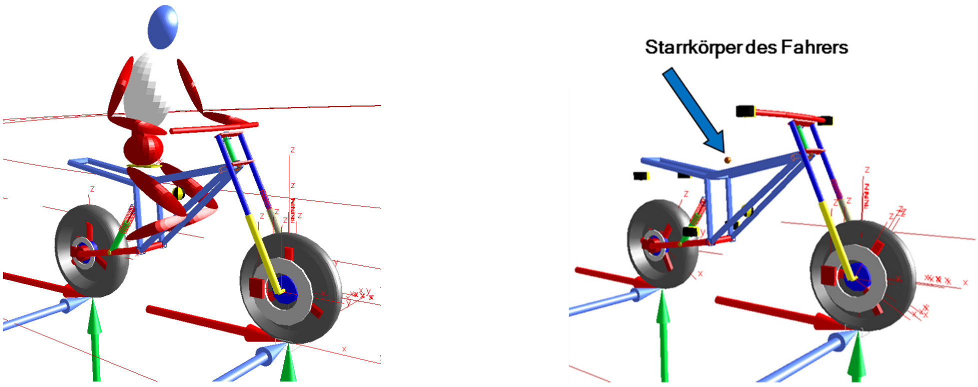


Abb. 3.2. Fahrermodellierung als MKS Modell (links) und als Starrkörper (rechts)

Die Fahrzeugführung durch den Fahrer wird mit Hilfe eines in MATLAB/Simulink implementierten Reglermodells abgebildet, das dafür verantwortlich ist, das Fahrzeug unter Berücksichtigung eines Sollgeschwindigkeitsverlaufs entlang der gewünschten Trajektorie zu führen. Das Reglermodell tauscht mit dem MKS Motorradmodell in einer Co-Simulation Mess-, Stell- und Zustandsgrößen aus, Abb. 3.3.

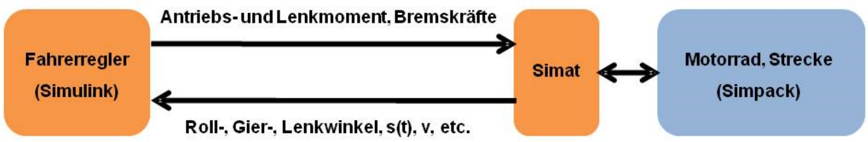


Abb. 3.3. Funktionsschema der Co-Simulation

Der Fahrerregler beinhaltet einen Längsdynamikregler, der die Einhaltung des aus der Geschwindigkeitsplanung resultierenden Sollgeschwindigkeitsverlaufs gewährleistet, und dazu als Stellgrößen ein Antriebsmoment am Hinterrad bzw. Bremskräfte an beiden Rädern an das MKS Modell übergibt. Ein Querdynamikregler leitet aus den Regeldifferenzen des Rollwinkels und der lateralen Abweichung von der Solltrajektorie ein Lenkmoment ab, das als Stellgröße an das MKS Modell übergeben wird. Informationen bezüglich des Streckenverlaufs und damit der zu folgenden Trajektorie bezieht der Fahrerregler dabei aus dem SIMPACK-Modell. Die wesentlichen Ein- und Ausgangsgrößen für die Co-Simulation sind in Abb. 3.4 dargestellt.

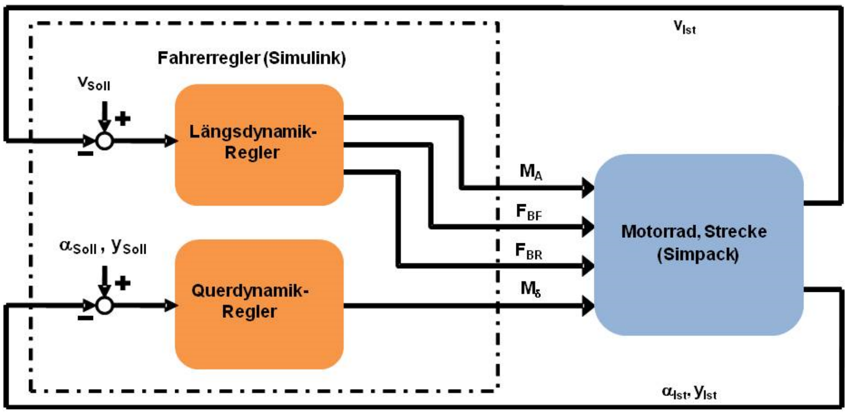


Abb. 3.4. Wesentliche Ein- und Ausgangsgrößen der Co-Simulation

3.1.2 Fahrbahnkontakt

Ein wichtiger Modellierungsaspekt ist die Abbildung des Kontakts zwischen Motorrad und Fahrbahnoberfläche. In normalen Fahrsituationen tritt nur Kontakt zwischen den Reifen und der Fahrbahn zur Übertragung der Antriebs-, Brems- und Seitenkräfte auf. In Unfallsituationen kann es zum Kontakt zwischen Fahrzeugteilen, wie z.B. dem Lenker, den Fußrasten oder dem Motorgehäuse und der Fahrbahn kommen.

Das in mehreren studentischen Arbeiten entwickelte Reifenmodell erlaubt eine realistische Abbildung der resultierenden Kräfte und Momente auch bei großen Sturzwinkeln. Derzeit stehen Parametersätze für einen Vorderreifen der Dimension 120/70 ZR 17 und einen Hinterreifen der Dimension 180/55 ZR 17 zur Verfügung.

Für den Kontakt zwischen der Fahrbahnebene und dem gestürzten Motorrad sind auf beiden Seiten des Motorrads je drei Kontaktstellen ausgewählt worden: Beim Sturz kann das Motorrad am Lenkerende, an der Fahrerfußraste sowie an der Soziusfußraste in Kontakt mit der Fahrbahn kommen. Die Kontaktkräfte wirken an diesen Stellen in Richtung der Fahrbahnnormalen. In der Tangentialebene des Kontakts wirken Reibkräfte in Längs- und Querrichtung. Beispielhaft zeigt Abb. 3.5 ein gestürztes Motorradmodell mit den Kontaktstellen an Lenker und Rahmen.

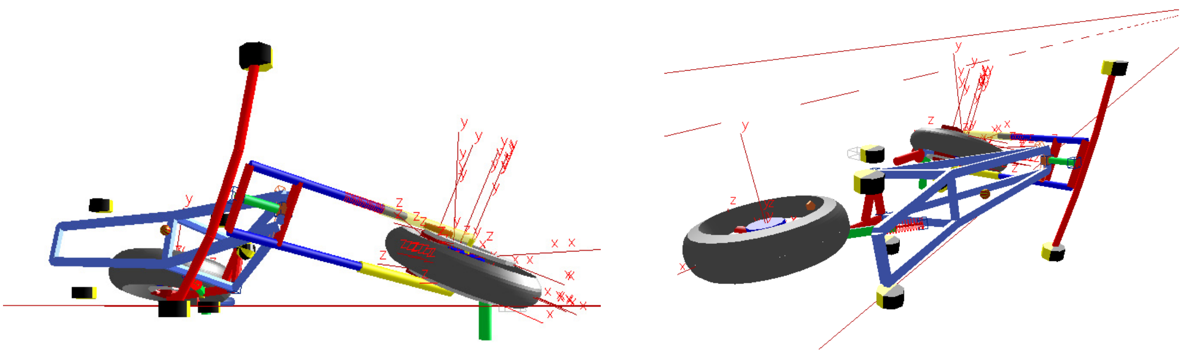


Abb. 3.5. Gestürztes Motorrad

3.2 Unfallsimulation

Damit eine Unfallsituation in der VUFO-Simulationsumgebung korrekt abgebildet werden kann, ist es notwendig dem Motorradmodell die entsprechende Startposition, den zu fahrenden Streckenabschnitt und das zugehörige Geschwindigkeitsprofil zuzuweisen. Diese Informationen werden der Datenbank der VUFO entnommen. Sie enthält für den jeweils betrachteten Unfall eine Unfallskizze und Parameterdateien mit den globalen Koordinaten der Startposition, dem Verlauf der Fahrlinie sowie das zugehörige Geschwindigkeitsprofil.

Die diskreten Messstellen der Fahrlinie werden für die Simulation mit Hilfe von Beziér Kurven beschrieben, um einen stetigen Krümmungsverlauf zu gewährleisten. Dies ist erforderlich um unrealistische Lenkmomentensprünge an Unstetigkeitsstellen, die sonst vom Fahrerregler generiert werden können, zu vermeiden. Eine approximierte Fahrlinie zeigt Abb. 3.6.

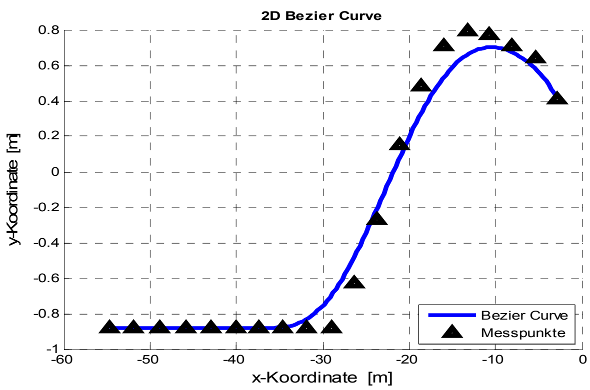


Abb. 3.6. Messpunkte und approximierte Fahrlinie

Beispielhaft wird im Folgenden die Simulation eines Kreuzungsunfalls vorgestellt. Das Motorradmodell mit Teleskop-Feder-Gabel zur Vorderradführung und einem Monolever zur Hinterradführung ist in Abb. 3.2 zu sehen. Bei diesem Unfall fuhr das Motorrad auf ebener und trockener Asphaltstraße geradeaus. Der entgegenkommende PKW bog nach links ab, wodurch das Motorrad mit diesem auf Höhe der Beifahrertür kollidierte, Abb. 3.7

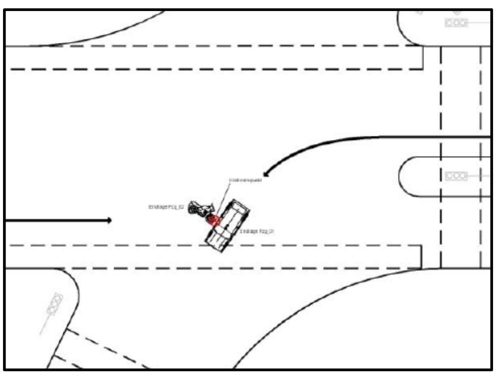


Abb. 3.7. Unfallskizze

Die Geradeausfahrt in dieser Unfallsimulation stellt für den Fahrerregler des Motorrades kein Problem dar. Die Einhaltung des vorgegebenen Geschwindigkeitsprofils erfolgt nahezu exakt. Das in Abb. 3.8 gezeigte Diagramm stellt die Geschwindigkeit über dem Fahrweg dar. Die Abweichungen zwischen der gewünschten und der zurückgelegten Bahn des Schwerpunkts liegen im Millimeterbereich und damit im Bereich der Messgenauigkeit bei der Unfallaufnahme.

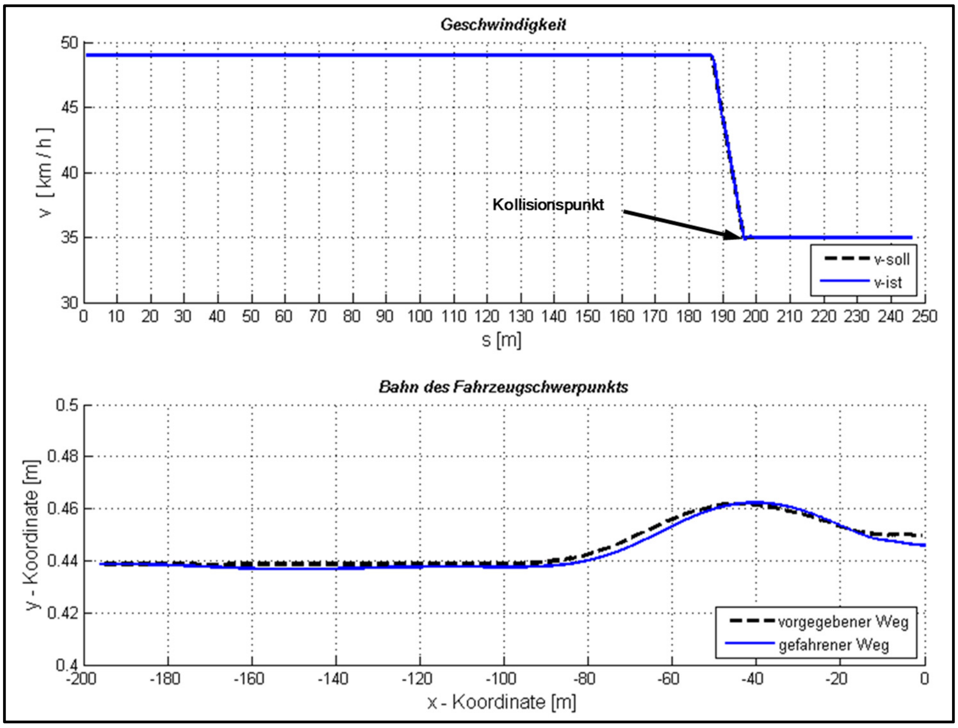


Abb. 3.8. Geschwindigkeitsverlauf (oben), Bahn des Fzg.-Schwerpunkts (unten)

Anhand dieses Unfallbeispiels soll im zweiten Schritt die Erweiterung des Fahrerreglers um eine ABS Funktionalität gezeigt werden. Das ABS fungiert hierbei als idealisierte Bremskraftbegrenzung und berücksichtigt nur die Reifenkraft in Längsrichtung. Aus der aktuellen Radlast und dem vorgegebenen Fahrbahnreibwert wird die maximal übertragbare Längskraft ermittelt. Über das Momentengleichgewicht am Rad wird nun die maximale Reibkraft an der Bremsscheibe berechnet und die Bremskraft auf diesen Wert begrenzt, so dass ein Blockieren des Rads verhindert werden kann.

Beim rekonstruierten Geschwindigkeitsprofil kommt diese Begrenzung noch nicht zum Tragen, da die Verzögerung nicht ausreichend groß ist. Deshalb wurde das Geschwindigkeitsprofil derart verändert, dass im Kollisionspunkt eine Geschwindigkeit von ca. 25 km/h erreicht werden soll.

Im Falle der Simulation mit ausgeschaltetem ABS blockiert das Vorderrad bereits nach wenigen Metern, wie aus dem Geschwindigkeitsverlauf in Abb. 3.9 hervorgeht.

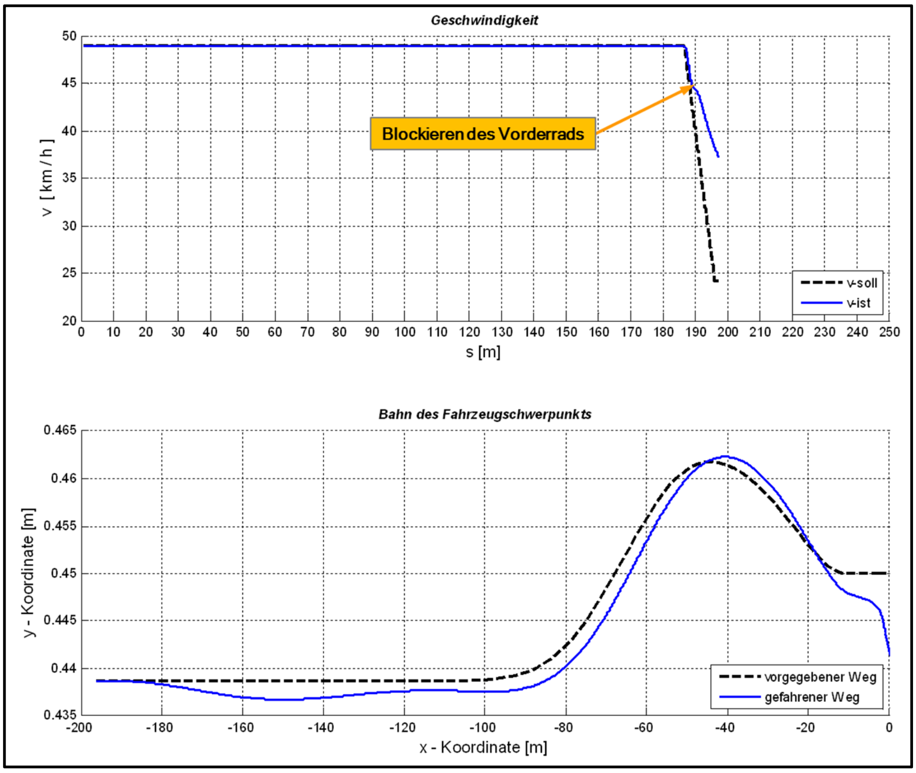


Abb. 3.9. Vollbremsung ohne ABS

Mit eingeschaltetem ABS ergibt sich der in Abb. 3.10 dargestellte Geschwindigkeitsverlauf. Es ist erkennbar, dass das Vorderrad nun nicht mehr überbremst und die Sollverzögerung erreicht wird.

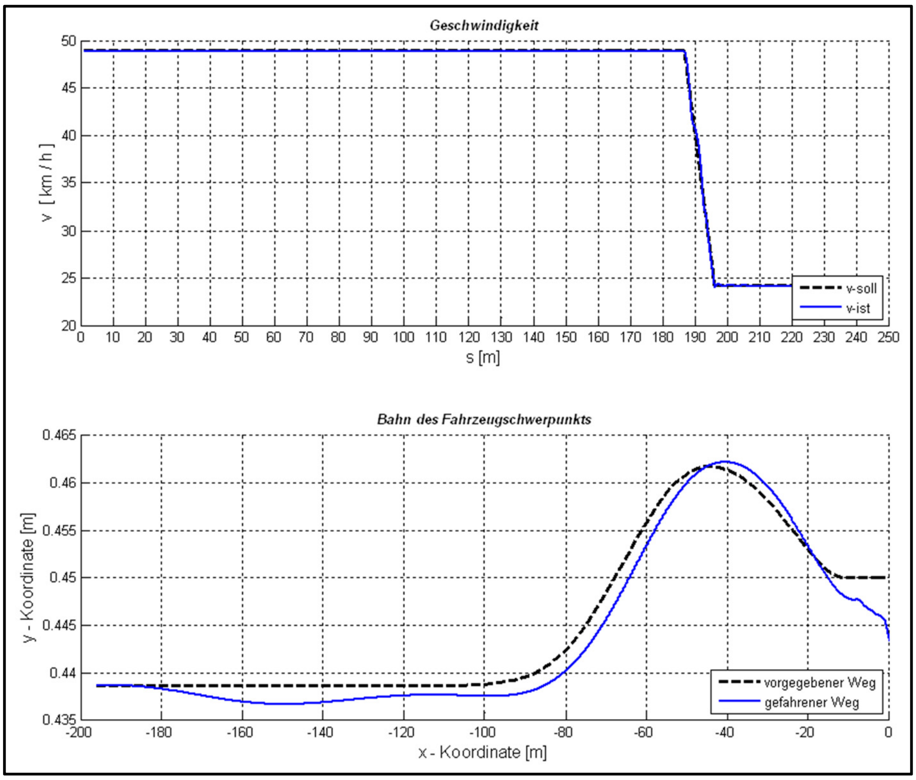


Abb. 3.10. Vollbremsung mit ABS

4 Zusammenfassung

In der vorliegenden Arbeit wurde beginnend mit einer ausführlichen Recherche zu Fahrerassistenzsystemen und Unfalldaten ein Verfahren entwickelt, das es ermöglicht, ohne aufwendige Case-by-Case-Untersuchungen von Unfällen Aussagen zum Wirkungsfeld von Fahrerassistenzsystemen zu treffen. Dazu wurden zunächst bestehende Fahrerassistenzsysteme analysiert und in ihren Wirkketten strukturiert. Danach wurden in den Wirkketten s.g. Basisfunktionen identifiziert. Diese Basisfunktionen geben je eine abgegrenzte Funktion des Systems an, die losgelöst aus dem Systemkontext eine Aufgabe zur Erkennung einer Gefahrensituation, zum Bewerten dieser oder zur aktiven Vermeidung des bevorstehenden Unfalls bzw. zur Reduktion der Unfallfolgen abbilden kann. Zur späteren Bewertung wurden die Basisfunktionen entsprechend des vorgenannten Schemas in die Module Erkennen, Bewerten und Agieren eingeteilt. Zusätzlich zu den bereits in Serie befindlichen Systemen wurden 35 weiter Systeme und Systemideen in die Untersuchungen einbezogen.

In einem weiteren Schritt wurden die durch die VUFO gelieferten Daten der Unfallanalyse näher analysiert und die Hauptunfallursachen der in der Einteilung abgebildeten Unfallszenarien betrachtet. Darauf aufbauend wurden dann szenarienspezifische Anforderungen an die Fahrerassistenzsysteme formuliert. Diese Anforderungen wurden dann in einem Bewertungsverfahren mit dem Umfang der in Module eingeteilten Basisfunktionen verglichen. Ziel dieser Schritte war die weitführende Objektivierung, ohne dabei auf aufwendige Fallbetrachtungen oder Unfallrekonstruktionssimulationen zurückgreifen zu müssen.

Der Bewertung wurde für die bereits in Serie befindlichen Assistenzsysteme eine Methodenstudie zur weiteren Objektivierung der Wirkfelduntersuchung in Richtung Wirkungsgraduntersuchung nachgestellt. Dazu wurde die Methodenmatrix vorgestellt.

Die hier entwickelte Methode zur Bewertung des Wirkfeldes bestehender und zukünftiger Fahrerassistenzsysteme stellt bereits in der aktuellen Ausbaustufe ein leistungsfähiges Werkzeug für strategische Entscheidungen zur Fahrsicherheit dar. Die Methode eignet sich besonders für aktive Systeme.

Die in der Wirkfeldmatrix vorgesehenen Fahrerfaktoren und Fahrereinflussfaktoren könnten bei einer entsprechenden Hinterlegung zum einen präzisere Aussagen zum Wirkfeld und zum anderen auf Kundengruppen bezogene Aussagen zur Wirkung der Fahrerassistenzsysteme liefern.

Im Rahmen des hier vorgestellten Projektes wurde mit dem Aufbau einer für die Entwicklung zukünftiger Assistenzfunktionen nutzbaren Simulationsumgebung begonnen. Für eine realitätsnahe Simulation des Unfallgeschehens ist dabei eine dynamische Interaktion beider Fahrzeugmodelle innerhalb der Unfallumgebung unerlässlich. Aus diesem Grund wurde im Rahmen dieses Projektes das Motorrad als

MKS Modell codebasiert in die VUFO-Simulationsumgebung integriert. Ein wichtiger sich daraus ergebender Vorteil ist, dass Zustandsgrößen wie Gierrate und Rollwinkel ermittelt werden können, die zur Entwicklung sicherheitsrelevanter Fahrassistenzsysteme notwendig sind.

Beispielhaft wurde ein mit dem von der TU Dresden entwickelten Motorradbaukasten in der Mehrkörpersimulationssoftware SIMPACK erstelltes Fahrdynamikmodell in die VUFO Simulationsumgebung eingebunden. Um einen Sturz des Motorrads simulieren zu können, erfolgte die Ergänzung des Motorradmodells um Normal- und Reibkontaktelemente.

Am Beispiel eines typischen Kreuzungsunfalls, der den am häufigsten auftretenden Unfallarten zuzuordnen ist, wurde die Möglichkeit, in der Simulationsumgebung ein Unfallgeschehen realitätsnah nachzubilden, veranschaulicht. Darüber hinaus wurde an diesem Beispiel gezeigt, dass mit Hilfe der Simulation Aussagen zur Wirksamkeit von Assistenzsystemen, hier durch den Vergleich des Bremsvorgangs mit und ohne ABS Funktionalität, getroffen werden können.

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Motorcycle-Car Multi-Driver Simulation – A new methodological Approach towards increased Powered Two Wheeler safety

Die vernetzte Motorrad-Pkw Simulation – ein neuer methodischer Ansatz zur Steigerung der Verkehrssicherheit für motorisierte Zweiradfahrer

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Abstract

Motorcyclists are still at high risk of getting involved in accidents that result in injury (DEKRA, 2010). Especially interactions with cars and trucks bear a high risk potential, e.g. if motorcyclists are overlooked or if their acceleration is underestimated. In 2012, in Germany alone, 14.129 crashes between motorcycles and other road users were registered (DESTATIS, 2012). Thus, it seems reasonable to not just focus on motorcycle immanent countermeasures, but broaden the research efforts towards interactions with other road users.

This paper deals with the new methodology of Motorcycle-Car Multi-Driver Simulation realized at the WIVW GmbH. It enables a motorcyclist and a car driver to interact in the same virtual environment. This approach widens the set of research methodologies to investigate safety-relevant aspects of Powered Two Wheelers (PTW). The basic idea of linking driving simulators has already been established for cars (Mühlbacher, 2013). The multi-driver simulation allows deeper insight into interactions and mutual behaviour adoption. Furthermore, it is possible to investigate and evaluate new technologies such as advanced rider assistance systems, on-bike information systems or bike2X-communication under controlled conditions and from a new point of view. The components of the Motorcycle-Car Multi-Driver Simulation (hardware, dynamic maps etc.) as well as relevant characteristics of study planning and conduction will be addressed. Additionally, results from the project UR:BAN, which was funded by the BMWi, will be presented exemplarily. Therein, the influence of a tailgating motorcycle on the car ahead was assessed. Taking eye movements, driving parameters and subjective ratings into account, the study revealed poor influence of the tailgating motorcycle. The car drivers were not significantly distracted and still able to react adequately to sudden critical events.

Based on these first experiences, the Motorcycle-Car Multi-Driver Simulation is a promising methodology in the field of empirical traffic sciences with the potential to increase PTW safety.

Keywords: powered two wheeler, motorcycle, methodology, simulation

Motorcycle-Car Multi-Driver Simulation – A new methodological Approach towards increased Powered Two Wheeler safety

1 Introduction

In general, Powered Two Wheelers are an increasingly popular mode of transport. This holds especially for urban areas, as more and more people see the benefits like e.g. less congestion or easier parking. The number of motorcycles in use within Germany has more than doubled in the last 20 years. In January 2014 there were 4,054,946 registered motorcycles (DESTATIS, 2014). Additionally, one can observe a trend towards more high-mileage riding (see Figure 1).

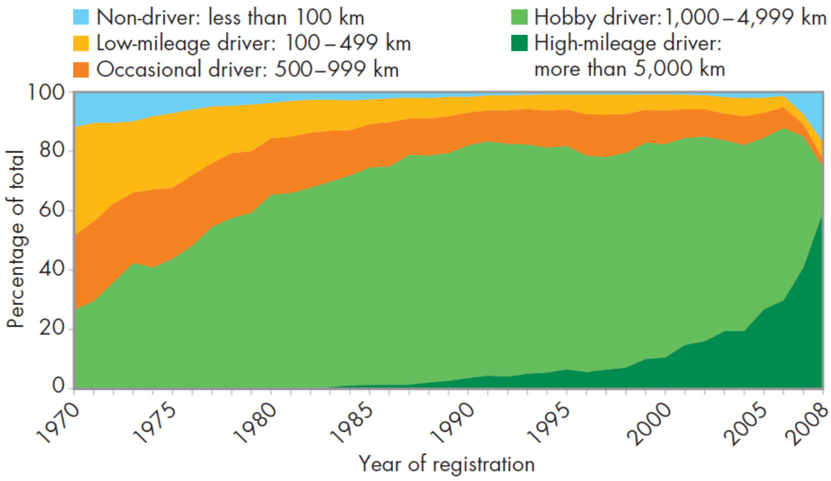


Figure 1. Pattern of motorcycle use in Germany showing average mileage per year from database 2007/ 2008 (DEKRA, 2010, p.8).

Unfortunately, motorcyclists are still at high risk of being involved in accidents that result in injuries (DEKRA, 2010). As data from 20 European countries show, the relative trend of PTW fatalities does not decline in the same amount as it does for other modes of transport (see Figure 2, Yannis, 2012).

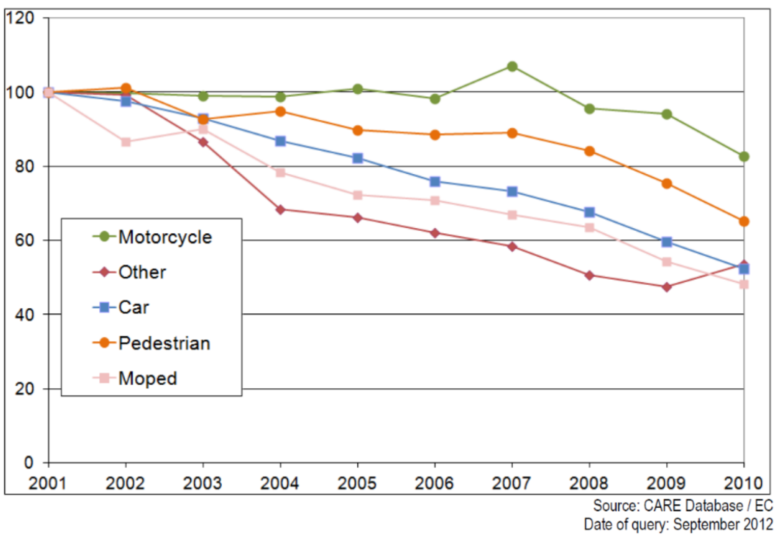


Figure 2. Index (2000=100) of motorcycle and moped fatalities compared with other modes EU-20, 2001 – 2010 (Yannis, 2012, p.6).

Whilst single-vehicle motorcycle accidents account for roughly 27% of the motorcycle accidents in European countries, the majority of accidents involve two or more parties. In 2012, in Germany alone, 14,129 multi-vehicle accidents involving a PTW were registered (DESTATIS, 2012). In 80% of these collisions the other vehicle was a passenger car (DEKRA, 2010). Typical crash reasons are the underestimation of PTW speed or that the silhouette of PTWs is simply overlooked.

Up to now, the field of empirical traffic sciences includes a few motorcycle simulators as research tools (Nehaoua, L., Arioui, H., & Mammar, S., 2011). Due to the fact that there is always one rider in a virtual programmed environment, motorcycle simulation allows the assessment of important research questions (e.g. Buld, S., Will, S., Kaussner, A., & Krüger, H.-P., 2014; Huth, V., Biral, F., Martín, Ó., & Lot, R., 2012), but always excludes real interaction that includes mutual behavior adoption. This reveals the need to investigate Powered Two Wheeler safety from a new point of view. Besides the important derived accident countermeasures like technical improvements of motorcycles (e.g. through ABS or traction control) or adequate rider training, the research efforts have to be broadened towards interactions between PTWs and other road users. Therein lays huge potential to increase PTW safety.

2 Methodology

The following passage describes the new methodology of Motorcycle-Car Multi-Driver Simulation realized at the WIVW (Wuerzburg Institute for Traffic Sciences). As mentioned above, there's a need to investigate the interaction between PTWs and other vehicles more in-depth.

2.1 Simulators

As driving simulation is a common tool in traffic sciences, the idea was to link a motorcycle simulator to a car simulator and have two subjects driving in the same virtual environment. The basic idea of linking driving simulators has already been established for cars (Mühlbacher, 2013; Houtenbos, M., 2008). This allows gaining deeper insight into interactions and mutual behaviour adoption of two real drivers in a safe and controlled environment.

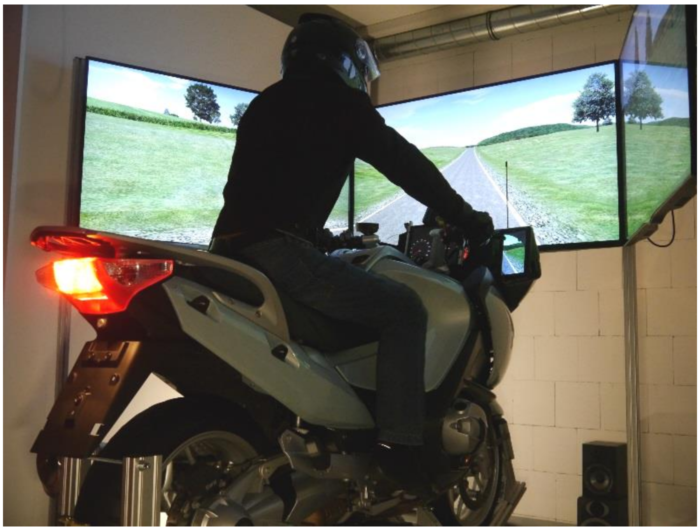


Figure 3. Motorcycle riding simulator.

The motorcycle simulator at the WIVW is equipped with a full-size BMW R 1200 RT motorcycle and prepared for intermountable mockups (see Figure 3). This enables the rider to interact with fully realistic components like usual handlebar, brake lever/ pedal, clutch, gear selector, etc. that he/ she is used to. The three 55 inch flat screens surrounding the rider offer a 180-degree field of view. A 10 inch touch screen is used as cockpit showing speedometer and revolutions per minute. Additionally, different Human-Machine-Interfaces (HMI) e.g. for Advanced Rider Assistance Systems (ARAS) or On-Bike Information Systems (OBIS) can be easily displayed there. Depending on the research question, riders can fill in questionnaires online or engage in secondary tasks displayed on the touchscreen (e.g. navigating through a board computer). Two 7 inch TFT-displays are installed as mirrors. An electrical actuator is used to produce a steering torque at the handlebar up to 50 Nm. Acoustic feedback including surrounding traffic is delivered by a 2.0 sound system. One speaker that is responsible for engine noise is installed under the motorcycle and works in combination with a shaker, installed under the seat, delivering the engine vibrations to the rider. The simulator is running with SILAB riding scenario control.

Figure 4. Car driving simulator with highlighted rear-view and wing mirror.

The car driving simulator includes a car mockup with real driving seat, steering wheel with force feedback and brake as well as accelerator pedal (automatic gear shift). Five projections produce a 300-degree field of view. A 15 inch flat screen is used as instrument cluster showing speedometer and revolutions per minute. A second 15 inch flat screen in the dashboard can be used to display a navigation system, secondary tasks or HMIs. Two 7 inch TFT-monitors are used as rear-view and wing mirror (see Figure 4). A 5.1 sound system is installed to deliver acoustic cues from the own simulated car and the surrounding traffic. Additionally, eye-tracking as well as physiological measures can be recorded. The simulator is also running with SILAB riding scenario control.

The motorcycle simulator and the car simulator are connected to a Multi-Driver Simulator via a 1GB Ethernet switch. A specific computer of the Multi-Driver Simulation is configured with the SILAB software and functions as the traffic main computer. In each time step the driving dynamics of the motorcycle as well as the driving dynamics of the car are both evaluated and the results are transferred to the traffic main computer. The traffic main computer is used to evaluate the driving models for all SILAB simulated vehicles in order to create the appropriate scenarios for the two human drivers.

This setup requires two operators: one for each simulator in order to take care of the participant, give instructions, hand out questionnaires etc. Both operators can observe driving parameters like velocity, lateral position etc. in real time and monitor the positions of both participants from a bird's-eye view. However, one of them is the main operator that is responsible for the run of the scenarios.

2.2 Synchronization methods

A Multi-Driver Simulation has extraordinary requirements for synchronizing vehicles. The simulated vehicles of SILAB and particularly the motorbike and the car of the human drivers have to be synchronized to match the needs of the appropriate scenario e.g. to meet each other at a junction. Only if this is guaranteed, a Multi-Driver Simulation can fulfill its purpose. Due to the fact that two real humans are involved, it is very difficult on the one hand to not restrict their behaviour and on the other hand to push them in the right direction in order to realize a specific situation.

The following examples illustrate some of the methods that can be used for synchronization:

- Following other vehicles

  For both participants front cars can be defined with a speed that is synchronized to each other in order match the relative position and speed of the vehicles of the real drivers for specific situations.

- Traffic lights

  Both vehicles can be stopped at traffic lights. The status of the traffic lights can be defined in order to synchronize the vehicles of the participants.

- Traffic rules and simulated vehicles

  The vehicle of a real driver can be slowed down e.g. by a junction with a yield sign. Other vehicles can be defined depending on the need to stop or slow down a human driver. As a result the human driver has to wait at a junction in order to give way for the simulated vehicles and continues his ride with a synchronized position to the other human driver.

2.3 Road network

The road network is dynamic and no geometrical consistency is needed. This means that depending on the drivers' performance, driving scenarios can be linked to each other during runtime. This is possible as the drivers have a limited range of vision, which enables SILAB to connect new scenarios unnoticed by the drivers. For example the researcher's intention is to investigate distraction of different secondary tasks when crossing an intersection. If some of the tasks were not performed by the riders, the dynamic road network would allow adding those intersections at the end of the course once again.

2.4 Use cases

In general, every situation where a car driver interacts with a motorcyclist could be relevant. Especially, interactions that are safety critical and therefore not suitable to be investigated on test tracks or in real traffic could be typical use cases. On the one hand, the Motorcycle-Car Multi-Driver Simulation could therefore be used to investigate rider and driver behavior in safety critical situations in general as there is a lack of knowledge concerning mutual behaviour adoption. On the other hand, specific systems like e.g. Car2Bike technology could be investigated. As it holds for simulation in general, an obvious advantage of the Multi-Driver Simulation is the controllability of the environment and the flexibility to include and simulate systems during all stages of the development process.

3 Study example

The following section will describe parts of a study conducted within the project UR:BAN in the Motorcycle-Car Multi-Driver Simulation as an example.

3.1 Background

The first study that was conducted with the new Motorcycle-Car Multi-Driver Simulator took a closer look at the phenomenon of tailgating. Of course, tailgating is not a motorcycle immanent phenomenon, but motorcycles are usually able to accelerate faster than cars. This enables quicker overtaking maneuvers. Maybe this is one of the reasons why PTW spend some time tailgating behind cars until a safe overtaking is possible (Spiegel, 2009). The main aim was to quantify the effect of a tailgating PTW on a car driver. The research question was if a tailgating PTW is that much distracting to the car driver that he/ she cannot react appropriately to suddenly appearing hazards anymore. As tailgating is a quite complex behaviour in its longitudinal and lateral characteristics, it is hard to program so that it looks realistic. Therefore the Motorcycle-Car Multi-Driver Simulation was conducted with a trained confident riding the tailgating motorcycle and one real participant driving the car.

3.2 Experimental design

N= 28 participants took part in the study. Due to technical problems only data from N= 24 could be used for data analysis. 13 participants were women. Mean age of all participants was m= 42.79 years (sd= 13.68 years). The youngest participant was 23 years of age and the oldest 63 years. All participants had more than five years driving experience. The participants were selected from an existing WIVW test driver panel. All participants had previously participated in extensive simulator training. The study was conducted using a within-subject design with experimental factor 'distance between motorcycle and car ahead' (tailgating vs. safe distance). A cover story was used to not direct the participants' attention too much towards the motorcycle rider. The participant driving the car and the motorcycle confident met before the beginning of the study. The confident acted as if he was a usual participant and the study was presented to focus on technical specifics of the new methodology of Motorcycle-Car Multi-Driver Simulation. Participants were therefore asked to give feedback on visual inconsistencies or anything they might notice during the test drive.

The road network included urban and rural roads. On both road types three hazard situations appeared that forced the driver to react. Every hazard situation appeared twice, once with and once without the tailgating motorcycle. In between there were longer periods without critical situations. The results given here focus on one of the six hazard scenarios called "pedestrian crossing". The car drives along an urban road with 50 km/h speed limit. A pedestrian appears between two parked vehicles, enters the road and crosses it in front of the car. In total, the motorcycle rider was tailgating behind the car half of the time in order to avoid the tailgater from acting as a hidden cue for critical situations. Table 1 shows the distance thresholds for following in a safe distance and tailgating.

Table 1. Thresholds of distance and Time Headway (THW) for tailgating and following in a safe distance.

	Tailgating		**Safe distance**	
	distance [m]	THW [s]	distance [m]	THW [s]
Urban	< 14.0	< 1.0	26.0 – 55.0	> 1.8
Rural	< 27.0	< 1.0	50.0 – 110.0	> 1.8

The confident had special distance information included in his projection, in order to be able to keep reproducible distances to the car (see Figure 5 left). The surrounding traffic was programmed in a way that the only proper reaction of the driver, in order to avoid a collision, was to brake. A lane change was not possible. In order to control sequence effects the scenario orders were randomly assigned to the drivers. It took the riders about 60 minutes to complete the course.

Figure 5. Tailgating distance information included in the motorcycle rider's field of view (left). Screenshot of the hazard situation with a hidden pedestrian crossing the road in front of the car (right).

3.3 Dependent variables

Besides recording objective data (velocity, Time-to-arrival, deceleration…) and gaze behavior, subjective ratings of the experienced criticality (Neukum et al., 2008) were assessed. Furthermore, the subjects rated to which extent they experienced the situation as surprising.

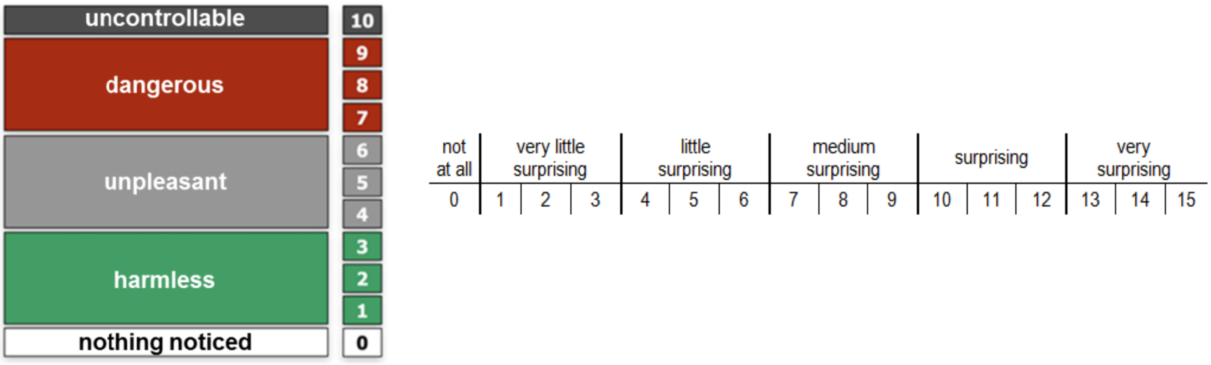


Figure 6. Subjective ratings on situation criticality (left) and surprise (right).

Except for the Time-to-arrival, all parameters are calculated relative to a certain road segment. This segment starts at the point where the driver was able to see the critical event (here the pedestrian) for the first time. It ends where the critical event has happened (where the pedestrian crossed the road). The Time-to-arrival is measured at the point of braking. The calculation of the parameters is illustrated in Figure 7.

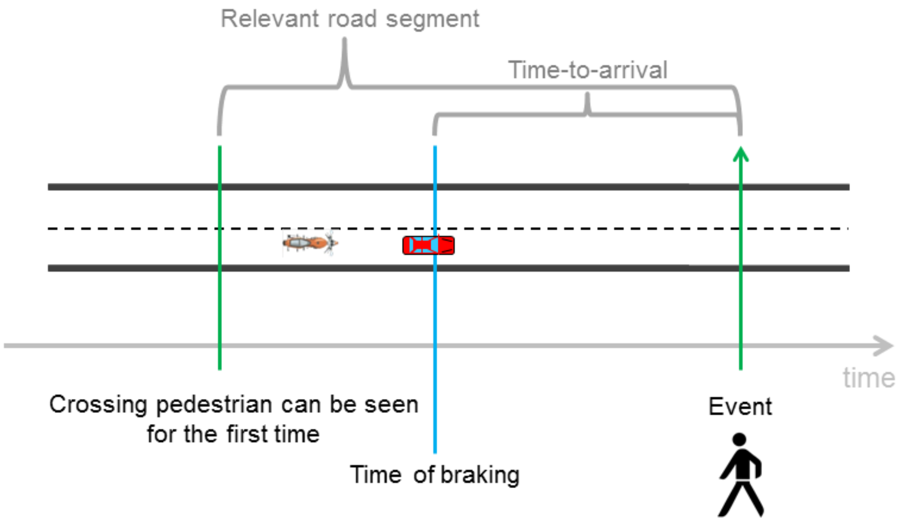


Figure 7. Illustration of the relevant road segments for calculation of parameters.

3.4 Results

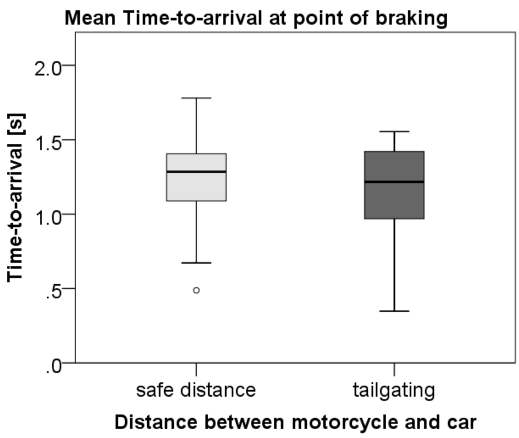
Statistical analysis was conducted using Analysis of variance (ANOVA) with an alpha level of 5%. Boxplots are used for illustration. The dark lines represent the median. The box itself marks the upper and lower quartile supplemented by whiskers. Outliers are plotted as individual points.

The manipulation check clearly shows that the confident followed the car in a smaller distance while tailgating (see Table 2).

Table 2. Descriptive statistics showing manipulation check.

Parameter	Mean	SD	ANOVA
THW (safe distance) [s]	3.13	0.48	$F(1,23)= 266.31$, $p < .001$, $\eta_p^2 = .920$
THW (tailgating) [s]	0.92	0.34	
distance (safe distance) [m]	27.91	7.17	$F(1,23)= 234.56$, $p < .001$, $\eta_p^2 = .911$
distance (tailgating) [m]	6.91	1.37	

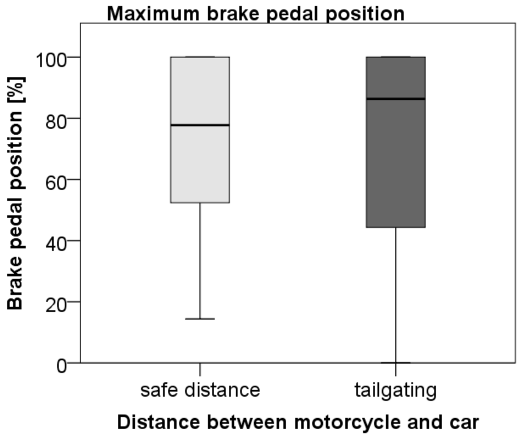
The variation in the distance between motorcycle and car has no influence on the time of braking ($F(1,21)= 1.46$, $p = .239$, $\eta_p^2 = .065$). Independently from the following motorcycle, participants begin braking at a Time-to-arrival of about one second (see Figure 8).



	M [s]	SD [s]
TTA (safe distance)	1.24	0.30
TTA (tailgating)	1.13	0.36

Figure 8: Boxplot (left) and descriptive statistics (right) showing mean TTA at point of braking.

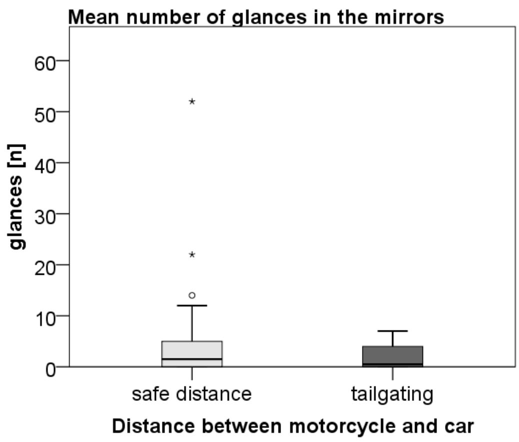
Concerning the deceleration, operationalized by the maximum brake pedal position, no influence of the tailgating motorcycle can be found ($F(1,23)< 1$). The huge variation between drivers is conspicuous (see Figure 9). Whilst some drivers react with full braking, others do not brake at all. This holds independently from the motorcycle's following distance.



	M [%]	SD [%]
max. brake pedal position (safe distance)	73.00	29.47
max. brake pedal position (tailgating)	70.83	34.32

Figure 9. Boxplot (left) and descriptive statistics (right) showing maximum brake pedal position ranging from 0 % to 100 % (fully pressed).

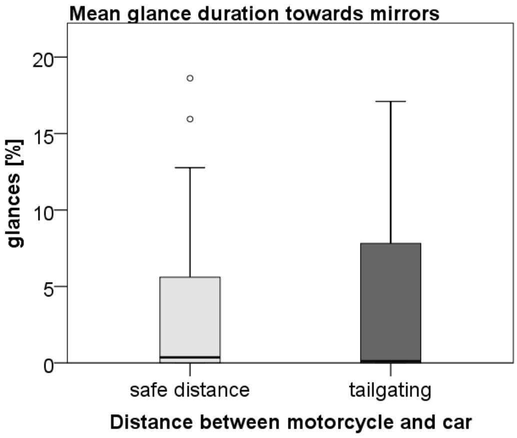
The analysis of the drivers' gaze behaviour reveals no difference between the two factor levels. Neither do car drivers look more often in general ($F(1,23)= 2.16$, $p = .155$, $\eta_p^2 = .086$) nor do they look longer in the mirrors ($F(1,23)< 1$), when followed by a tailgating motorcycle. This can be seen in Figure 10 and Figure 11.



	M [n]	SD [n]
Number of glances into mirrors (safe distance)	5.54	11.33
Number of glances into mirrors (tailgating)	1.92	2.50

Figure 10. Boxplot (left) and descriptive statistics (right) showing the number of glances into the mirrors.

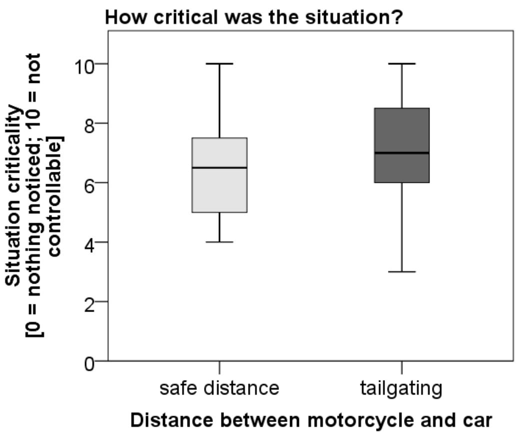
Participants' gaze behaviour is quite similar in the number of glances in and the duration of glances towards rear-view and wing mirror. A few individuals stick out as they look in the mirrors extremely often or long. Further analysis of all critical scenarios reveals that those participants do not show this gaze behaviour constantly.



	M [%]	SD [%]
glance duration into mirrors (safe distance)	3.60	5.38
glance duration into mirrors (tailgating)	3.77	5.66

Figure 11. Boxplot (left) and descriptive statistics (right) showing the mean glance duration towards the mirrors.

The subjective ratings reflect the results of the driving data pretty well. Consequently, the manipulated distance between motorcycle and car does not affect the participants' subjective situation criticality ratings ($F(1,23)= 2.32$, $p = .142$, $\eta_p^2 = .091$). Except for one driver, all other drivers rate the situation at least as unpleasant (see Figure 12).



	M	SD
Situation criticality (safe distance)	6.67	1.66
Situation criticality (tailgating)	7.21	1.86

Figure 12. Boxplot (left) and descriptive statistics (right) showing the mean reported situation criticality.

Only the ratings on how surprising the critical situation was revealed a difference between tailgating and safe distance following of the motorcycle ($F(1,23)= 4.58$, $p = .043$, $\eta_p^2 = .166$): Participants rate the situation as more surprising when a tailgating motorcycle follows them (see Figure 13).

	M	SD
surprise (safe distance)	9.71	2.66
surprise (tailgating)	10.92	2.78

Figure 13. Boxplot (left) and descriptive statistics (right) showing the mean reported surprise.

The intended manipulation of producing unpredictable critical situations seems to be fulfilled, as participants' ratings of situation criticality and surprise mostly lie in the upper half of the scales.

3.5 Discussion

The main aim of the study was to evaluate the effect of a tailgating motorcycle on the car driver ahead. The study was conducted in the Motorcycle-Car Multi-Driver Simulation. Manipulation check of riding data showed that the tailgating was implemented reproducibly. Except for one car driver, all others noticed the changing behaviour of the following motorcycle regarding its distance to the car. A lack of awareness of the tailgater is therefore no possible explanation for the results. Participants regularly took a look in the mirrors. This allows to systematically modifying the behavior of a following vehicle if required by the research question.

Generally, the influence of a tailgating motorcycle is clearly smaller than previously expected. The car drivers' ability to react appropriately in critical situations is not influenced by a tailgating motorcycle regarding time of braking, maximum deceleration or gaze behaviour. The subjective ratings revealed an effect for surprise but not situation criticality. In an inquiry after the study some participants stated that they took a closer look in the mirrors when the motorcyclist came too close, as they felt distracted. On the contrary, others said that they paid more attention to what was happening behind them, when the motorcycle lagged behind. Those participants wondered whether they "lost the other driver" and tried to keep the two vehicles together. This might explain some variation in gaze behaviour.

The following might offer possible explanations: (1) Car drivers were maybe more attentive when followed by a tailgating motorcycle, as they knew about the consequences of a harsh braking. (2) The other way round: Car drivers did not pay too much attention to the tailgater, as the motorcycle is a vulnerable road user. An accident would affect the motorcyclist more than themselves. A tailgating truck would maybe lead to more behaviour adaption. (3) In case of an accident the tailgater would bear the blame.

To summarize from a methodological point of view one can state that the Motorcycle-Car Multi-Driver Simulation has an additional value for investigating interaction. The possibility to have a confident who specifically provokes situations that are hard to program realistically, is one of the method's advantages that were shown.

4 Summary & Outlook

With regard to accident statistics, the new methodology of Motorcycle-Car Multi-Driver Simulation is a promising step in the right direction, as it offers the possibility to take a closer look at interactions between PTW and other vehicles in a safe and controllable environment. Depending on the research question this advantage has to be seen in relation to the potential downsides of a Multi-Driver Simulation like e.g. the need for more operators to run the study, the coordination of two participants, the synchronization methods needed, etc.

The first study described above proved that the new simulation runs stable. End of 2014, a second study within the project UR:BAN will be conducted in the Motorcycle-Car Multi-Driver Simulation. In this study the focus will lie on the potential gain for PTWs of a Car2Bike based intersection support. The upcoming Vehicle2Vehicle technology is a research topic for years now, mainly focusing on cars and trucks. The study aims at delivering first empirical data on interaction patterns at intersections with respect to which vehicle gets assistance (none, both, just car or just motorcycle). However, at this point it must be emphasized that further studies are needed to extend and confirm the fields of application for Motorcycle-Car Multi-Driver Simulation.

Nevertheless, this new methodology has the potential to enrich the field of empirical traffic sciences and to contribute to higher Powered Two Wheeler safety.

5 Acknowledgements

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A study of visual interface on development of Vehicle to X communication system for motorcycles

Studie über ein visuelles Interface bei der Entwicklung von „Vehicle to X-Kommunikationssystemen“ für Motorräder

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YAMAHA MOTOR CO., LTD.

Abstract

We have been developing visual interfaces on an advanced rider assistant system using vehicle to X communication. In providing the information about an object that is not directly visible for a rider, which is a feature of the V2X system, motorcycles have less ways to provide the information, and moreover, can provide less the information at the same time than automobiles. Therefore, we evaluate the best way to provide the information, and what information is useful for riders using the V2X system for a rider by testing on actual traffic environment. In this paper, we focus on the visual interfaces, and will present the experimental study. We have experimentally developed a V2X system for motorcycle based on the DRIVE C2X specifications, and measured the vehicle and rider behavior when the system provides information in the field operational test of DRIVE C2X. The use cases are IVS (In-Vehicle Signage), CBW (Car Breakdown Warning), and RWW (Road Works Warning). Three test riders are not ITS specialists. The motorcycle is equipped with a LCD, 3 LEDs, and a helmet mounted speaker as the interfaces for a rider. As a result, it is found that an effect on rider behavior is different depending on the use cases in using these interfaces. In addition, the information of distance to the object and the information of urgency to the event as well as the event pictogram (symbol/icon) are required by the riders.

A study of visual interface on development of Vehicle to X communication system for motorcycles

1 Introduction

It is reported that 23% of all motorcycle related fatal and seriously injured accidents in Europe were collisions occurred in intersections, and another 27% was a single vehicle accident such as falling on roadways or running off roadways. These data shows that accidents such as colliding to other vehicles (mostly passenger cars), and single accidents of motorcycles account for the majority of all serious motorcycle accidents.(1) In order to prevent these types of accidents, we consider that it is effective to improve the conspicuity of motorcycles at intersections, and to improve the acquisition of information for motorcycles especially of the routes ahead. We are working on the development of V2X rider support system (Cooperative system), in order to aware car drivers of the motorcycles nearby, and to inform the motorcycle riders of the upcoming dangers and risks, by using the Cooperative-ITS. In Europe, standardization and validation of V2X system are in progress, and efforts towards practical use are activating. So we decided to work on developing a V2X system for motorcycles in Europe. However, there are few studies of the V2X system verification for motorcycles, so task clarification of the actual use on roads are still left to be investigated. To make progress in these tasks, we participated in the DRIVE C2X project. DRIVE C2X goes beyond the proof of concept and addresses large-scale field trials under real-world conditions at multiple national test sites across Europe. The systems to be tested are built according to the common European architecture for cooperative driving systems defined by COMeSafety, thus guaranteeing the compliance with the upcoming European ITS standards.(2)

2 Objective of the experiment

The objective of this experiment is technology acquisition for system development and task clarification in the actual traffic environment. As for system development technology, we aimed to achieve technology such as evaluatable vehicle and system configurations, technology and methods to evaluate the influences towards riding or the system acceptability of the rider.

And for the task clarification, we aimed to clarify tasks such as communication quality, positioning accuracy, judgment logic, and information providing means. Among these tasks, in this paper, our objective is to clarify the best way to provide information and to determine what information is useful for riders.

The reference system and functions in DRIVE C2X are basically considered as a four-wheeled vehicle. Compared to the four-wheeled vehicle, motorcycle riders are limited in ways to be provided information, and the quantity of information that can be received at one time is also limited. Moreover, means to provide information is greatly influenced by environmental factors such as wind, sunshine, and rain. Therefore, we focused on the effect and acceptability for riders, by considering the system as a Human Machine Interface (HMI). In this paper, we report an experimental analysis about visual interface on actual traffic environment.

3 Experimental Procedures

3.1 System architecture and Testing motorcycle

Figure 1 shows the main system diagram. We used an on-vehicle mainframe computer as the controller, and also placed a non-directional 5.9GHz antenna as illustrated in Figure 2. We basically used the reference software shared in the DRIVE C2X project. Meanwhile, we specially developed the HMI controllers and some of the I/O, such as CAN-bus and vehicle signals.

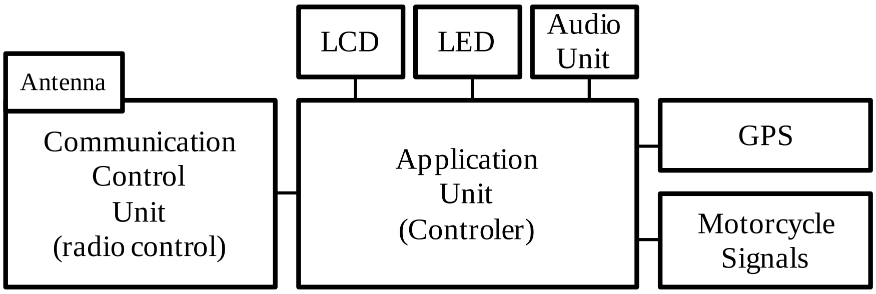

Figure 1. Component schematic diagram

Figure 2. placement of antenna

3.2 Human Machine Interface

Figure 3 shows the schematic view of the interface which provides information to the rider. The concept of these HMI is to obtain high awareness of the rider to the provided information and to ensure the information to be highly understandable in one short glance. We tested three types of interfaces, which are a combination of three LEDs, a 3.5 inch LCD built in the dashboard, and a Bluetooth connected headset speaker. Since our system provides many kind of information, we use LCD as well as LED to distinguish information.

The LEDs are placed as high as possible so that they are recognizable by the rider's peripheral vision. Each of the three LEDs shows the direction of the informed object. The middle LED means the object exists in the frontward, the right and left LED means the object exists in each sides, and when all three of the LEDs blinks, it means the object is behind. We chose the monochromatic LCD which is highly visible under the sunlight. Also, we displayed pictograms so as the rider can easily recognize the object. In auditory, the voice guidance is announced after a notification sound.

Figure 3. Prototype HMI

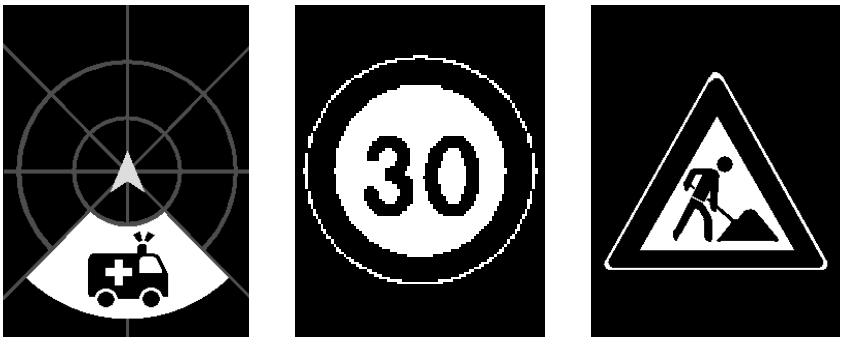

Figure 4. examples of pictogram

3.3 Evaluation Points

Assessments of rider acceptance of the HMI: Can the rider detect the information from auditory and display interfaces? Can the rider understand what the information means? How does the rider accept the information?

The effect of receiving the information: Is there a difference in rider behavior with or without the provided information? Can the rider behave as the system intended?

3.4 Functions

We installed eight software bundles, which supports the use cases shown in Table 1. Four of these functions were evaluated in the Field Operational Test. Below are the details of the four functions of which we evaluated. The specification of the algorithm which judges the output of the HMI is common among the DRIVE C2X. The specification of the algorithm which judges the output of the HMI is common among the DRIVE C2X.

Table 1. Use cases of functions

Function	Overview of use case
In-Vehicle Signage	Provide the information of Road signs e.g. Speedlimit, one way
Road Works Warning	Provide the information of Road works ahead
Car Breakdown Warning	Provide the information of a car breakdown ahead
Approaching Emergency Vehicle	Provide the information of an emergency vehicle
Motorcycle Approaching Indication	Provide the information of an approaching motorcycle and the direction
Slow Vehicle Warning	Provide the information of a Slow Vehicle ahead
Green Light Optimized Signal Advisory	Provide the information of the speed that can pass through a green light
Wrong Way Driving in Gas Station	Provide the information of the car driving in the wrong way

3.5 Location of the experiment

The experiment took place at a section in a highway of northern Italy, with a course length of approximately 20km. An actual road side unit, emergency vehicle, and road works were placed within the test course. On account of the recruitment, the participants were three test-riders who are not ITS specialists. Before performing the test, the participants were sufficiently explained about the overview of the cooperative system, the function of the system, and the information provided from the system. After the instructions, the participants first rode the course without being provided information (which is called "Baseline"), and then rode again this time with information (which is called "Treatment"). After the experiment, they answered a questionnaire about the HMIs. We instructed them to pay full attention to safety, make sure to ride as usual, and keep the laws.

4 Experiment Results

Since there were only three participants, we cannot perform a statistical investigation. But still, the test data are a very valuable data performed in actual road environment. We examined the data to figure out the trends.

4.1 Acceptance of HMI

The result of the questionnaire about the HMI is presented below.

- Audio: Cannot make out the announcements when riding in high speed.

  The sound was difficult to understand.

- Visual: Recognizable under sun light.

  The pictograms were able to understand.

Since the experiment took place on highways, the wind noise seems to be too loud to hear the announcements. Thus, an audio device that could be heard in high speed is required. The LCD panel we selected which has high contrast under sunlight, resulted in high evaluation in visibility. Figure 4 shows the motorcycle traveling speed of a participant when the Car Breakdown Warning (CBW) was presented. It can be seen that the traveling speed is reduced 1 second after the presentment of CBW. This result indicates that the LCD panels built in the meter clusters can be adequately recognized under circumstances when there is enough time to react, even though they have large depression angles.

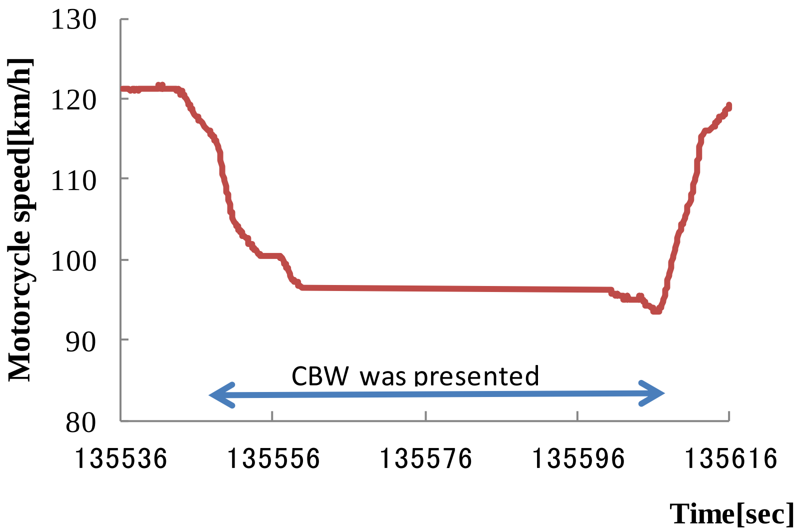

Figure 4. Motorcycle traveling speed of a participant when the CBW was presented

In the description of the questionnaire, we got a feedback that information about the distance to the target object will help. Providing such information will help the rider to conduct a proper judgment and reaction. Thus, it is likely to enhance the rider's acceptability. In the mean time, the quantity of information must be considered, because excess of information may cause confusion.

4.2 Benefit of functions

In Vehicle Signage (IVS)

IVS assists the rider to determine their traveling speed by displaying the speed limit. In this paper, we defined the IVS is effective when the traveling speed does not exceed the speed limit, and we verified this by comparing the traveling speed of Baseline and Treatment. Eleven data of IVS 30km/h were collected. Figure 5 shows the average speed during the section where the IVS information was provided. We could not see any speed suppressing effect in this usecase.

In this test, the display simply showed only the speed limit, and it did not present any specific indications for the rider. e.g. "Slow down." Therefore, it seems that the riders did not decide to decelerate. The results show that the average speed of Treatment is higher than that of Baseline. This could be due to the order effect: all participants were tested in orders of Baseline first and then Treatment.

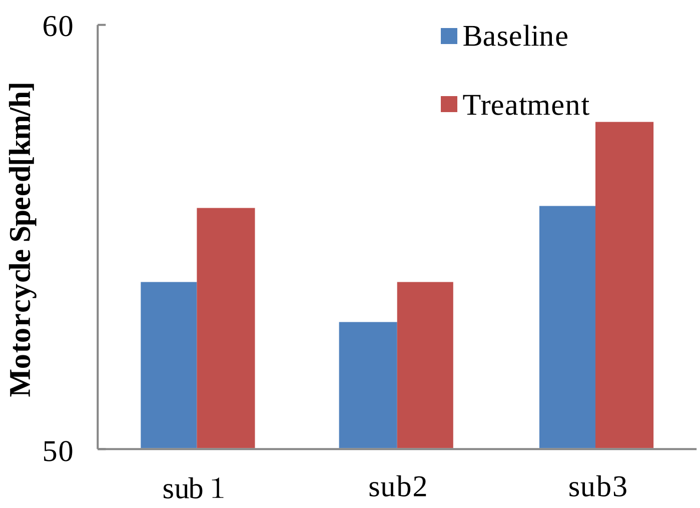

Figure 5. Average speed during the section where IVS was provided

Road Works Warning (RWW), Car Breakdown Warning (CBW)

RWW and CBW provide the information of potentially dangerous objects ahead, and seeks the rider's attention to forwards and encourages them to restrain their speed. The warning is presented 300 meters before the object, so as to provide the rider enough time to react. In this paper, we defined the RWW/CBW is effective when the traveling speed is restrained, and we verified this by comparing the traveling speed before and after the information was provided. All of the participants received the information correctly once in this experiment. The results of CBW and RWW were practically similar. So in this paper, we will describe the results based on the data of CBW. Figure 6 shows the average speed within the section where the information was provided, and the average speed of 10 seconds before providing the information. The data plotted in the bottom right area of the diagonal line shows that the rider reduced the speed after the information was provided. The data plotted on the diagonal line shows that the rider did not change the traveling speed. It can be seen that all of the participants reduced their traveling speed after the information was provided. Since we did not instruct the traveling speed, each rider's reduced speed varied. A rider who traveled in higher speed tends to reduce their speed more than a rider who traveled in lower speed. In any case, we can say that CBW and RWW were effective to all of the participants.

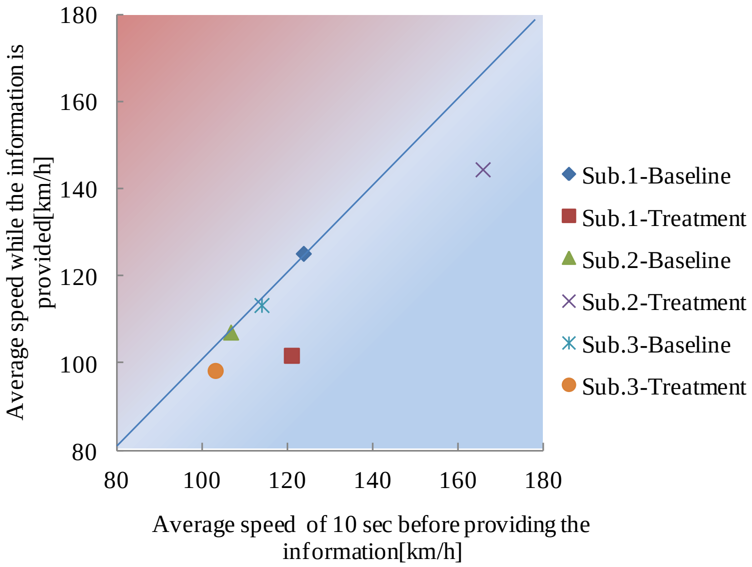

Figure 6. Average speed before and after providing the information of CBW

Approaching Emergency Vehicle (AEV)

AEV provides the information of the direction of an approaching emergency vehicle. The information helps the rider to behave not to interfere the emergency vehicles. In this experiment, we tested a scenario of which an emergency vehicle approach from behind and overtake the motorcycle. Unfortunately, we could not collect any valid data because the emergency vehicle was not able to approach in a timely manner, due to reasons like the high traveling speed of the motorcycle. In summary, it is found that the information of existing dangerous objects which riders can easily imagine was effective for all participants.

5 Conclusions

The results of experimenting HMI acceptance and effects of providing information under real traffic conditions are as below. The effects and acceptability depends on the function.

The effects and acceptability depends on the function.

Since road works and car breakdowns are easy to imagine and are recognized as dangerous objects, these functions are highly effective.

The effects of information like speed limits were not seen in this experimental condition.

The riders are able to fully understand the information from LCD and LED placed in the dashboard, in a non-urgent situation.

Providing additional information like distance and urgency may improve the acceptability of the rider. Requirements such as the timing to provide information, installation requirements of the HMI, and the types of required information, should be considered by testing many more participants under more controlled conditions. We are working on these analyses by using a riding simulator. Through these experiments of both simulator and real environment, we will clarify the requirements of HMI design.

Acknowledgments

We would like to thank the system developers of DRIVE C2X who supported us on our system construction, and the staff of Auto der Brennero, Centro Ricerche Fiat who warmly accepted our participation and supported us during the experiment.

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Motorcycle riding simulation to assess instrument and operation concepts and informing riding assistance systems

Motorrad-Fahrsimulation zur Absicherung von Anzeige-Bedien-Konzepten und informierenden Assistenzsystemen

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Abstract

Due to the increasing functionalities in the motorcycle sector (entertainment system, navigation, on-board computer, etc.), BMW Motorrad acts within the scope of the company's strategy *Safety 360°* [2] and finds itself obligated to optimize the communication between vehicle and rider. This includes both rider inputs as well as information output by the motorcycle which is presented to the rider in an increased manner during the ride. The aim is to counteract the potential that the rider is overburdened by the new functionalities, system operations or the flood of information which can result in frustration regarding the product or even in a decreasing riding performance. Identifying and eliminating these potential risks accounts for safe riding.

Based on this background, a method has been developed to measure user acceptance, rider workload and distraction by the increase of new functionalities and by new instrument and operation concepts. This allows rating and comparing of different concepts. To provide a reproducible, safe test environment, a motorcycle simulator has been developed in cooperation with the Wuerzburg Institute for Traffic Sciences (WIVW GmbH) and the Institute of Automotive Engineering (FZD) at the Technical University of Darmstadt.

Whereas flight and car simulators are widely used for education, testing and research, the use of motorcycle simulators is still rather uncommon, most of all in the research and testing sector. In this publication the challenges and resulting minimum requirements to develop a motorcycle simulator are presented. Special focus is placed on the subjective riding experience. During a BMW Motorcycles study, an existing static motorcycle simulator was tested and rated in order to find optimization potential for a new dynamic concept. The publication ends with a presentation of future upgrades of the static simulator derived from the developed requirements and based on the identified optimization potential.

Kurzfassung

Durch die stark steigende Anzahl an Funktionen im Motorradsektor (Entertainment-System, Navigation, Bordcomputer, usw.) sieht sich BMW Motorrad im Rahmen der Strategie *Sicherheit 360°* [2] vor der Herausforderung, die Kommunikation zwischen Fahrzeug und Fahrer zu optimieren. Dies betrifft sowohl Fahrereingaben als auch Informationsausgaben durch das Motorrad, die dem Fahrer in gesteigertem Ausmaß während der Fahrt bereitgestellt werden. Ziel ist deshalb dem Potential, dass der Fahrer von neuen Funktionen, Bedienkonzepten oder einer Informationsflut überfordert wird, frühzeitig entgegen zu wirken. Hierdurch kann eine Frustration bezogen auf das Produkt bis hin zu einer Verschlechterung der Fahrleistung vermieden werden. Die Identifikation und Eliminierung dieser potentiellen Gefahrenquellen unterstützt somit das sichere Fahren.

Basierend auf diesem Hintergrund wird ein Verfahren entwickelt, um die Nutzerakzeptanz, Fahrerbelastung und -ablenkung durch die Steigerung der Umfänge neuer Funktionalitäten sowie neuer Anzeige-Bedien-Konzepte zu messen. Hierdurch entsteht die Möglichkeit, unterschiedliche Konzepte bewerten und vergleichen zu können. Zur Bereitstellung einer reproduzierbaren, sicheren Testumgebung wird deshalb in Kooperation mit dem Würzburger Institut für Verkehrswissenschaften (WIVW GmbH) sowie dem Fachgebiet Fahrzeugtechnik (FZD) der Technischen Universität Darmstadt ein Motorrad-Fahrsimulator entwickelt.

Während Flug- und Pkw-Simulatoren ein etabliertes Werkzeug zur Ausbildung, Erprobung und Forschung darstellen, ist die Anzahl der Anwendungen von Motorrad-Simulatoren vor allem im Forschungs- und Erprobungsbereich noch sehr begrenzt. Im Rahmen dieser Veröffentlichung werden die Herausforderungen zur Entwicklung eines Motorradfahrsimulators dargestellt und daraus Mindestanforderungen für einen Simulator abgeleitet. Besonderer Fokus wird auf den subjektiven Fahreindruck – das „Fahrgefühl“ – gelegt. Während einer BMW Motorrad internen Studie wurde hierzu ein vorhandener statischer Motorrad-Simulator bewertet, um weitere Optimierungspotentiale für ein neues dynamisches Konzept zu erarbeiten. Die Vorstellung der aus diesen Anforderungen und Optimierungsmöglichkeiten abgeleiteten Optimierungen bildet den Abschluss der Veröffentlichung.

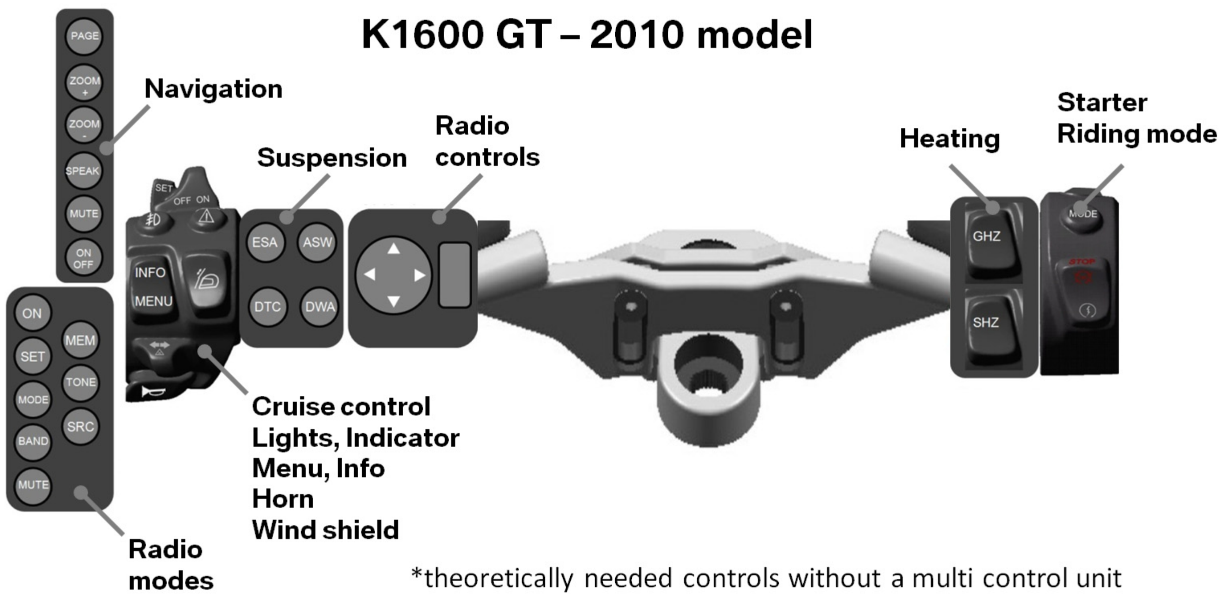
Motorcycle riding simulation to assess instrument and operation concepts and informing riding assistance systems

1 Introduction

During the last decade there have been changes in the motorcycle riding tasks [1, 4]: New technologies like cruise control for motorcycles or motorcycle mounted navigation systems have changed the primary and secondary driving task and most of all the tertiary driving tasks have become more and more relevant for powered two wheelers. Some new features, such as antilock brake or wheelie assistant ease the stabilization task while other functions provide more comfort like a handle bar heating.

The increase of functions brings a raise of controls (see Picture 1) as well as an increase of information for the rider. The prospective increase can possibly overburden the rider, so that he focuses too much on a tertiary riding task while neglecting the primary or secondary riding task, which can lead to riding errors up to dangerous traffic situations [7].

BMW Motorrad commits itself to provide maximum safety and carefree riding pleasure by the strategy *Safety 360°* [2]. Therefore, counteracting potential risks by the future increase of controls and information is part of this strategy.



Picture 1. Theoretically needed controls a BMW K1600GT motorcycle

Comparing and assessing different input and output concepts is a part of usability testing (DIN EN ISO 9241). It is described as a method to measure the user's efficiency, effectiveness and joy while using a product. Therefore usability testing gives tools to optimize instrument and operation concepts related to these three aspects. One important question concerning the rider's security is whether a new system or a modification has a negative influence on the rider's driving behavior.

As discussed above, a road test can be too dangerous for participants. Thus, a test environment is needed that produces valid and reliable results but which at the same time does not implement a risk for the test person. In other words, an environment must be provided that imitates the real riding situation so that the rider behaves as if riding a real bike and is physically and mentally as loaded as in real traffic situations.

1.1 Presence as indicator for a valid test environment

The phenomenon that participants behave in a virtual environment (VE) as in a real situation is called "Presence" [5]. As per Sanchez-Vives and Slater state, three constraints are required to produce presence:

1. Sensomotory loop
2. Statistical plausibility
3. Behavior-response correlations

Item three is not considered in this paper as it is a part of the virtual traffic model, which is not in the focus here.

The sensomotory loop describes the low latency connection of proprioception and sensory data, or in other words transferred to the test environment the natural system response to an input e.g. the roll reaction of the motorcycle on a steer impulse.

Statistical Plausibility is based on the theory that the human's brain works like an ongoing correlation algorithm that searches for correlations between current sensory inputs and sensory inputs from the past (see "correlational presence" in [6]). By this means single missing information can be overwritten by strong memories of similar sets of stimuli. Transferred to virtual environments, it is essential to produce sufficient output data so that the brain correlates the sensory input to similar inputs from a former real set of stimuli.

In order to design a presence producing test environment it is necessary to know which stimuli the rider perceives during riding a motorcycle and which of these stimuli are necessary to be reproduced within the test environment so that the participant's conscience correlates the virtual situation with a real situation. Modern physiology distinguishes between nine senses. Referring to the riding task four of nine are excluded for all further research (olfaction, degustation, thermoreception, nociception) so these five senses will be tested during further investigations:

- Visual perception
- Audition
- Tactile perception
- Equilibrioception
- Proprioception

Since no information about the influence and importance of these senses on the experience of presence in a test environment for riding motorcycles could be found, the following research was initiated.

1.2 Riding simulator as a special test environment to experience Presence

Usability laboratories in general consist of a working zone where a test person interacts with the system that is being tested and an area where the investigator monitors the person's ability to use this system. Advantages of the laboratory are controllable surrounding conditions and providing good observability.

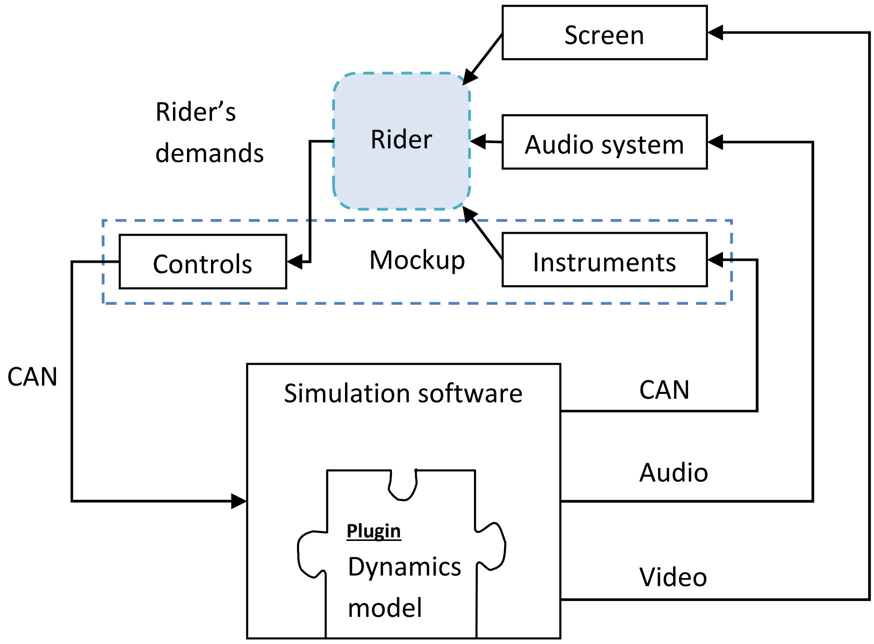
In 2009, BMW Motorrad started with tests in a usability laboratory to assess an instrument and control concept. The test environment produced visual and auditory outputs (video sequences of traffic scenes were shown). It was demonstrated that some usability measuring methods could be transferred from the automotive sector to the powered two-wheelers like "free exploration", "thinking aloud" and "questionnaire" for a first usability assessment. However in order to measure the rider's distraction during a riding task, this test environment was not recommended but to build up a motorcycle simulator as one way to imitate the riding task in an interactive way. Hence, BMW Motorrad decided to build up a motorcycle driving simulator in the fall of 2011.

2 Concept of the first BMW motorcycle riding simulator

The first BMW motorcycle riding simulator consists of the following four components (Picture 2): Mockup, simulation software, audio and visual output. The Mockup is built on a BMW K1600 GT (Picture 3). In order to fake the instrument signals and to measure the rider's inputs, the motorcycles data circuit (CAN bus system) was manipulated (CAN-Gateway between display and control devices), so that bus signals can be logged and changed during simulation.

The rider's inputs are processed in a dynamics model (changeable plugin of the simulation software) which calculates translational and rotary kinetic quantities of a virtual motorcycle model based on the inputs throttle, breaking pressures and steering angle. The current dynamics model is a modified car model (Mini Cooper with automatic gearbox and without anti lock brake) with reduced weight, gauge of the track, higher brake capabilities and engine power. In addition the roll angle's output data was inverted and increased to fake motorcycle's incline during cornering (participant's acceptance to this manipulation is shown in chapter 4.2).

The kinematic quantities are interpreted by an in-house simulation software that calculates video and sound signals. The rider experiences a virtual reality by a 4x3m video screen and a 4.0 sound system. The virtual horizon is rotated by the modified roll angle so that the rider experiences an incline.



Picture 2. Components of the BMW motorcycle riding simulator

Picture 3. Simulator mockup built on a BMW K1600 GT motorcycle

3 Study to assess simulator's quality

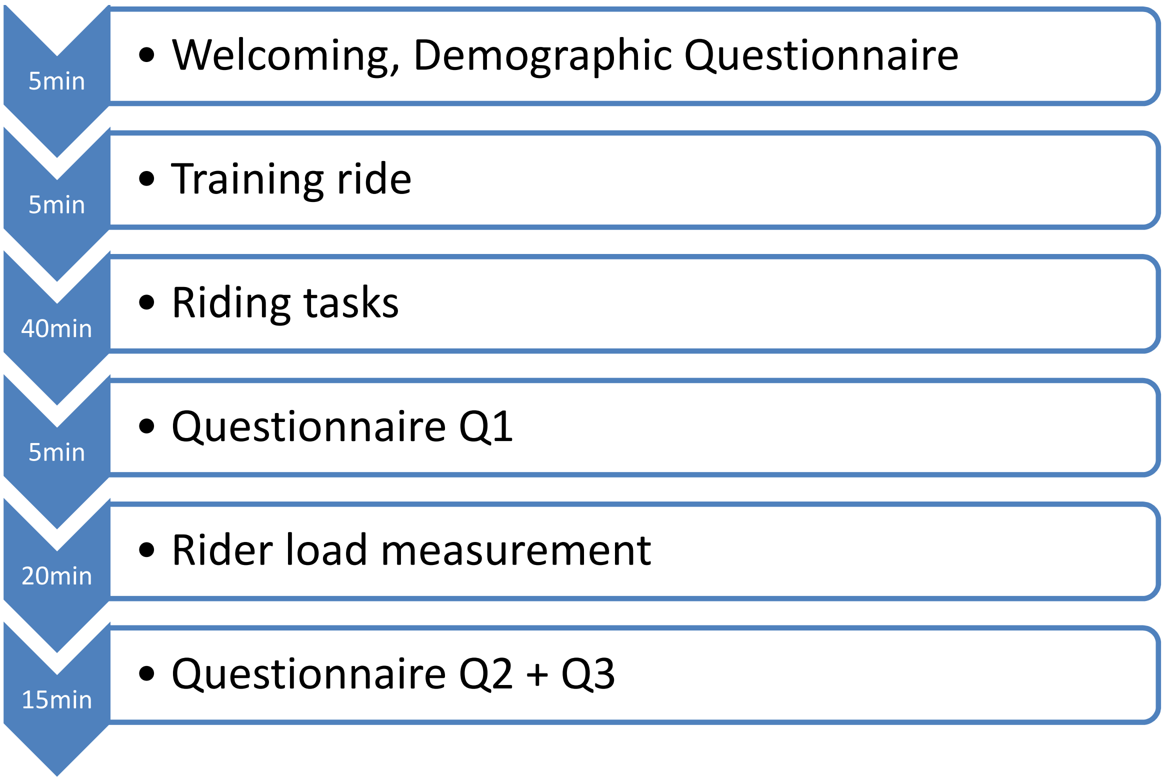
This study seeks to inquire information about the subjective impression on the experimental setup to identify the most important points to improve the sense of presence. In order to make the simulator comparable to a project partner's (WIVW GmbH) simulator, their internal questionnaire (see "Questionnaire for assessing motorcycle simulations") was used along with two questionnaires by BMW.

3.1 Testing group

The testing group consists of 18 men and two women between 24 and 56 years old (average 34 years) all having a motorcycle driving license and all working at BMW Motorrad. Six participants answered to ride less than 5,000km per year, ten between 5,000km and 10,000km, three between 10,000km and 20,000km and three more than 20,000km per year. All riders were wearing their own helmets and motorcycle gloves during the experiments.

3.2 Experimental procedure

The experiment took about 90min per participant (see Picture 4). After being welcomed each participant answered a demographic questionnaire.



Picture 4. Experiment's structure and duration

The simulator's controls were explained to the participants and the simulator ride started with a short introduction ride (about 5min) consisting of an acceleration maneuver, breaking and two lane changes on a straight highway. The introduction ride was held very shortly in order to measure the training effects on the following maneuvers (not part of this article).

In order to ease answering of the questionnaire about assessing the simulator's quality, the following maneuvers had to be accomplished:

Acceleration and breaking

The driver was told to accelerate from standstill up to 100km/h and hold this speed on a straight highway without any traffic. After 1km he saw a row of pylons on the road. The rider was told to break as late as possible and decelerate so that the front tire of his motorcycle is in a line with the virtual pylons.

Assessing constant speed

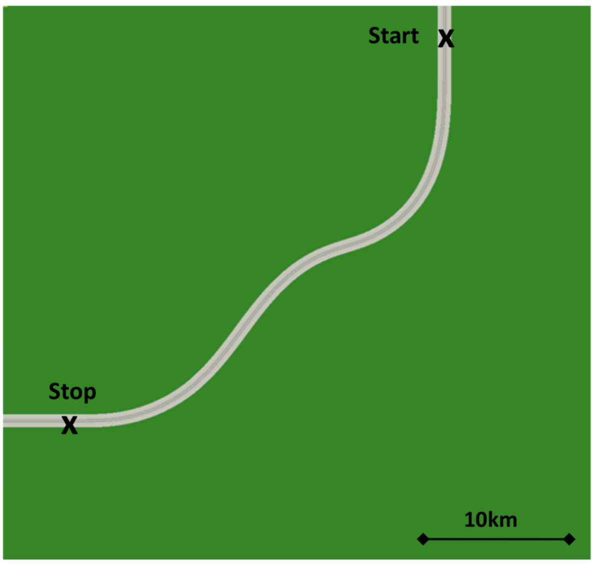
In order to assess a constant speed without looking at the speedometer, the rider was told to accelerate from standstill to 50km/h, 100km/h, 130km/h (randomized order for each rider) on a straight highway without traffic, a disabled speedometer and a disabled revolution counter. In order to indicate when he thinks he has reached the speed aimed at, the participant was told to turn up the headlights as a sign. After ten seconds the headlights automatically turned down which was the signal for the rider to stop the bike slowly. This procedure was repeated three times so that he assessed every speed.

Lane change on highway

In order to get an impression how the simulator behaves on lane changes, a scenario was implemented in which two cars were driving 60km/h with a gap of 800m on the rightmost lane of three on a straight highway. The rider was told to overtake each car separately and stop the motorcycle after that on the breakdown line.

Constant cornering

In order to create an impression of how it feels to take wide curves in the VE, the participants were told to follow a highway with three curves at a speed of 100km/h on the rightmost lane. After driving these curves, he had to stop the bike on the breakdown lane. For the exact route see Picture 5.

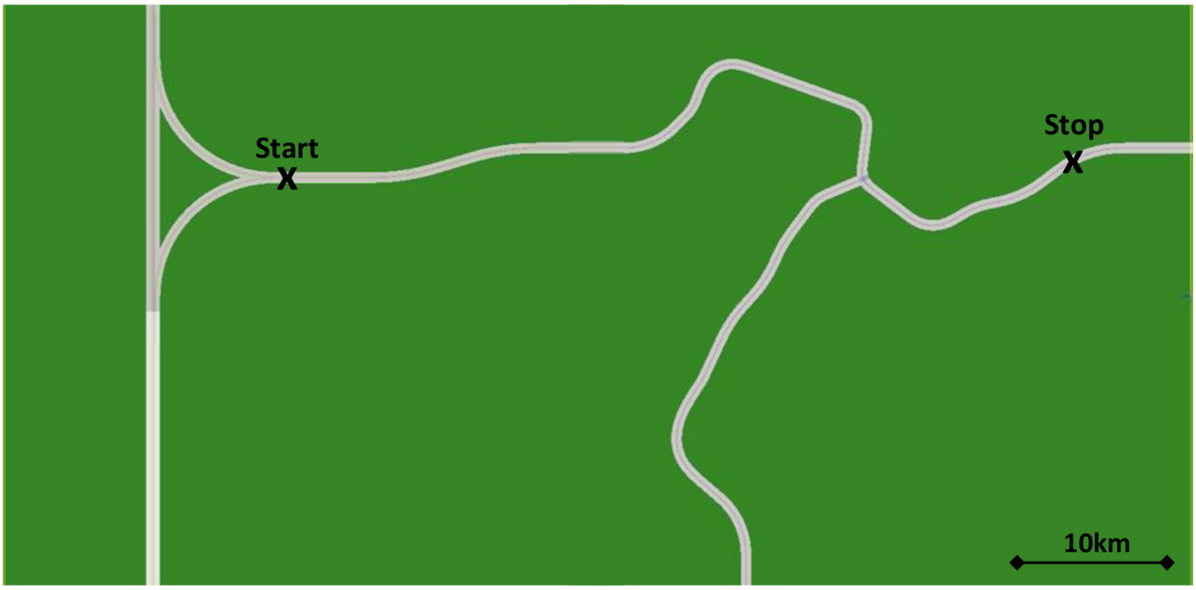


Picture 5. Scenario for constant cornering

Countryside highway

The last riding task for this study constitutes riding on a curvy countryside road with different speed limits and some traffic (Route depicted in Picture 6). The rider was told to drive safely and within the speed limits until he sees roadworks and to stop before the construction area. This scenario was chosen to get an overall impression of the handling and to make it easier to compare the simulator's behavior with real motorcycle riding.

All of these riding scenarios were driven three times. After completion, two questionnaires had to be answered: "Questionnaire for assessing motorcycle simulation" and a questionnaire directed to the described riding tasks (details to the questionnaires in chapters 3.3 and 3.4).



Picture 6. Scenario countryside highway

After that the second part of the study started with another riding task about work load measurement which is, however, not part of this article. The experiment for every participant ended with a last questionnaire about the simulator's quality relating to the sensory perception (see chapter 3.5).

3.3 Questionnaire for assessing motorcycle simulations (Q1)

The focus of this study was to filter the important points for a realistic riding experience from the participant's field of view. To get to this information and to have a base to compare the BMW Motorrad simulator later on to the one our project partner WIVW GmbH is using an internal questionnaire from WIVW GmbH was used. This questionnaire is a modified version of the Witmer and Singer questionnaire [8] by Will, S. and Neukum, A. (internal document of WIVW GmbH) to fit the motorcycle simulator purposes (see Picture 7). The original one by Witmer and Singer to assess virtual environments had to be modified, because interacting with a VE in a CAVE differs from riding or driving within a VE on a motorcycle mockup. As the focus was on fulfilling a riding task, questions regarding examining virtual objects were irrelevant for our purpose. Nevertheless, it should be mentioned that that one question of the modified questionnaire concerning traffic was deleted, as there was simply no traffic except for two vehicles that had to be overtaken during the lane change task.

All of the questions incorporated the concept of reported Presence [5] and were used to clarify whether the chosen configuration of inputs and outputs is realistic from the participant's point of view. The scale in this questionnaire reaches from 0 to 15 and is subdivided into 6 subcategories:

0	Not at all	7-9	middle
1-3	Very little	10-12	much
4-6	little	13-15	Very much

3.4 Questionnaire to assess riding tasks (Q2)

This questionnaire is divided into the three categories: acceleration/deceleration, cornering and overtaking/avoiding. The questions can be rated on a scale from one (=bad) to 5 (=good).

As mentioned above, some modifications and scaling to the original dynamics model had to be made to use the car model for motorcycle simulations. All modifications and scale factors were acquired iteratively by expert's riding tests. The questions of this questionnaire were designed to rate these acquired modifications.

Question one and two in category acceleration/deceleration rate the visual perception of acceleration and deceleration. Question three rates pitching during braking. The next two questions assess the scale factors between rider's inputs (breaking and throttle) to the simulated acceleration/deceleration. Every category ends with a question to rate the overall impression of the category.

Category *cornering* and *overtaking/avoiding* contains a question to the correlation between steering torque and the motorcycle's reaction besides the question to the overall impression. In addition to this, category *cornering* asks about the visual impression of the incline and category *overtaking/avoiding* about the latency of the simulation to the inputs. All questions are shown in chapter 4.2.

3.5 Questionnaire to sensory perception (Q3)

This questionnaire was asked to be answered after completion of the whole experiment in order to give the rider much time to grasp a complete impression of the simulator. The questions dealt with the subjective perception of reality related to the different senses.

Four questions concern visual perception, two acoustics, two haptics and two realism in general: The first three categories all include one question explicitly focusing on the appearance of reality, the first two about how helpful this channel is to estimate the rider's speed. Category *visual perception* also included one question about the ability to estimate distances based on this channel and whether the missing channels for the rear mirrors disturbs the rider.

The category haptics included a question whether the rigid fixation of the mockup disturbs the rider. The last two questions dealt with an overall impression of the realism and how well control inputs fit the riding simulation. All questions are shown in detail in chapter 4.3.

4 Results

All questions of the questionnaires, its average results, the medians, quartiles, interquartile ranges and minimums and maximums are displayed in the Picture 7 to Picture 9. The results are analyzed in the following subchapters and discussed in chapter 5.

4.1 Results: Assessment of the Simulator

First of all, it is to mention that questions 12 and 16 have been formulated negatively, while the other are formulated positively. In general, it can be seen in Picture 7 that most of the questions were answered with a medium value (9 of 16 questions). The answer "not at all" was chosen seven times (2.1% of all times). The highest value (15) was never chosen.

The questions 3 and 4 were answered slightly below medium on average (6.20 and 6.05) and two of seven times "not at all" was given in this category. These questions describe the simulators presentation of positive and negative acceleration. Question 7 which was about being able to imagine touching and being touched by virtual objects was answered with a wide dispersion and the weighting "little" was given on average (5.86). Participants did not have many problems with disorientation after the simulation (Question 12, average: 6.05 – negatively formulated). The rider's perspective (Question 13) and the VE's visual depiction were reviewed above medium (10.2 and 9.9). Simulation's overall latency was rated low on average (5.85).

4.2 Results: Questionnaire to assess the riding tasks

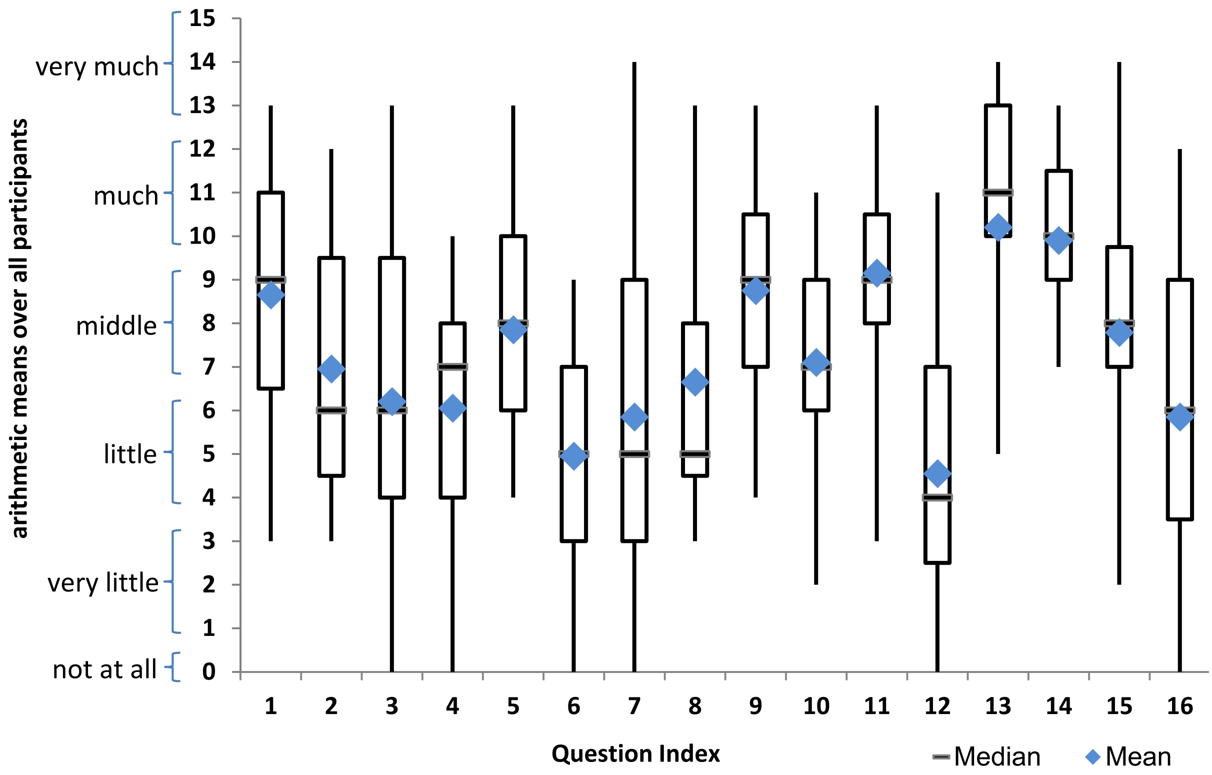
Picture 8 shows the results of the questionnaire to assess the riding tasks. It can be seen that 9 out of 12 questions were answered with a medium value ($2.50 < x < 3.50$) and 10 of 12 questions were answered with a wide spread (questions assessed with values from minimum to maximum).

Question 8 about the motorcycle's reaction in comparison with the steering torque during steady state cornering was answered clearly under average (2.15) contrary to the same question (Question 10) during overtaking/avoiding (3.10).

Clearly positive rated were questions 11 and 12 concerning the latency from motorcycles input to the outputs and the overall impression about overtaking and avoiding.

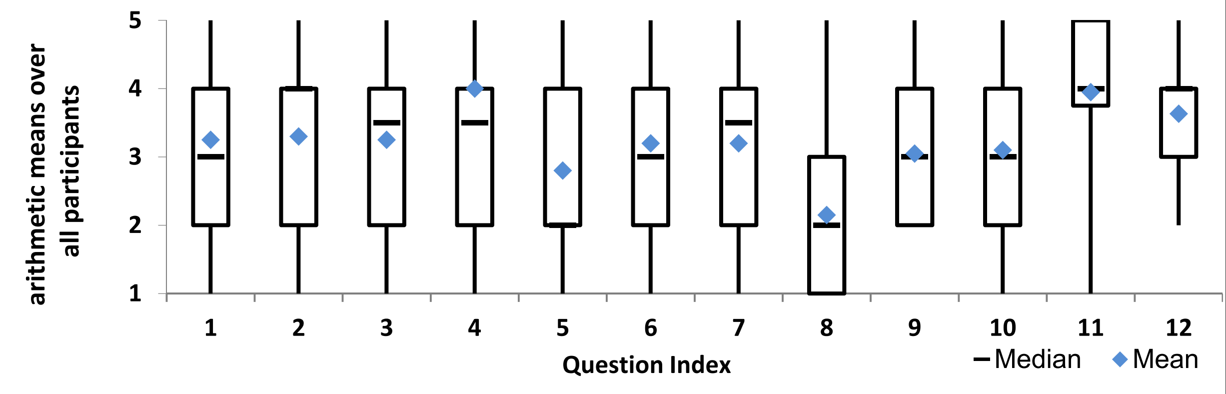
4.3 Results: Questionnaire to sensory perception

The questionnaire about sensory perception was also mostly answered with medium values (8 of 10 between -1 and 1, see Picture 9). The helpfulness of the visual feedback to estimate distances (Question 2) was rated slightly above one on average (1.15) as well as the interaction between inputs and riding (1.35 – Question 10). Question 8 - the haptic feedback - was rated slightly negative as well as question 8 which asked whether the mockup's stiffness felt irritating.



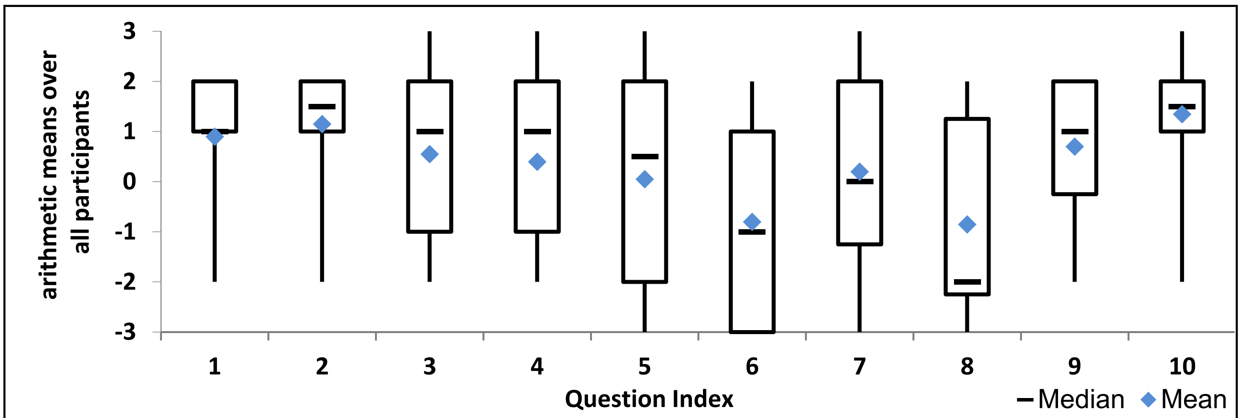
1. During the trip, I only had on my mind riding a motorcycle and hardly thought about anything else.
2. I had the feeling to drive a motorcycle on a street.
3. The acceleration impression was realistic.
4. The deceleration impression was realistic
5. I was able to ride the motorcycle without any problem (direction, brakes, acceleration) and riding gave me no trouble at all. It is right…
6. During the ride I had forgotten completely that I was on a riding simulator.
7. I imagined touching the objects in the virtual world and that the objects could touch me.
8. The speed impression was realistic.
9. During the trip, I had the feeling that I was surrounded by cars, trees, houses and people of the virtual world.
10. During the trip, everything fit together - seeing (scenery), hearing (engine/wind sound) and feeling (movement impression).
11. I had the feeling that the other road users and the surrounding objects were at the same place as I was (other vehicles, houses, trees, pedestrians etc.).
12. When the trip was over, I was disorientated at first and had to get used to the real surrounding again.
13. The rider's perspective of the simulation was convincing.
14. The simulation's visual representation was convincing.
15. The simulation's auditive representation was convincing.
16. The delay between my actions and the simulation's reactions was distracting.

Picture 7. Results of the questionnaire for assessing motorcycle simulations



acceleration / deceleration	1. How do you assess the visual perception of the deceleration? 2. How do you assess the visual perception of the acceleration? 3. How do you assess the visual impression of brake and acceleration pitch? 4. Does the vehicle's acceleration fit the manipulation of the throttle? 5. Does the deceleration fit the manipulation of the brake handle? 6. How do you assess the general impression of the acceleration and deceleration?
cor-nering	7. How do you assess the visual impression of the roll angle? 8. Does the motorcycle’s reaction fit the applied steering torque? 9. How do you assess the general impression to the trip’s curves?
overt. / avoiding	10. Does motorcycle’s reaction fit the applied steering torque? 11. Does the motorcycle react immediately on driver's inputs? 12. How do you assess the whole feeling / the general impression of overtaking / avoiding?

Picture 8. Results of the questionnaire to assess the riding tasks



1. The visual feedback of the riding simulation feels realistic.
2. The visual feedback helped me to estimate distances.
3. The visual feedback helped me to estimate my speed.
4. The acoustic feedback was realistic.
5. The acoustic feedback helped me to estimate my speed.
6. The riding simulation's touch feedback feels realistically.
7. I felt irritated because of the absence of the pictures in the rear mirrors.
8. I felt irritated because of the stiffness / immobility of the mockup during cornering.
9. The overall impression of the riding simulation feels realistically.
10. The interaction between controlling and riding feels realistically.

Picture 9. Results of the questionnaire to sensory perception

5 Discussion

The questionnaires' results (Q1…Q3) show that most of the rated simulator components reach a medium level. The rider's perspective (Q1-13), the visual representation in general (Q1-14) as the simulators latency (Q1-16, Q2-11, Q3-10) are better than medium so that the focus on the simulator optimization won't be in these categories first.

One clear deficit of the simulator is haptics/steering torque (Q2-8, Q3-6). Comparing the simulator to real motorcycle riding, there are two main differences:

1. The simulator does not emit vibrations (originating from the engine / road surface)
2. The steering torque just depends on friction of the designed test setup and is not controlled by the motorcycle's riding conditions

Also, positive and negative acceleration reproduction was rated low in comparison to the rest of the questions. Analyzing an acceleration maneuver on a real motorcycle, the rider gets three important inputs:

1. Visual data: motorcycle pitches, visual speed perception changes
2. Vestibular data: above a threshold the human equilibrium organ registers acceleration
3. Kinesthetic data: joints and muscles register translational acceleration and difference in steering torque

The simulator only gives a visual feedback for which vestibular and kinesthetic information are missing. Relating to Slater et al. [6] who describe human perception as a correlation machine, the simulator does not seem to give enough information about acceleration maneuvers so that a correlation between virtual and real accelerations can be found. In other words: to depict a realistic perception of accelerations, participants need more information than just visual.

Another interesting result of the questionnaires is that the participants answered they had difficulties imagining to touch and to be touched by virtual objects (Q1-7) but the question about feeling to be surrounded by cars, houses and people (Q1-9) and about feeling to be on the same place like the virtual road users and surrounding objects (Q1-11) were rated comparatively high (see Table 1).

Table 1: Comparison of Q1-7, Q1-9 and Q1-11

Question	arithmetic means over all participants
Q1-7. I imagined touching the objects in the virtual world and that the objects could touch me.	5.85
Q1-9. During the trip, I had the feeling that I was surrounded by cars, trees, houses and people of the virtual world.	8.75
Q1-11. I had the feeling that the other road users and the surrounding objects were at the same place as I was (other vehicles, houses, trees, pedestrians etc.).	9.15

One reason for this difference is probably that most of the time objects are distant as this would also be the preferred behavior in reality to avoid collisions. This is possibly also the reason for the wide dispersion of ratings for Question 1-7.

Another reason can be seen in the fact that some people meant to hit an object during the simulation by accident but nothing happened. The reason for this is the simulation software is also used for dynamic simulation at BMW Forschung und Technik and displaying to hit a wall or any other object would be dangerous for participants within the dynamic simulator. Probably the differences in these answers would vanish if there was more traffic on the virtual roads, so that other objects are closer to the participants within the VE. Otherwise a collision feedback could be implemented so that the participant recognizes contact with other objects without being in danger.

6 Optimization and future work

In order to improve the development speed of the simulator, a cooperation with Technical University Darmstadt and Wuerzburger Institut fuer Verkehrswissenschaften GmbH was started. In cooperation with these two partners, the following optimizations will be executed and a second simulator will be built up.

One important point for a realistic motorcycle simulation seems to be realistic steering torque simulation. In order to produce realistic steering torque, an electric drive will be mounted to the mockup's front wheel. To calculate the steering torque depending on the dynamic motorcycle states like incline, speed etc., the dynamics model needs to be changed. It is assumed that a consistent motorcycle model will also influence other factors in a positive way, such as acceleration and breaking, incline etc., which were calculated by correction factors out of the Mini dynamics model.

In order to optimize the criticized acceleration and deceleration perception, two upgrades are planned: After a report by Born [3], an increase of acceleration sensation can be created by pulling at the participants torso to simulate inertia forces. A prototype will be built up to verify this idea. The second update will be a small motion base to move the mockup.

Since motorcycles vibrate much more and are much louder than cars, another focus will be on vibration and sound. To optimize acoustic sound, vibration sound and structure-borne noise, samples will be recorded to emit realistic sound and vibrations.

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The Motorcycle Fuel Tank and Pelvic Injury in Crashed Motorcyclists

Der Motorradtank und hierdurch bedingte Beckenverletzungen bei Motorradunfällen

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Abstract

Pelvic and lower abdominal injuries are a serious concern for motorcyclists involved in collisions. Despite their importance, the limited research that has been undertaken has commonly attributed these injuries to contact with the motorcycle fuel tank. Following earlier studies, Wobrock et al. used MADYMO simulation to investigate the effect of tank angle for an average rider on a sports bike. They found pelvic loads to be exponentially related to tank angle, suggesting minimising tank angle may result in a reduced risk of injury.

Using data from 139 in-depth motorcycle crash investigations in Sydney and Adelaide, Australia, the relationship between tank angle, motorcycle type and the occurrence of pelvic and lower abdominal injuries in crashes associated with a predominantly forward rider movement was examined.

Of the 139 riders involved in crashes, 60 experienced forward momentum following the collision. Of those 60, 27 riders sustained injury to the pelvic/abdominal regions attributable to the fuel tank (45%). Pelvic/abdominal injury occurred in a further four cases however these were not attributed to direct contact with the fuel tank.

Pelvic/abdominal injuries were more common among riders of cruisers (80%) than other motorcycle types (45%). Statistical modelling demonstrated that cruiser riders were seven times more likely to sustain pelvic/abdominal injury than other riders (95% CI 1.3-38.5), and importantly, after controlling for motorcycle type, the likelihood of pelvic/abdominal injury significantly increased with increasing petrol tank angle ($p<0.05$).

These results indicated that, while tank angle does play a role in pelvic/abdominal injuries, the relationship is likely to be complicated by other characteristics of tank and motorcycle design. Further work is required to identify optimum tank and motorcycle design to improve rider protection for pelvic and abdominal injury.

The Motorcycle Fuel Tank and Pelvic Injury in Crashed Motorcyclists

Introduction

Injuries to the pelvis and lower abdominal region carry a significant health burden. Injuries to this region occur frequently in motorcycle crashes with debilitating effects, including the ability to walk, reproduce and urinate. For motorcyclists, it has been suggested that the fuel tank is a major cause of pelvic and lower abdominal injuries in the event of a crash [1]. It is notable that despite the consequences of these injuries and the changes to the design of powered two-wheeler, there is a paucity of research in this area, with much of it done in the early 1980's.

Ouellet and Hurt [1] investigated a sample of 900 motorcycle collisions and found that 13% of riders sustained a pelvic or lower abdominal injury. Ouellet and Hurt stated that the fuel tank was the predominant contact surface and was associated with 88% of pelvic injuries. In discussing their findings, they suggested that a tank with a smooth profile, rising gradually from the seat, or one which would distribute the force to the pelvis over a larger surface area would be advantageous in reducing pelvic injuries. In contrast, Ruter, Hontschick and Jessl [2] suggested that a broad, flat tank situated at seat level would be beneficial in reducing contact with the fuel tank and promoting rider ejection. In an earlier study (1973), Bothwell, Knight and Peterson [3] stated that the tank top should not rise above the surface of the seat and the tank shape should be designed to minimise pelvic impact loads.

In 1976 Hight, Seigal and Nahum [4] investigated 127 motorcycle collisions and found there were only six riders who sustained injury to the perineum, scrotum, testicles or penis. This investigation did not include the examination of pelvic fractures. They did however propose that the width and height of the tank relative to the seat affected the injury pattern.

A study by de Peretti et al. [5] conducted in 1994 examined nine cases of riders who had sustained pelvic injuries, six of these being due to contact with the fuel tank. The authors proposed that the spreading of the riders' legs was a potential mechanism of injury, and inferred that the petrol tank should not be wedge-shaped but rather the sides should be well padded, the petrol tank cap should not protrude and the upper part of the tank should be on the same level as the seat and should not overhang.

More recently, Wobrock et al. [6] performed MADYMO simulations of riders impacting the motorcycle fuel tank. They investigated the effect of tank angle on the force to the pelvis by running simulations of a pelvis impacting the fuel tank of a sports motorcycle with different tank angles (20, 55 and 90 degrees). A 50th percentile sized male was used in the simulations. Wobrock et al. reported that the force on the pelvis increased exponentially as the fuel tank angle increased. This is an important finding that warrants further study in modern powered two wheelers. The analysis of a sample of real-world motorcycle collisions studied in-depth offers a way to determine if the relationship between the tank angle and the force on the pelvis is reflected in the risk of sustaining an injury in the real world where a range of factors may be at play.

This paper presents the preliminary analysis of work which aimed to investigate the injury mechanisms involved in pelvic and lower abdominal injuries to motorcyclists involved in crashes. In doing so, this paper aims to assess the nature of the relationship, if any, between the angle of the motorcycle fuel tank and the occurrence of pelvic or lower abdominal injuries.

Methods

Two convenience-based data sets were used in this study to examine the effect of tank angle on the occurrence of pelvic/lower abdominal injuries. The first data set was obtained from motorcycle crashes occurring on public roads within a three hour drive of Sydney from August 2012 to July 2014. Eligible participants were motorcyclists aged 14 years and older who had been admitted to hospital. Motorcyclists were recruited by research nurses from three Sydney hospitals and one regional hospital.

Motorcyclists completed an interview which outlined the overall scope of the crash and gave suggestions as to the causes of their injuries. Medical records were also examined to provide the injury outcome of the crash. Injuries were classified using the National Accident Sampling System (NASS), Occupant Injury Classification (OIC) scheme [7]. The crash scene, clothing worn and motorcycle ridden during the crash were also inspected to increase the evidence-base for the crash details and to determine if any of these factors had an influence on the outcome of the crash. The petrol tank angle was measured during the motorcycle inspection using a goniometer.

From the crash details, the cause of pelvic injury was determined. The cases were then reviewed at an inter-disciplinary panel meeting consisting of engineers, injury specialists, motorcycle specialists and police officers where the most likely mechanism of injury was identified. Images of the fuel tank, the vehicle inspection notes (including whether any deformation of the tank was evident), and medical notes were available to the panel.

This data set was expanded by including cases of fatal and non-fatal motorcycle crashes occurring in Adelaide from an in-depth crash investigation program which has been operating since 2006. This sample of data was collected using on-scene collection protocols where the crash investigation team was notified by an automatic paging service every time the South Australian Ambulance Service was called to a crash. The team immediately attended the scene of the crash. This sample included any type of road crash within a 100 km radius of metropolitan Adelaide, which resulted in at least one crash participant being transported to hospital.

The information collected for each crash includes: photographs of the scene immediately post-crash, photographs and examination of crash-involved vehicles, interviews with witnesses, interviews with police, an engineering survey of the crash site, drive-through videos of the crash site, police reports, Coroner's reports for a fatal crash, injury data from hospitals and all other crash-related medical information, licensing histories for all drivers/riders, crash history for the crash site, crash history for the vehicles involved, a computerised reconstruction of the crash, and detailed interviews with consenting crash participants about the crash and all relevant background information.

As a result of the different data collection protocol in the Adelaide sample, rider interviews and details were not always obtained. The cause of injury could be determined from photos of the motorcycle at the crash scene as well as rider descriptions. Pelvic injury, including fractures, soft tissue injury and internal injuries, were attributed to the fuel tank when tank deformation was present and/or if stated by the rider.

Cases where the motorcycle rider experienced forward momentum following the collision were extracted from both datasets. Each case was coded as involving a pelvic injury due to contact with the fuel tank or not. The effect of tank angle on the occurrence of pelvic injury and the type of injury was investigated using logistic regression while controlling for motorcycle type.

Each case was also coded in terms of severity of the pelvic injury using the categories: “Abbreviated Injury Scale (AIS) of 2 or greater” (internal injuries and fractures); and “AIS of 1 or less” (soft tissue or no injury). Where there was more than one pelvic injury, the maximum AIS injury (MAIS) in the region was used. The analysis was performed using SPSS Statistics 20 [8]. Logistic regression was used to examine the association between tank angle, motorcycle type and severity of pelvic injury[9].

This study was approved by the Royal Prince Alfred Hospital Ethics Committee and the University of Adelaide Human Research Ethics Committee.

Results

Description of Sample

In-depth data was collected from 139 motorcycle crashes in the Sydney and Adelaide. Of these cases, 60 of the riders experienced forward momentum. Within the 60 riders, there were 27 cases of pelvic injury that was associated with contact to the fuel tank (45%). There were a further four cases of pelvic injury which were unrelated to the fuel tank and which did not occur in crashes where the rider experienced forward momentum; these were not included in the analysis.

The 60 cases in which forward momentum was experienced involved 57 male riders and 3 female. Most of the crashes involved an impact with another moving vehicle (78%) and at an impact speed of 60km/h or less (57%). The mean age for the riders was 38 (range: 16-74 years), the mean height was 177cm (range: 150-194cm), the mean weight was 90kg (range: 57-132kg) and the mean BMI was 28.52 (range: 19.2-41.5). Comparing this sample of riders to the National Health Statistics Report [10], the majority of the riders had a BMI which was in the 50th percentile or higher (56%), with 17% being above the 90th percentile. The largest proportion of riders fell into the obese category (39%), followed by overweight (32%) and healthy (29%).

Motorcycle types and pelvic injuries

The majority of the motorcycles ridden were sports motorcycles (55%) followed by cruisers (17%) and touring motorcycles (12%). Pelvic/abdominal injuries were observed more often among riders of cruisers (80%) than among riders of other motorcycle types (45%) (Figure 1). Statistical modelling demonstrated that cruiser riders were seven times more likely to sustain pelvic/abdominal injury than other riders (95% CI: 1.3-38.5).

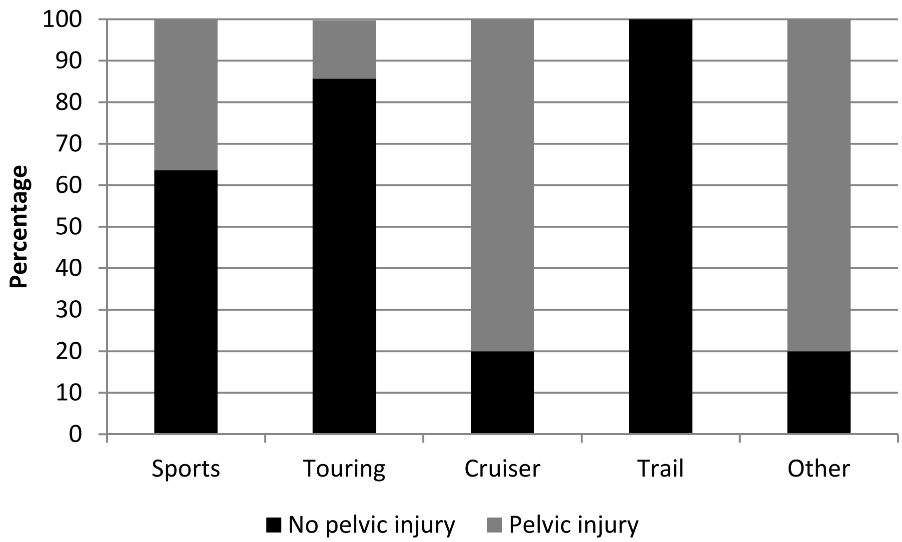

Figure 1. Percentage of riders with a pelvic injury on the different motorcycle types

Using univariate logistic regression, there was no significant association between fuel tank angle and the occurrence of pelvic injury. However, once motorcycle type was included in the statistical model, the odds of pelvic/abdominal injury was seen to increase with increasing petrol tank angle (OR =1.068, 95% CI: 1.013-1.127.

Overall, 74% of the riders who experienced a pelvic or lower abdominal injury due to the fuel tank sustained a fracture. For 19% of the cases, the highest AIS injury experienced by the rider was a soft tissue injury such as laceration, contusion or abrasion to the pelvic or lower abdominal region (AIS 1). There were two cases in which the highest AIS injury was a bladder haematoma. There were clear differences in the types of injuries sustained by riders of the different types of motorcycles (Figure 2).

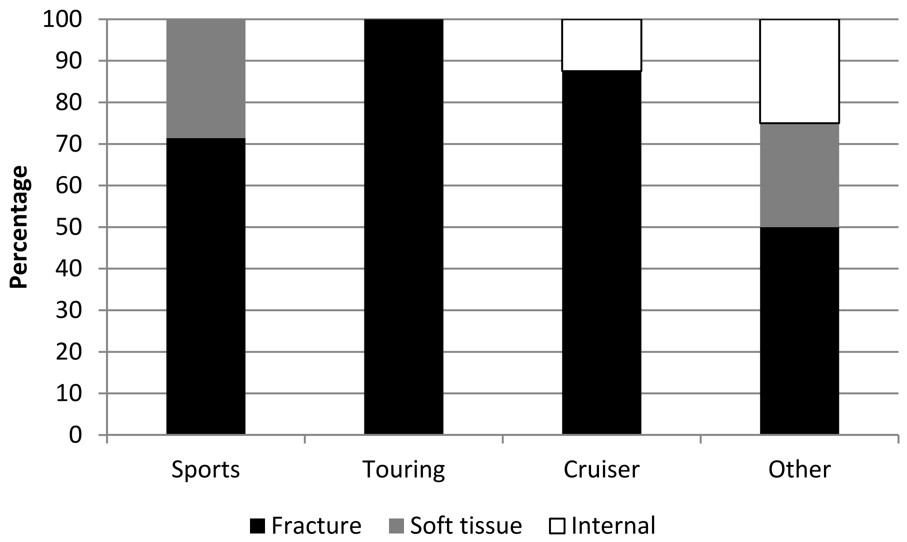

Figure 2. Type of pelvic injuries suffered by riders of the different motorcycle types

Following Figure 2, analysis highlights that riders of cruisers were nine times more likely to suffer an AIS pelvic injury of 2 or greater than other riders of other motorcycle types (95% CI: 1.214-69.349). Interestingly, for these more serious injuries, the fuel tank angle was not statistically associated with serious injury (AIS 2+).

Discussion

The key finding of this analysis was that in frontal crashes, cruiser riders were more likely to sustain pelvic injury than riders of other motorcycle types. It was also the case that increasing petrol tank angle was only significantly associated with pelvic injury once motorcycle type was included in the statistical model.

It is interesting to consider the seating position of cruisers and other motorcycles, and how these differences might be associated with differential pelvic injury risk. The overall shape of cruisers leads to the rider adopting a more backward leaning posture than riders of other motorcycle types with the rider's legs being straight out toward the front of the motorcycle, while riders of sports motorcycles lean over the fuel tank. It may be that the different rider posture changes the rider kinematics in frontal motion, with the backward leaning posture of cruiser riders potentially forcing the pelvis to slide forward into the tank during following a frontal collision. It may also be due to the shape of cruisers. Cruisers typically have a wedge-shaped petrol tank which interestingly is the tank shape that de Peretti et al. [5] concluded should be avoided.

Rider height and weight may also influence the rider posture and/or the rider kinematics following the crash and could be an influential factor in the force with which the pelvis impacts the fuel tank. The

MADYMO simulations by Wobrock et al. [6] only investigated force on the pelvis using a 50^{th} percentile male. Within the present sample, a large number of the riders involved in crashes have high BMIs, with 17% in the 90^{th} percentile or higher. Future research investigating the relationship between petrol tank design and pelvic injury risk therefore needs to consider rider anthropometry into consideration.

While we did see a significant relationship between increasing tank angle and likelihood of pelvic injury when motorcycle type was adjusted for, other tank dimensions, such as the overall shape, height and width of the fuel tank, may be influencing the rider kinematics and force distribution on the rider's pelvis, as suggested by previous research [1-5]. Further analysis is being undertaken to examine the role that overall shape of the petrol tank might play in pelvic injury mechanisms.

Other factors which should also be considered include the rider's age and anthropometry (e.g. height, weight and body mass index), as well as the crash severity (e.g. impact speed and collision object). The exclusion of other potential confounding factors related to petrol tank shape, rider and crash characteristics in the logistic regression analysis can be considered a limitation of this preliminary work. This analysis was limited by a small sample size and an analysis of a larger sample taking into account these additional factors, would be of value.

Conclusion

This preliminary analysis of in-depth motorcycle crashes indicates an increased likelihood of pelvic injury among cruiser riders compared to riders of other motorcycle types in frontal impacts where forward momentum is evident. While the results support previous findings that are suggestive of a relationship between tank angle and the risk of pelvic or lower abdominal injuries, it appears the combination of whole tank shape with rider posture may be more important and is worthy of further research.

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Improving car drivers' perception of motorcycles: Innovative headlight design as a short-term solution to mitigate accidents

Verbesserte Erkennbarkeit von Motorrädern bei Pkw-Fahrern: Innovativer Frontscheinwerfer zur Senkung der Anzahl von Unfällen

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Abstract

The most frequent motorcycle accidents involve another vehicle violating the motorcycle's right-of-way at an intersection. The low visual conspicuity of motorcycles (especially because of their small size) is the primary reason why motorcycles are often not detected or seen or too late. The main safety measure in the past has been the use of daytime running lights (DRLs) by motorcycles, which became compulsory in the seventies in many countries. This conspicuity advantage of motorcycles as the only vehicles with DRLs is presently getting lost by the growing use of DRLs by cars as well. In a previous study (Cavallo & Pinto, 2012) we have shown that car DRLs are competing light patterns that create visual noise and decrease the detectability of motorcycles. In addition to detection errors, the misperception of the approaching motorcycle's speed and time-to-arrival also contributes to accident occurrence and severity.

In order to reduce motorcycle accidents, and especially to improve motorcycle perceptibility (both detection and speed perception) by other vehicle drivers, ITS based on vehicle-tovehicle communication will probably provide effective long-term solutions (>15 years). But until then, other solutions have to be found and could quite easily be implemented, by considering innovative headlight configurations for motorcycles.

In two simulator studies, we tested various motorcycle headlight configurations, intended to remedy *simultaneously* the two perceptual errors made by other vehicle drivers. The impact of different headlight configurations (using colour coding and additional lights) was studied in the presence of visual distractors (car front lights: only LEDs, only dipped beams, LEDs and dipped beams) and in different illumination conditions (nighttime, dusk and daytime conditions).

The results indicate that headlight configurations comprising additional yellow lights on the fork and on the motorcyclist's helmet significantly improve motorcycle perceptibility by other vehicle drivers. Furthermore, the simultaneous use of daytime running lights (LEDs) and dipped beams by cars, as frequently observed nowadays, has been shown to be particularly detrimental to motorcycle detectability.

Improving car drivers' perception of motorcycles: Innovative headlight design as a short-term solution to mitigate accidents

1 Introduction

Motorcyclists are very vulnerable road users and their safety has become a critical issue in many developed counties. The number of killed and seriously injured motorcyclists has not been reduced these last years, contrary to other categories of road users. For instance, in Italy, France, and Switzerland motorcyclists represented as much as 30, 26, and 24 %, respectively, of the total number of road fatalities (IRTAD, 2013).

In-depth analyses (ACEM, 2009; Hurt, Ouellet, & Tom, 1981; Vis, 1995) show that in many motorcycle (MC)[1] accidents the motorcyclists' right of way was violated by other vehicles (in 51 and 81%, as indicated by Hurt et al. and Vis respectively). The most typical accident happens at intersections where a car turns left and collides with an oncoming MC.

Perceptual errors made by car drivers are one of the main accident causation factors in collisions between cars and MCs (in 60 or 70% of these accidents, according to Van Elslande & Jaffard, 2010, and Hurt et al., 1981, respectively). The two kinds of perceptual errors are today well identified:

a) Non (or late) detections of the MC on the one hand, which are due to the low conspicuity (especially due to its small size, but also to dark colours and irregular contours) of MCs. The main safety measure in the past has been the use of daytime running lights (DRLs) by MCs, which became compulsory in the seventies in many countries and made them clearly distinguishable from other road users. This conspicuity advantage of MCs as the only vehicles with DRLs, which has been proven to effective in accident reduction, is presently getting lost by the growing use of DRLs by cars as well. In a previous study (Cavallo & Pinto, 2012), we have shown that car DRLs are competing light patterns that create visual noise and decrease the detectability of MCs.

b) The second, and less studied error, is a misperceptions of the MC's speed, distance (Tsutsumi & Maruyama, 2008; Gould, Poulter, Helman, & Wann, 2012), and time-toarrival (Horswill, Helman, Ardiles, & Wann, 2005). This error is due to the small dimensions of the MC, which lead to low angular velocities when the MC is approaching. As a consequence, MC speed is underestimated and its arrival time overestimated. This misperception results in short temporal intervals and safety margins accepted by other vehicle drivers when they interact with MCs.

[1] By motorcycle, we understand all powered two- and three-wheelers.

MC manufacturers bet on “digital conspicuity”, i.e., ITS based vehicle-to-vehicle communication that will probably provide effective solutions in the long term (at least >15 years). These technological solutions will circumvent the problem related to the limits of visual perception and attention, but until having reliable systems at our disposal, other solutions have to be found. Innovative MC headlight configurations could quite easily be implemented and could be an efficient means for improving MC safety in the coming years.

An increasing number of studies carried out in the last 7-8 years highlight a renewal of research interest for MC headlight ergonomics. Several investigations have been devoted to the definition of a new visual signature for MCs to indicate the presence of these road users and favour their detectability. A T-shaped light configuration (additional lights at the fork and the handlebars forming a T) (Rößger, Hagen, Krzywinski, & Schlag, 2012) as well as an alternating-blinking light system on the motorcyclist’s helmet have been shown to be effective (Gershon & Shinar, 2013), but are difficult to implement. Pinto, Cavallo and SaintPierre (2014) examined much simpler light arrangements and showed significant benefits when motorcycles had yellow headlights, and also when motorcyclists had an additional light on their helmet. Contrary to Maruyama, Tsutsumi and Murata (2009), Pinto et al. did not find a detection benefit for triangle headlights (with two additional lights on the MC’s handlebar).

Other studies addressed the influence of innovative MC headlights arrangements on the perception of the MC’s speed and arrival time. Tsutsumi and Maruyama (2007) have demonstrated that headlight configurations that vertically enlarge the MC (with additional lights on the handlebar and the fork) afford longer accepted gaps than motorcycles equipped with just a standard front light, and this in night-time as well as in daytime conditions. Gould et al. (2012), on the contrary, found an improved MC speed perception when the MC was horizontally enlarged that when it was vertically enlarged. These authors also noted improved speed discrimination when MCs were equipped with a triangle configuration.

All of these studies have focused on only one of the two kinds of perceptual errors. But the motorcyclist who equips his MC with additional light wants to prevent both kinds of perceptual errors made by other vehicle drivers. The present study is the first one that investigated headlight configurations that effectively counteract detection errors, and at the same time reduce motion perception errors. The tested headlight configurations therefore combined design characteristics that are efficient for motorcycle detection on the one hand, but that have also been proven efficient for motorcycle motion perception. We have specifically chosen colour coding (yellow) and MC vertical enlargement which features seemed to have the highest potential for improving MC perception.

Our study consisted of two simulator experiments. The first one evaluated the effect of several headlight configurations on MC motion perception, by measuring the gaps accepted by drivers when turning left in front of a MC. The best performing configurations were chosen for the second experiment, in which we tested their capacity of improving MC detectability.

2 Experiment 1

2.1 Method

Participants

Three groups of 23 volunteers took part in the experiment. The groups were matched with regard to age (31 years), gender (7 women and 16 men in each group), and driving experience. All had normal vision and were regular drivers.

Driving simulation

A small-scale interactive driving simulator was used, comprising control devices (force-feed-back steering wheel, gear lever, gas, clutch and brake pedals) as well as visual and auditive rendition systems. The road environment was displayed on two 47'' high fidelity LCD screens: one in front of the driver and the other one left to him. The visual scene represented a rural intersection with a road going off 45° to the left (Figure 1). The traffic (MCs, cars, vans, trucks) approached head-on at different speeds (40 and 60 km/h at nighttime; 60 and 90 km/h at dusk and daytime) and with different time gaps between the vehicles (3 – 7 s). The MCs were equipped with four different headlight configurations (Figure 2). The participants' task was to turn left through the traffic stream when they judged that turning was safe.

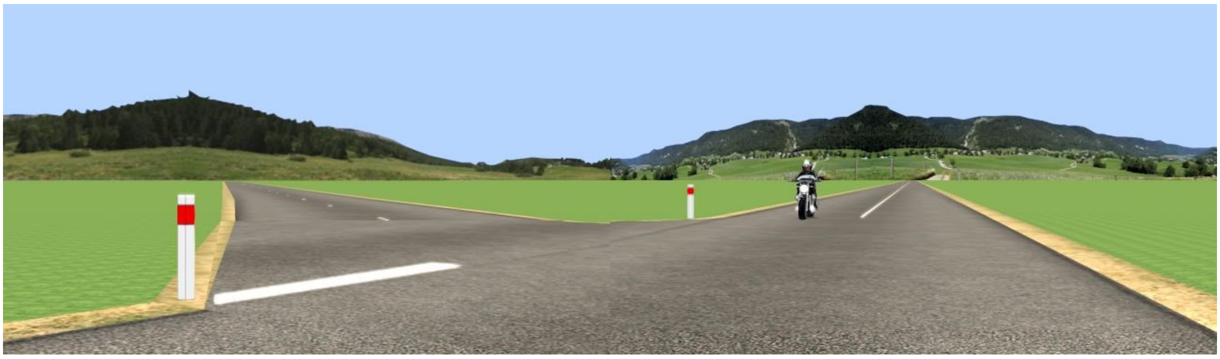

Figure 1. MC with the vertical configuration approaching the intersection at daytime.

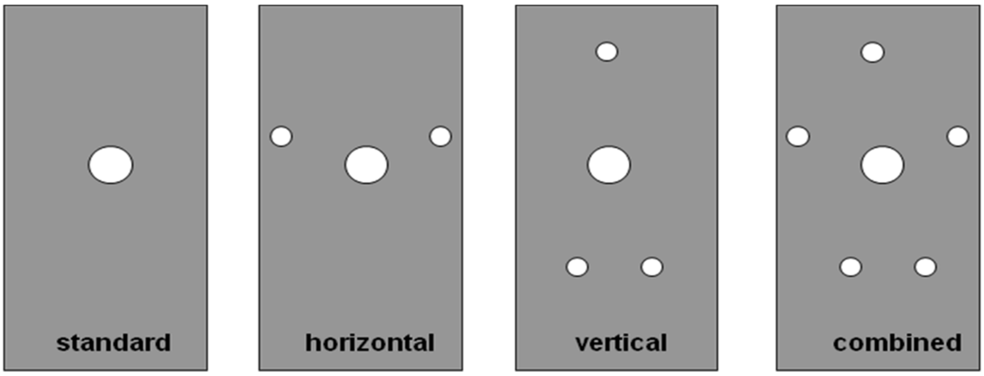

Figure 2. The four MC headlight configurations tested in a left-turn situation.

2.2 Results

Night-time

The Figure 3 shows that the vertical and the combined configurations afforded longer accepted gaps at night-time, when the MCs approached at the higher speed (here, 60 km/h). The chosen gaps were equivalent to those accepted toward cars. At 60 km/h, the time gain for the vertical and combined arrangements as compared to the standard headlight was .91 s and .94 s, respectively. This means an additional safety distance of about 15 m, which is a sizable asset when cars interact with motorcycles.

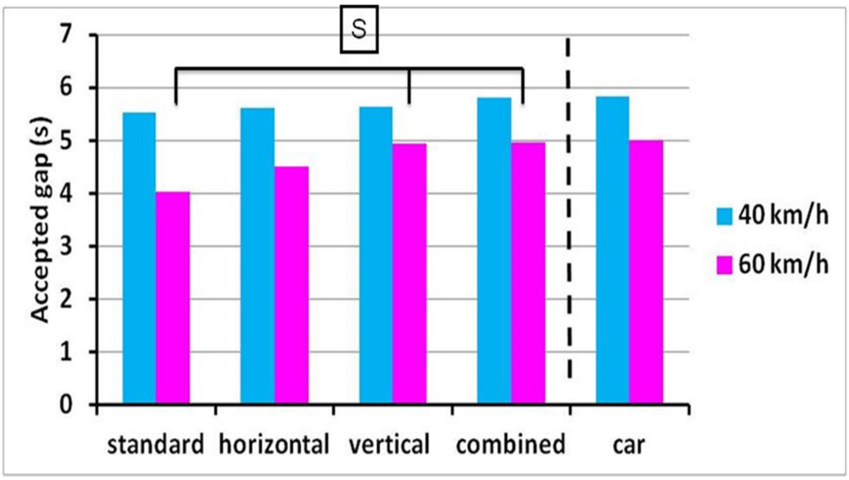

Figure 3. Accepted time gaps (in s) according to approach speed, for motorcycles equipped with different headlight configurations and for cars, at nighttime conditions.

Dusk

Figure 4 reveals similar results at dusk conditions. At the higher speed (here, 90 km/h), the vertical and the combined configurations led drivers to accept time gaps towards MCs which were notably longer than for MCs fitted with the standard headlight, and which were equivalent to cars. The horizontal configuration afforded the same time gaps as the standard headlight and did not provide any advantage.

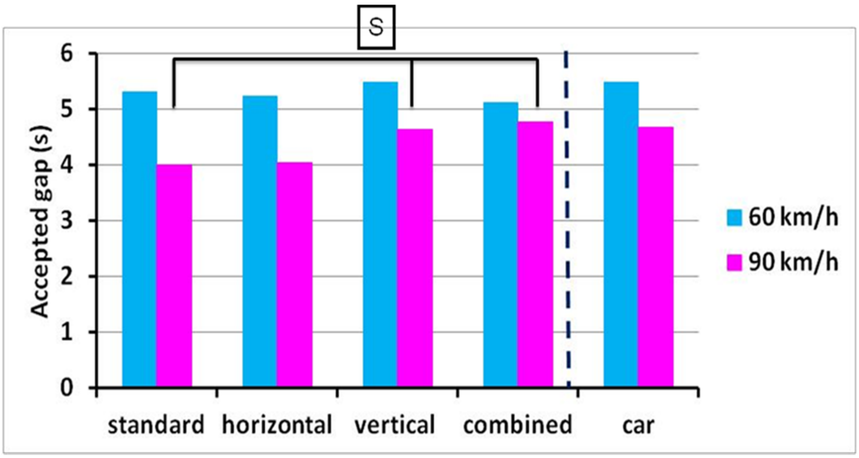

Figure 4. Accepted time gaps (in s) according to approach speed, for motorcycles equipped with different headlight configurations and for cars, at dusk conditions.

The time gain for the vertical and combined configurations at dusk was .62 s and .76 s with respect to the standard headlight, and .60 s and .74 s with respect to the horizontal arrangement. These time increments correspond to additional safety distances between 15 and 19 m at dusk, when turning left in front of motorcycles equipped with these light arrangements.

Daytime

Figure 5 shows a similar pattern at daytime, with time gains for the vertical and combined configurations at the higher speed (here, 90 km/h) of about .50 s, but none of these time benefits were statistically significant.

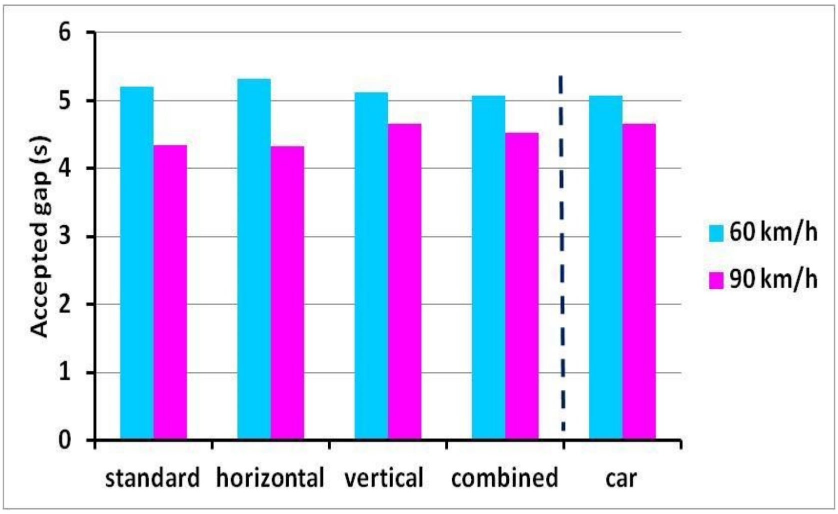

Figure 5. Accepted time gaps (in s) according to approach speed, for motorcycles equipped with different headlight configurations and for cars, at daytime conditions.

2.3 Discussion

The findings of the first study indicate that only light arrangements that accentuated the vertical dimension of the MC/motorcyclist, i.e., the vertical and combined configurations, provided substantial improvements as compared to MCs equipped with only standard headlights or with the horizontal arrangement ("triangle"). Interestingly, the time gaps accepted in front of MC fitted with these configurations were equivalent to those accepted in front of cars.

The beneficial effect of configurations that accentuate verticality was found to be modulated by ambient lighting conditions and the motorcycle's approach speed: these two configurations were found to be all the more effective that ambient lighting was reduced and the MC approach speed high, i.e., in conditions where the perception of the MC's motion was particularly difficult.

In terms of application, the use of the vertical configuration is without doubt preferable to the combined configuration, because it requires less additional lights and may be easier accepted by motorcycle riders. The vertical configuration was then tested in the second experiment regarding its capacity of improving MC detectability.

3 Experiment 2

3.1 Method

Participants

Three groups of 19 volunteers took part in the experiment. The groups were matched with regard to age (30 years), gender (4 women and 15 men in each group), and driving experience. All had normal vision and were regular drivers.

Driving simulation

Only the central screen of the driving simulator (see Experiment 1) was used. The participants were presented with sequences of 250 ms displaying daytime traffic scenes with cars and MCs approaching four lanes intersections at constant speed (50 km/h). Cars were fitted with (1) LEDs, (2) dipped headlights, or (3) LEDs *and* dipped headlights lit together (Figure 6). These three environmental conditions were introduced in order to evaluate the effect of visual distracters, consisting in car DRLs, on MC detection. Four MC headlight configurations were tested (see Figure 7). The participants' task was to detect whether vulnerable road users (MCs, cyclists, pedestrians) were present in the traffic scene. The vulnerable road users appeared at different distances and eccentricities.

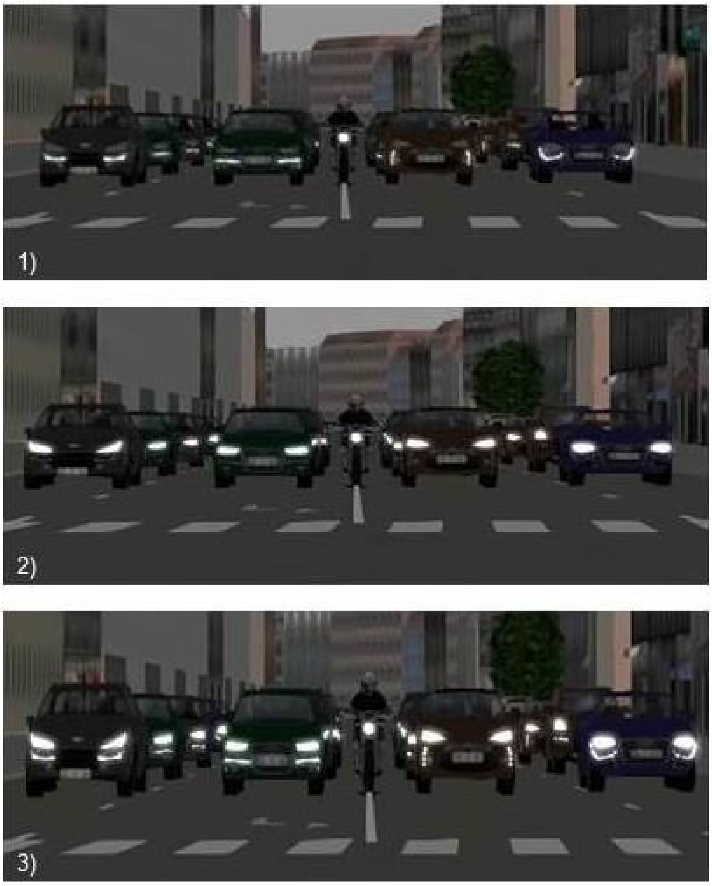

Figure 6. The three environmental conditions comprising different kinds of visual distactors.

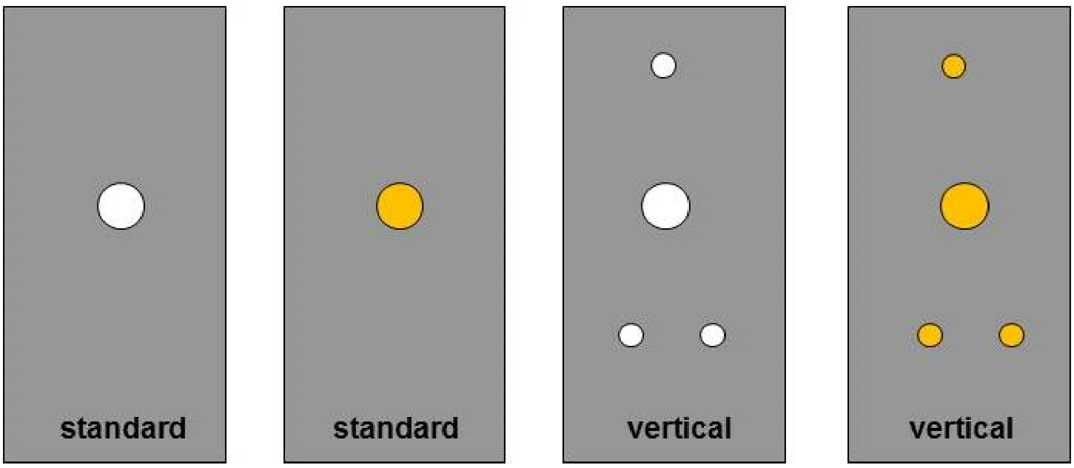

Figure 7. The four MC headlight configurations tested for their detectability in a traffic environment with visual distractors.

3.2 Results

Effect of headlight configuration

Figure 8 clearly indicates that the MCs were better detected when they were fitted with configurations comprising yellow lights. The increase in detectability, compared to the standard headlight, was considerable, 29 and 19 % points for the yellow vertical and the yellow standard configurations, respectively. The yellow vertical arrangement amounted to almost 90 % of correct detections.

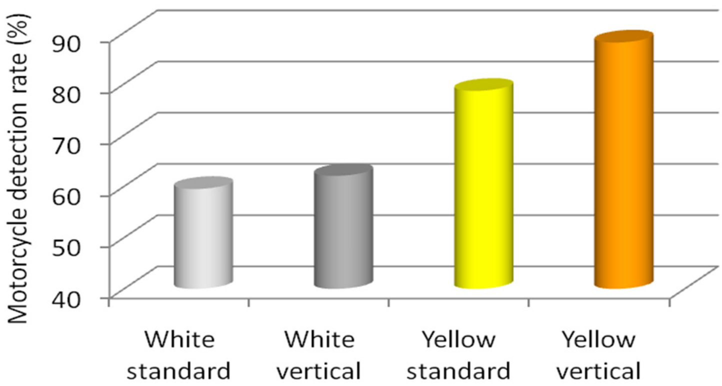

Figure 8. Motorcycle detection rates (%) as a function of motorcycle headlight configuration.

Effect of car DRLs in the visual environment

Figure 9 illustrates the detrimental effect of visual distracters formed by car DRLs, especially when numerous light sources were present around the MC. This happened when cars had their dipped lights and LEDs lit simultaneously. The difference in correct detections between the most MC-friendly environment, when cars were lit by LEDs only, and the most detrimental environment, when cars lit LEDs and dipped headlights at the same time, is about 11 % points. In the most distracting visual environment (LEDs + dipped beams), only the yellow vertical configuration provided a significant benefit as compared to the white standard headlight.

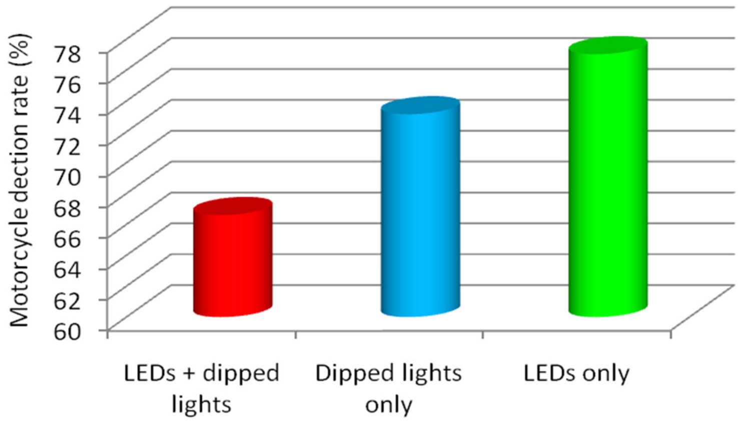

Figure 9. Motorcycle detection rates (%) as a function of lit car lights in the environment.

3.3 Discussion

The findings emphasize the beneficial effect of the yellow standard lights, and even more, the yellow vertical configuration. They suggest that colour coding (here, the yellow colour) improved MC detection and identification, by clearly distinguishing it from other vehicles that all have white front lights. These results are in line with earlier findings that demonstrated a clear benefit of a yellow MC headlight over a conventional white headlight (Pinto et al., 2014).

The conspicuity advantage of the yellow configurations also depended on the visual complexity of the MC's environment. When many car light sources are visible in the vicinity of the MC, then only the yellow vertical configuration guarantees a real detectability improvement as compared to the white standard headlight.

4 Conclusions

We have shown that the yellow vertical configuration is the most beneficial one: it improves the perception of the MC's motion as well as its detection and identification. This configuration brings together the characteristics of the two best performing arrangements: the enlargement of the MC's vertical dimension and the colour coding.

In terms of application, it is probably not realistic to assume that MC could be equipped with yellow frontal headlights, because they are less efficient for lighting the street and may produce colour distortions in road sign perception. We rather recommend a MC lighting configuration that combines a white central front light and 3 additional yellow lights, one on the helmet and two on the fork. Using the LED technology for these additional lights could be a good solution to limit power demands.

The recommended light arrangement is less complex than the T-configuration suggested by Rössger et al. (2012) and also more realistic than an alternating-blinking light on the helmet as suggested by Gershon & Shinar (2013). Incidentally, both light arrangements have been tested only with regard to MC detection, but not regarding MC motion perception.

The yellow vertical arrangement has also been shown to be much more effective than the triangle configuration advised by Gould et al. (2012). The triangle configuration has also the favour of the MC manufacturers, but we have proven that it does not improve MC motion perception at all. A slight benefit in terms of detectability of the triangle configuration could be expected if the additional 2 lights on the handle bar are of a different colour (yellow, orange) than car lights, but this effect has not been evidenced yet.

Finally, it should be noted that MC detectability suffers from distracting light sources on cars, especially when cars simultaneously light dipped beams and dedicated DRLs. A better separation of these two functions, involving improved car lighting regulations, could help making MCs easier to detect by other vehicle drivers.

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Quo Vadis, Darmstadt Method for Abrasive Testing

Quo Vadis, Darmstädter Methode für Schutzkleidungsprüfung

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Abstract

The “Darmstadt Method for Abrasive Testing” miniaturizes the sliding process of a fallen 75 kg rider on real road surfaces by means of a three-armed rotor with scaled mass-, inertia, and aerodynamic properties. Over more than 30 years, it has proven to be an appropriate method to determine the friction coefficient and protective potential of motorcyclists’ garments. While the functional principle remains the same since the 1980s, achievements in modern control- and measurement-systems make it possible to analyze the material behavior of the test specimen on a much deeper level.

In advance to the pending revision of the European standard for the testing of protective clothing, the Institute of Automotive Engineering (FZD) of the Technische Universität Darmstadt revised their test-rig accordingly, in matters of control, measurement and mechanics. Moreover, additional test-rigs were built that use the same principle, but work with different parameters such as sliding diameter, mass, inertia, friction, and aerodynamic drag.

This paper explains the functionality of the method in detail, highlighting its pros and cons. Modifications to the test-rig are presented to make it suitable for even more testing scenarios (e.g. testing of motorcycle gloves).

Besides discussing the mechanical improvements to the test-rig, the paper shows how continuous data acquisition is used to extract the material-only behavior from the measured data through computation of a continuous friction coefficient.

With these optimizations, the Darmstadt Method is made suitable for both the use in certification as well as development of motorcyclists’ protective clothes.

Kurzfassung

Das „Darmstädter Verfahren für Schutzkleidungsprüfung“ stellt das Rutschen eines 75 kg Fahrers auf einer realen Fahrbahnoberfläche dar. Dazu werden dessen Massen-, Trägheits- und Luftwiderstandseigenschaften auf einen dreiarmigen Probenträger skaliert, welcher bei gegebener Startgeschwindigkeit auf einer Fahrbahn bis zum Stillstand rutscht. Seit über 30 Jahren wird das Verfahren erfolgreich für die Bestimmung des Materialreibwerts sowie der Schutzwirkung von Motorradfahrerbekleidung angewandt. Wenngleich das Prinzip der Prüfung seit den 1980er Jahren unverändert blieb, ermöglicht moderne Mess- und Regelungstechnik eine weitaus genauere Betrachtung des Materialabriebverhaltens.

Im Vorfeld einer anstehenden Revision der europäischen Schutzkleidungsprüfnorm wurde der Prüfstand des Fachgebiets Fahrzeugtechnik (FZD) der Technischen Universität Darmstadt hinsichtlich Mechanik, Mess- und Regelungstechnik überarbeitet. Zudem wurden bei Projektpartnern weitere Prüfstände aufgebaut, welche zwar nach dem gleichen Verfahren, jedoch mit variierenden Maschinenparametern wie Reibradius, Masse, Trägheit, Reibung und Aerodynamik arbeiten.

Im vorliegenden Paper wird das Verfahren detailliert erläutert. Ebenso werden seine Stärken und Grenzen beleuchtet. Es werden Überarbeitungen des verwendeten Prüfstands vorgestellt, die weitere Testszenarien ermöglichen sollen (z.B. Handschuh-Tests).

Neben der Diskussion der mechanischen Verbesserungen am Prüfstand wird beschrieben, wie die kontinuierliche Datenerfassung es ermöglicht, das materialspezifische Reibverhalten zu ermitteln. Verschiedene Ausprägungen des Reibverhaltens werden aufgezeigt und interpretiert.

Durch die aufgezeigten Prüfstandsoptimierungen wird das Verfahren sowohl zur Verwendung als Zertifizierungs- sowie Entwicklungswerkzeug für Motorradfahrer-Schutzbekleidung tauglich gemacht.

Quo Vadis, Darmstädter Methode für Schutzkleidungsprüfung

1 Einleitung und Motivation

Trotz rasanter Entwicklungen in den Bereichen aktiver und passiver Sicherheit im Motorradsektor gehören Motorradfahrer weiterhin zu den am meisten gefährdeten Straßenverkehrsteilnehmern. Im Jahre 2012 überstieg die Anzahl der verletzten Motorradaufsassen die Anzahl aller unfallbeteiligten Motorräder . Somit endete nahezu kein in der Statistik erfasster Motorradunfall ohne Verletzte.

Die einzige Schutzwirkung in Folge eines Sturzes oder einer Kollision geht von der Bekleidung des betroffenen Motorradfahrers aus. Die Linderung von Unfallfolgen kann demnach nur durch geeignete Schutzkleidung erfolgen. Die Anforderungen an diese sind dabei vielfältig. Neben Komfort und Wetterschutz seien hier genannt:

- **Schlagdämpfung** – zum Schutz vor Prellungen und Frakturen an aufprallgefährdeten Körperregionen.
- **Zug- und Reißfestigkeit** (v.a. auch an Nahtstellen) – um ein Auftrennen der Schutzkleidung unter Last zu verhindern.
- **Abriebfestigkeit** – um Lochbildung an der Schutzkleidung und damit die Gefahr von Schürfwunden zu mindern.

Vor mehr als 30 Jahren wurde am Fachgebiet Fahrzeugtechnik (FZD) der TU Darmstadt das „Darmstädter Verfahren für Schutzkleidungsprüfung“ entwickelt . Während es zunächst aus mehreren Tests für verschiedene Materialkenngrößen bestand, konnte sich lediglich der Abriebversuch bis in die heutige Zeit durchsetzen.

Kapitel 2 des vorliegenden Dokumentes diskutiert das dem Abriebversuch zu Grunde liegende Funktionsprinzip und stellt dessen Stärken und Schwächen hervor. Es wird anschließend (Kapitel 3) dargestellt, wie durch eine Überarbeitung der Mechanik sowie Mess- und Regelungstechnik der Prüfstand für die Zukunft gerüstet wird. In Kapitel 4 wird die Tauglichkeit des Verfahrens zur Verwendung innerhalb einer europäischen Prüfnorm diskutiert. Schließlich wird das Potential des Verfahrens nicht als reines Prüfmittel, sondern als Entwicklungswerkzeug aufgezeigt und in Kapitel 6 ein Fazit gezogen.

2 Prüfverfahren

Der Abriebversuch des Darmstädter Verfahrens für Schutzkleidungsprüfung wurde zu Beginn der 1980er Jahre entwickelt, um – in Abgrenzung zu damals in der Textilindustrie gebräuchlichen Abriebversuchen – den Motorradunfallhergang möglichst realitätsgetreu abzubilden. Dieser teilt sich in folgende Phasen auf, die gleichsam auf dem Rutschsimulationsprüfstand dargestellt werden:

- Flug- /Sturzphase
- Aufprall
- Rutschphase
- Stillstand

Im Realunfall finden diese Phasen, sofern keine Hindernisse im Rutschweg liegen, als annähernd geradlinige Bewegung statt. Dabei können Rutschwege von weit über 50 Metern erreicht werden. Um den Test sinnvoll unter Laborbedingungen durchführen zu können, wird dieser lineare Rutschweg auf eine Kreisbahn transformiert. Die auf dem Prüfstand zwischen Probenmaterial und Fahrbahn erzeugte Flächenpressung von 1,875 N/cm² entspricht der durch einen 75 kg-Fahrer mit 1,75 m Körpergröße auf dem Rücken liegenden Menschen erzeugten Flächenpressung (Kontaktfläche ≈ 3,9 dm²). Die genannten Körpermaße bedingen zudem die Gesamtträgheit der rotierenden Teile des Prüfstands, wie Abbildung 1 verdeutlicht.

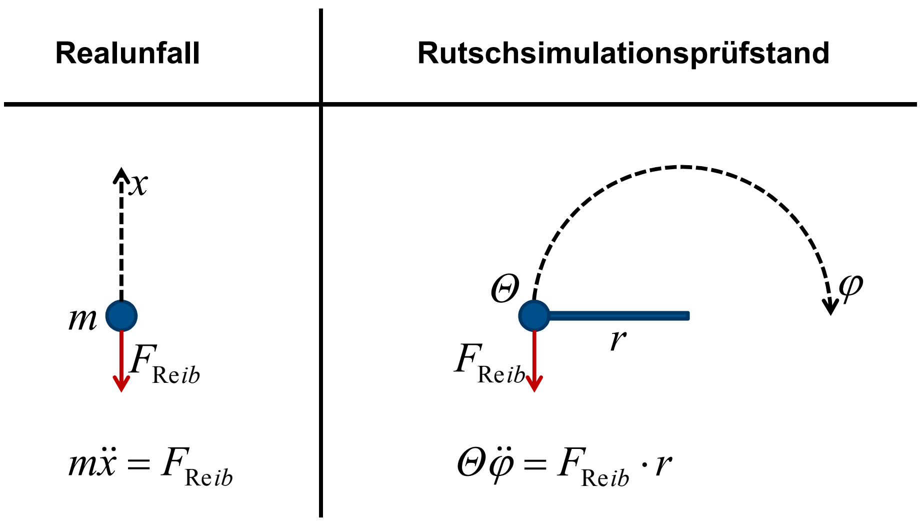

Abbildung 1. Transformation des Rutschwegs auf eine Kreisbahn

$$\ddot{\varphi} = \frac{\ddot{x}}{r}, \quad \theta = m \cdot r^2$$

Um die Dimensionen des Prüfstands auf ein sinnvolles Maß zu reduzieren, findet bei vorgegebener Flächenpressung eine Skalierung von Anpresskraft und Reibfläche statt. Es ergibt sich im realen Aufbau eine Reibkreisbahn mit einem Durchmesser von 0,9 m. Die auf knapp 60 cm² skalierte Reibfläche erfordert eine Anpresskraft von ca. 110 N, die durch die Gewichtskraft eines dreiarmigen Probenträger-Sterns erzeugt wird. Um die Rotationsträgheit des Gesamtsystems auf das korrekt skalierte Maß anzuheben, ist ein zusätzlicher Massenstern verbaut. Die Gesamtträgheit ergibt sich folglich durch den Rotor des Antriebsmotors, Antriebswelle, Probenstern sowie Massenstern.

Der Prüfstand ist schematisch in Abbildung 2 dargestellt.

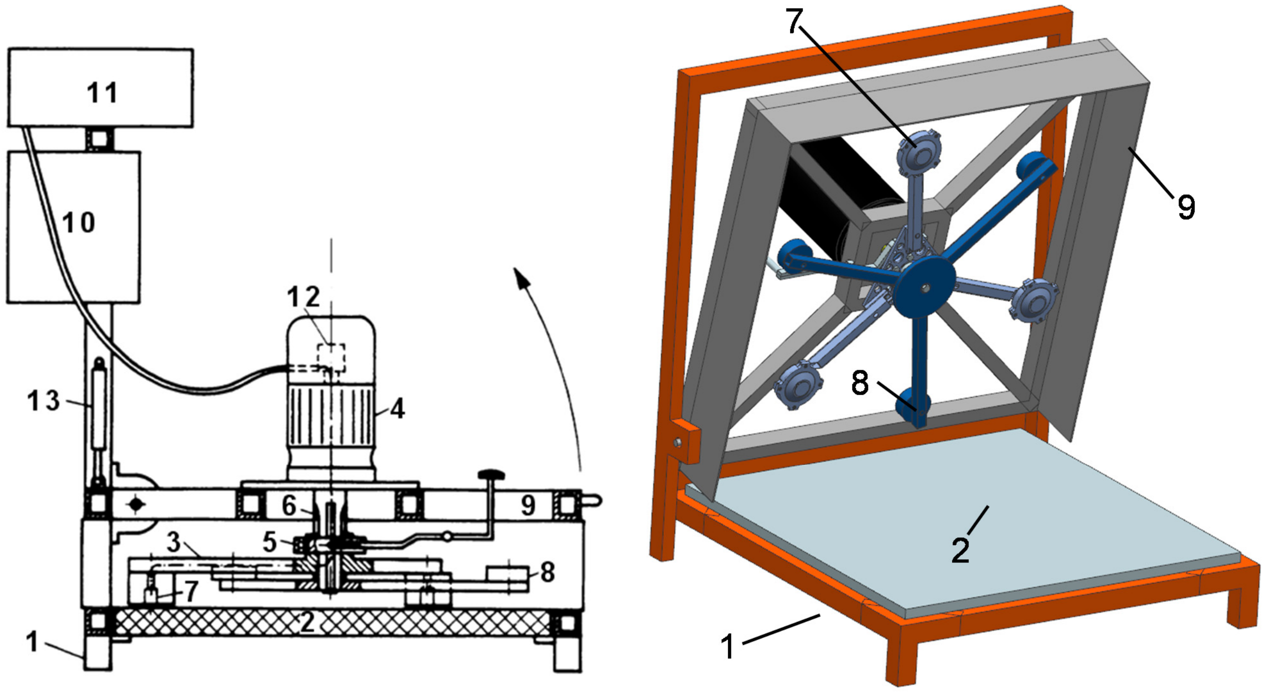

Abbildung 2. Rutschsimulationsprüfstand (links:)

Auf dem Prüfstandsrahmen (1) liegt die Fahrbahnkachel (2) auf. Asynchronmaschine (4), Massenstern (8) und Probenstern (7) sind an einem schwenkbaren Deckel (9) montiert, der im geöffneten Zustand das Bestücken des Prüfstands ermöglicht. Der Probenstern ist auf einer Vielkeilwelle (6) axial beweglich und kann durch die Wippe (5) in einer angehobenen Position axial fixiert werden. Dadurch ist eine Beschleunigung des Systems ohne Kontakt zwischen Probenmaterial und Fahrbahn möglich.

Zur Prüfung eines Probenmaterials werden jeweils drei Proben aufgespannt. Der Antriebsmotor beschleunigt auf die gewünschte, frei wählbare Startgeschwindigkeit, wobei der Probenstern in erhöhter Lage arretiert ist, sodass die Proben ca. 10 mm über der Fahrbahn schweben. Bei Erreichen der Testgeschwindigkeit wird die Arretierung gelöst und der Antriebsmotor abgeschaltet. Der Probenstern fällt herab, sodass die Proben auf die Fahrbahn treffen. Der Rotor verzögert entgegen der Gesamtrotationsträgheit, bedingt durch Materialreibung, Luftwiderstand und geringe Verluste durch Lagerreibung. Ein zusätzliches Lastmoment, das bspw. ein permanentmagneterregter Motor auch bei abgeschalteter Spannungsversorgung erzeugen würde, wird durch die Verwendung einer Asynchronmaschine verhindert. Der Versuch endet bei Stillstand des Rotors. Rutschweg und Rutschdauer werden aufgezeichnet und ermöglichen unter Kenntnis der Startgeschwindigkeit die Bestimmung der mittleren Verzögerung. Zudem können Masseverlust und Lochbildung an den einzelnen Proben ausgewertet werden.

2.1 Diskussion des Verfahrens

Das vorgestellte Verfahren ermöglicht die Abbildung vieler Teilaspekte des realen Unfallhergangs. Während alternative Verfahren praktisch ausschließlich mit sehr niedrigen Testgeschwindigkeiten arbeiten, können hier realistische Startgeschwindigkeiten bis 130 km/h erreicht werden. Nach Erreichen dieser Geschwindigkeit fallen die Materialproben auf eine realgetreue Asphalt- oder Zementbeton-Fahrbahn, wodurch sie anschließend – wie in Realität größtenteils bedingt durch die Reibung zwischen Schutzkleidung und Fahrbahn – verzögert werden. Bei Versuchen mit einem Fahrerdummy im Jahre 2005 haben sich zudem die zusätzlich verzögernd wirkenden Einflüsse durch Luftwiderstand am Prüfstand als vergleichbar mit dem in Realunfall auftretenden Luftwiderstand herausgestellt. Nach einer Überholung der Steuerelektronik im Jahre 2013 wird zudem die Startgeschwindigkeit wesentlich genauer eingestellt ($\Delta v \leq 0{,}3$ m/s) . Somit konnte die Reproduzierbarkeit der Messergebnisse noch weiter erhöht werden. Am Beispiel der mittleren Verzögerung zeigt Abbildung 3 inwieweit einzelne Prüfläufe streuen.

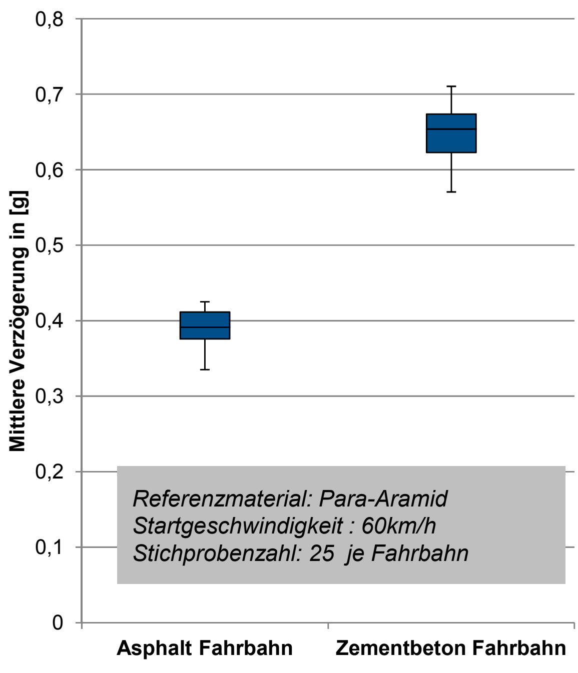

Abbildung 3. Reproduzierbarkeit von Messergebnissen

Die Abbildung zeigt zudem den großen Einfluss der Fahrbahn auf das Messergebnis. Die deutlich niedrigere mittlere Verzögerung auf der aktuell verwendeten Asphaltfahrbahn kann durch die niedrigere Mikrorauigkeit im Vergleich zur Betonfahrbahn begründet werden.

Trotz der gegebenen Vorteile durch die hohe Realitätsnähe sowie die hohe Wiederholbarkeit fällt eine Grenze des Verfahrens sofort ins Auge: Durch die Transformation der Reibstrecke auf eine Kreisbahn, überfahren die einzelnen Proben ihre eigene Reibspur mehrfach. Dies hat vor allem dann einen großen Einfluss auf die Messungen, wenn das Probenmaterial schmierende Inhaltsstoffe, wie z.B. das Indigo in Motorrad-Jeans oder weitere Appretur Rückstände enthält. Solche Schmierstoffe können in teils hohem Maße den gemessenen Reibwert reduzieren und wirken sich zudem auf das Lochbildungsverhalten der Materialproben aus.

Neben dem Schmiereffekt ist in Bezug auf die Fahrbahnoberfläche auch deren Abnutzung über die Nutzungsdauer kritisch zu beurteilen. In Abhängigkeit des Probenmaterials wird eine Fahrbahn unterschiedlich stark beansprucht. Kritisch sind in dieser Hinsicht polierende Beschichtungen, bspw. Keramik-Beschichtungen, die beim Abrieb über die Fahrbahn Rauigkeitsspitzen in der Fahrbahnoberfläche polieren.

Während schmierende Komponenten erfahrungsgemäß sehr gut durch eine Reinigung der Fahrbahn – z.B. auch durch Testläufe mit dem Para-Aramid-Referenzmaterial – beseitigt werden können, ist die Kompensation der Fahrbahnabnutzung weniger einfach. So liegt der Schwerpunkt aktueller Untersuchungen bei FZD auf der Sicherstellung konstanter Reibeigenschaften der Fahrbahn

- während eines einzelnen Testlaufes (Schmiereffekt),
- im Verlauf einer Testreihe (Schmiereffekt & Abnutzung),
- über die Lebensdauer (Abnutzung),
- verschiedener Prüfmaschinen in unterschiedlichen Laboren (Fahrbahnfertigung).

Die Notwendigkeit dieser Untersuchungen zeigt die folgende Abbildung auf. Darin ist die mittlere Verzögerung einer Textilprobe auf den beiden rund 10 Jahre alten Testfahrbahnen unter gleichen Versuchsbedingungen jeweils bei einem Test im Jahr 2012 und einem Test im Frühjahr 2014 abzulesen .

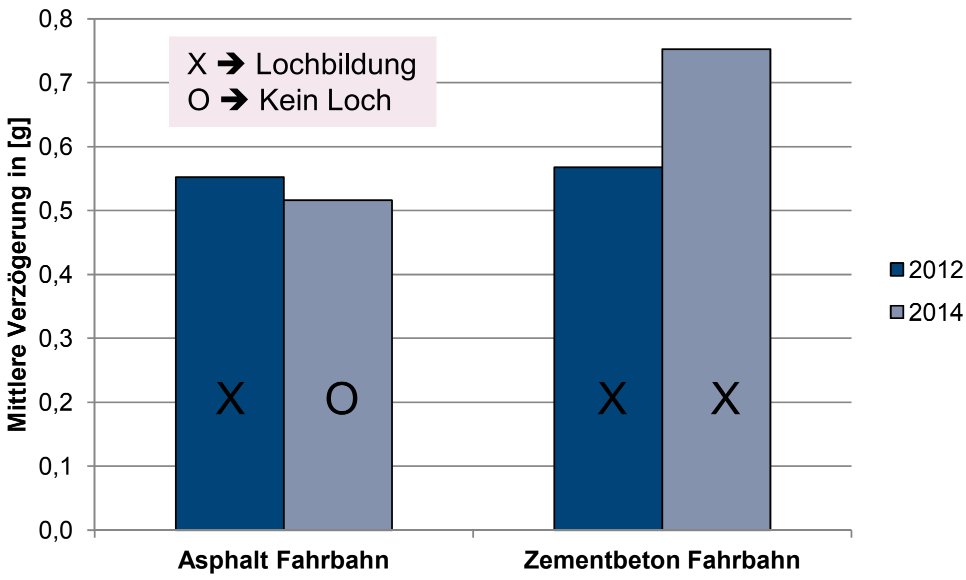

Abbildung 4: Zeitabhängigkeit des Fahrbahnverhaltens

Während heute wie damals auf der Asphaltfahrbahn eine ähnliche mittlere Verzögerung gemessen wird, unterscheidet sich diese auf der Betonfahrbahn deutlich. Gleichzeitig kann jedoch bei den neuen Messungen auf der Asphaltfahrbahn keine Lochbildung an den Proben beobachtet werden, während das Lochbildungsverhalten auf der Betonfahrbahn erhalten geblieben ist. Gleiche Tendenzen zeigen sich bei mehreren unterschiedlichen Textil- sowie Lederproben, die ein erstes Mal in einem Zeitraum von 2008 bis 2012 und erneut in 2014 geprüft wurden und lassen auf eine maschineninhärente Problemstellung – augenscheinlich die Fahrbahnbeschaffenheit – schließen. Auch eine Alterung der Testmaterialien könnte Einfluss auf deren Reibverhalten genommen haben. Somit müssen weitere Untersuchungen des Langzeitverhaltens durchgeführt werden, um die Validität des Verfahrens über die gesamte Nutzungsdauer zu bewerten.

3 Überarbeitung

Das zuvor beschriebene Verfahren hat sich seit nun über 30 Jahren als zuverlässiges Werkzeug in der Schutzkleidungsentwicklung bewährt. Um den modernen Möglichkeiten der Mess- und Regelungstechnik gerecht zu werden, wurde jedoch in 2012 die Steuerelektronik überholt. So gibt nun ein digitaler Encoder mit einer Auflösung von 1440 Schritten je Umdrehung und einer Ausgabefrequenz von 500 Hz den zurückgelegten Weg sowie die aktuelle Drehgeschwindigkeit aus. Beide werden je Zeitschritt in eine Textdatei geschrieben und stehen somit für weitere Auswertungen zur Verfügung, worauf im Folgenden weiter eingegangen wird. Anschließend wird auf Anpassungen des mechanischen Systems eingegangen.

3.1 Kontinuierliche Datenauswertung

Mit der ursprünglich am Prüfstand verbauten Messtechnik wurden praktisch ausschließlich Mittelwertbetrachtungen durchgeführt. Heute besteht unterdessen die Möglichkeit, sich über einen Testlauf sowohl Rutschweg als auch -geschwindigkeit mit einer Ausgabefrequenz von 500 Hz ausgeben zu lassen. Weitere Differentiation liefert die Verzögerung $\ddot{x}_{Rotor}$. Diese ergibt sich zum größten Teil aus der Materialreibung, jedoch auch aus Luftwiderstand und Lagerreibung.

In Analogie zum Ausrollversuch eines Fahrzeugs, können letztere messtechnisch ermittelt werden, indem der Rotor des Prüfstands aus einer bestimmten Startgeschwindigkeit ausläuft, ohne dabei den Probenstern auf die Fahrbahn fallen zu lassen. Wird die Verzögerung des Rotors bezogen auf die Länge des Probenträger Arms $\ddot{x}_{Rotor}$ über dem Quadrat der Rutschgeschwindigkeit v aufgetragen, ergibt sich ein annähernd linearer Verlauf. Für $v = 0$ ergibt sich die Verzögerung bedingt allein durch Lagerreibung, welche als konstant angenommen wird. Die Steigung der Geraden lässt auf den Luftwiderstand schließen.

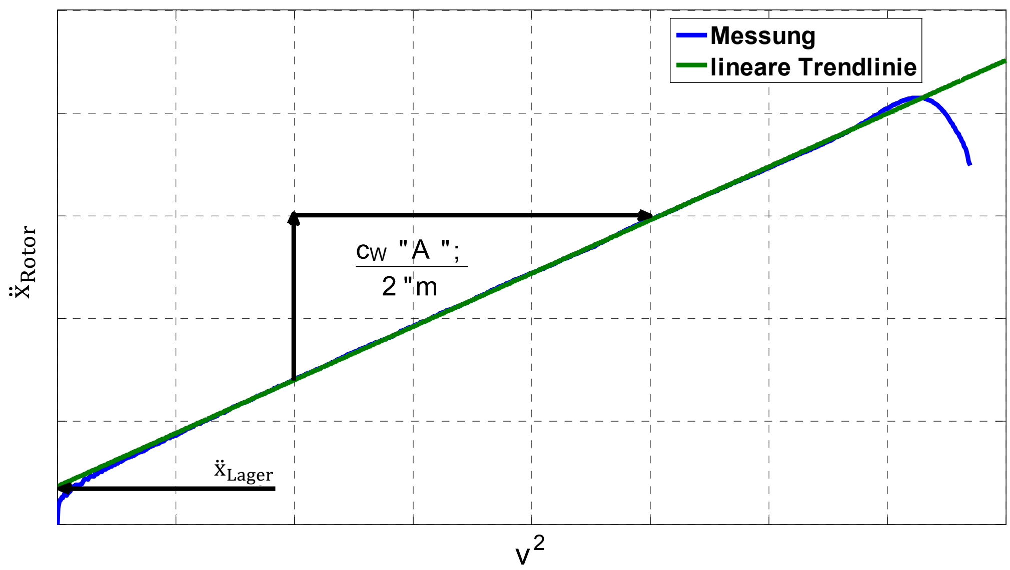

Abbildung 5. Bestimmung von Luft- und Lagerverzögerung im Auslaufversuch von v_0 = 100 km/h

$$\ddot{x}_{Aero} = \frac{c_W \cdot A \cdot \rho}{2 \cdot m} \cdot v^2$$

Abbildung 6 zeigt die gemessene Verzögerung am Rutschsimulationsprüfstand bei einem Auslaufversuch sowie den Verlauf der nach obigem Prinzip durchgeführten Approximation. Vor allem im Bereich hoher Geschwindigkeiten ist eine sehr gute Übereinstimmung zu erkennen.

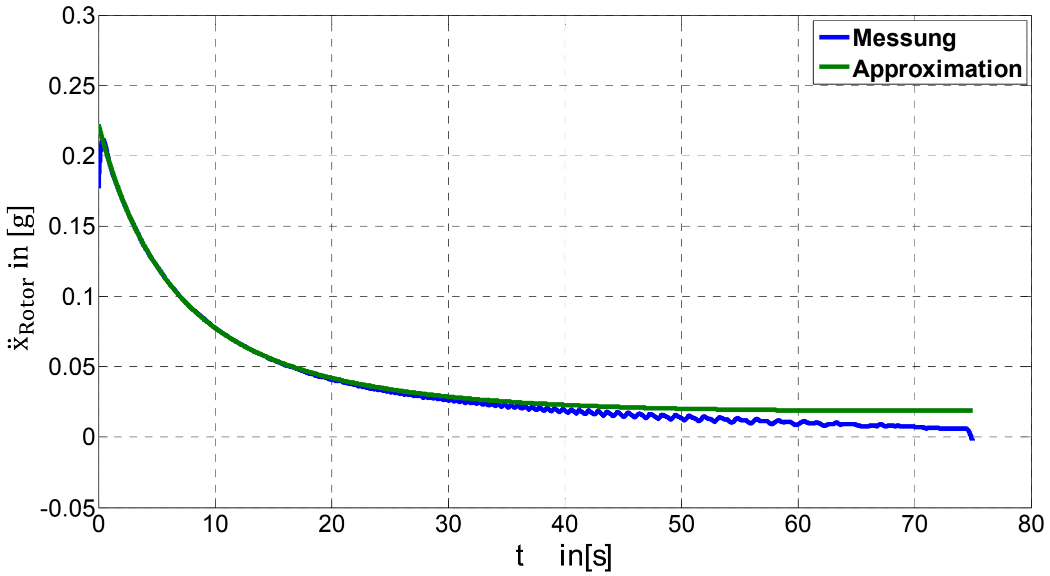

Abbildung 6. Auslaufversuch am Rutschsimulationsprüfstand von v_0 = 100 km/h

Werden die approximierten Anteile $\ddot{x}_{Aero}$ und $\ddot{x}_{Lager}$ in einem anschließend durchgeführten Materialtest von der Gesamtverzögerung abgezogen, ergibt sich die allein durch die Reibung des Probenmaterials erzeugte Verzögerung $\ddot{x}_{Material}$:

$$\ddot{x}_{Material} = \ddot{x}_{Rotor} - \ddot{x}_{Aero} - \ddot{x}_{Lager}$$

Ist diese Reibverzögerung bekannt, kann schließlich der Reibwert des Probenmaterials bestimmt werden:

$$\mu = \frac{F_{Reib}}{F_{Normal}} = \frac{m \cdot \ddot{x}_{Material}}{m \cdot g} = \frac{\ddot{x}_{Material}}{g}$$

Abbildung 7 zeigt den Verlauf der Gesamtverzögerung sowie der Reibverzögerung (in diesem Fall gleichzusetzen mit dem Reibwert) über der Zeit. Da der Einfluss des Luftwiderstands mit der Rutschgeschwindigkeit abnimmt, nähern sich beide Kurven im Verlauf der Messung aneinander an. Die bleibende Abweichung resultiert aus der Lagerreibung. Der genaue Verlauf des Reibwertes ist erwartungsgemäß stark abhängig vom getesteten Material. Eine Interpretation verschiedener Verläufe wird in Kapitel 5 vorgenommen.

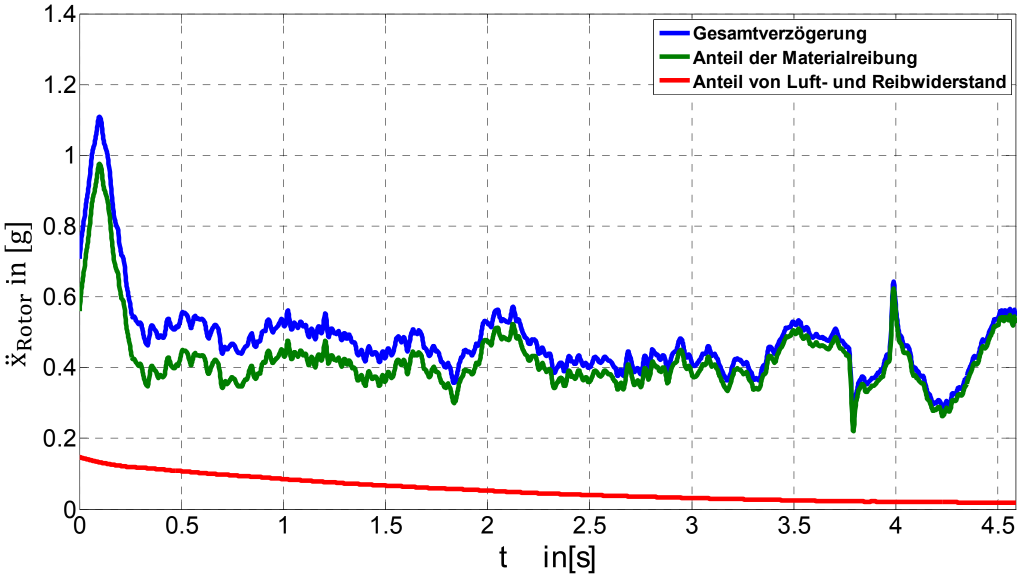

Abbildung 7. Anteile der Gesamtverzögerung am Rutschsimulationsprüfstand

3.2 Mechanische Anpassungen

Neben der Modernisierung der Elektrik- und Elektronik-Komponenten wurden und werden mechanische Optimierungen durchgeführt, die die folgenden Punkte zum Ziel haben :

- Effizienzsteigerung des Prüfablaufes
- Ergonomieverbesserung
- Verstellbarkeit von Maschinenparametern (Anpresskraft, Trägheit)
- Erweiterung des Funktionsumfangs (z.B. Handschuhtest)

Zudem werden Peripheriegeräte entwickelt, wie z.B. eine Nivelliervorrichtung, um eine Ausrichtung der Fahrbahnkachel parallel zur Rotationsebene des Probensterns zu erleichtern, oder eine Schneidevorrichtung zur teil-automatisierten Probenherstellung.

Der momentane Aufbau des Rutschsimulationsprüfstands erzeugt die Anpresskraft allein bedingt durch das Gewicht des Probensterns. Sie ist somit – abgesehen von dynamischen Effekten durch Fahrbahnunebenheiten – annähernd konstant und zudem nicht anpassbar. Für einen Nachfolger des Prüfstands wird daher die Möglichkeit untersucht, die Anpresskraft durch einen geregelten Aktor zu erzeugen. Dadurch könnten z.B. definierte Kraftspitzen beim Aufprall auf die Fahrbahn – oder gar ein wiederholtes Aufprallen, wie es beim Purzeln des gestürzten Motorradfahrers auftreten kann – nachgestellt werden. Zudem ergeben sich Möglichkeiten, geänderte Testszenarien, wie z.B. Abriebversuche von Handschuhen oder Stiefeln abzubilden, die andere Flächenpressungen erfordern.

Sofern es – durch eine eigene Aktorik oder nur durch austauschbare Gewichte am Probenstern – möglich ist, die Flächenpressung an alternative Testszenarien anzupassen, sind neue Probenträger erforderlich, um beispielsweise Handschuhe aus der Serienproduktion aufspannen zu können. Die Anbringung neuer Probenträger oder von Gewichten zur Erhöhung der Flächenpressung wirkt sich direkt auf die Rotationsträgheit des Gesamtsystems aus. Folglich ist auch der Massenstern derart zu konstruieren, dass beispielsweise die radiale Position der verwendeten Massen veränderlich ist, oder die Massen selbst erhöht oder verringert werden können. Dabei ist besonderer Wert auf die Auswuchtung der rotierenden Teile sowie die Mittensymmetrie des Massensterns zu legen. Bei Probengeschwindigkeiten von 130 km/h treten Querbeschleunigungen von bis zu 300 *g* auf, die andernfalls zu radialen Lastüberhöhungen in den Lagern führen, oder zu Biegemomenten im Massenstern.

Abbildung 8 zeigt oben den derzeitigen Querschnitt des Massensterns schematisch auf. Durch die Exzentrizität des angebrachten Gewichtes und die hohen auftretenden Zentripetalkräfte F_ω konnte im Lauf der Jahre eine plastische Verbiegung des Massensterns beobachtet werden. Die radiale Position des Gewichtes ist durch eine einzelne Bohrung vorgegeben und nicht veränderlich. Die nachfolgende Darstellung zeigt eine Möglichkeit zur Unterdrückung des zentripetalkraftinduzierten Biegemoments und der Montage von Gewichten an veränderlichen Positionen.

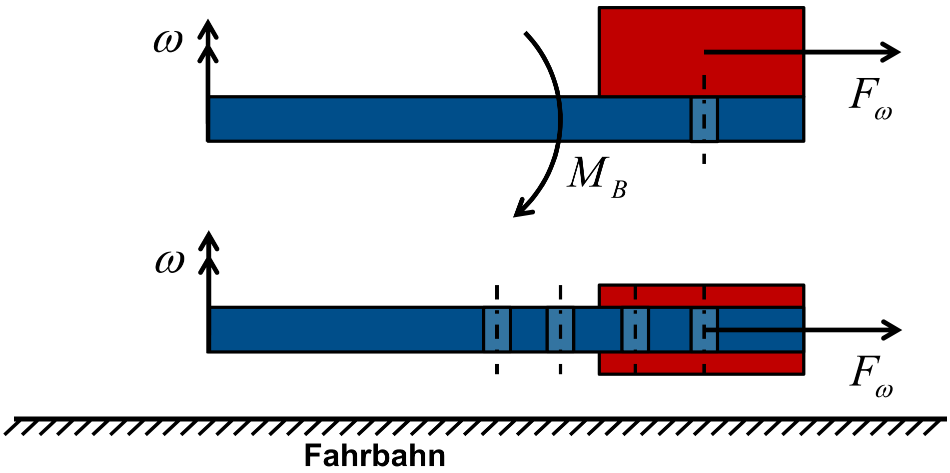

Abbildung 8: Mögliche Überarbeitung des Massensterns

Weitere Untersuchungen bei FZD betreffen die Möglichkeit, die Fahrbahnkachel während eines Versuchs horizontal zu verschieben, um den beschriebenen Schmiereffekten entgegenzuwirken.

4 Normung

Für die Verwendung des Verfahrens in einer Europäischen Prüfnorm muss es sich vor allem durch folgende Eigenschaften auszeichnen:

- Hohe Reproduzierbarkeit der Messergebnisse
    - über die Zeit
    - in unterschiedlichen Prüflaboren
- Erzeugung eines objektiven Kennwertes

Beim derzeit in der europäischen Prüfnorm EN 13595 genutzten Verfahren wird eine Materialprobe bei konstanter Reibgeschwindigkeit von 8 m/s durch handelsübliches Schleifpapier abgerieben. Als Kenngröße für das Materialverhalten wird die Dauer herangezogen, die benötigt wird, um ein Loch durch die komplette Dicke der Probe zu reiben.

Wenngleich mit diesem Verfahren ein gewisser Abstand zum Realunfallgeschehen hingenommen wird, so liefert es mit der Lochbildungsdauer – zumindest theoretisch – eine objektive Kenngröße, die eine Relativbewertung verschiedener Probenmaterialien zueinander ermöglicht. Im Prüfbetrieb hat sich jedoch die Reproduzierbarkeit der Messungen als ungenügend herausgestellt. Probleme stellen sowohl das Schleifpapier dar, das kein gleichbleibendes Abriebverhalten gewährleistet, als auch das Kalibrierungsverfahren, in dem ein Denim-Gewebe, welches ebenfalls kein konstantes Materialverhalten besitzt, als Referenzmaterial verwendet wird. So werden bei sonst identischen Messbedingungen in verschiedenen Labors unzufrieden stellende Messunterschiede erreicht. Für die Verwendung innerhalb einer Prüfnorm sind derartige Messunterschiede untragbar, weshalb ein Alternativverfahren gefunden werden muss.

Dafür empfiehlt sich das beschriebene Darmstädter Verfahren. Wie in den Kapiteln zuvor beschrieben, zeichnet es sich durch eine hohe Reproduzierbarkeit und Realitätsnähe aus. Als Kennwert bietet sich in Analogie zum bisherigen Verfahren die Lochbildung an. So können Testmaterialien auf Lochbildung bei vorgegebener Startgeschwindigkeit getestet werden. Als Mehrwert im Vergleich zur bisher genutzten Methode steht zudem der Reibwert der Materialprobe zur Verfügung. Sollte eine Zielvorgabe für den Reibwert in die Prüfnorm aufgenommen werden, bedeutet dies einen Sicherheitszuwachs für Motorradfahrer, da die Schutzkleidungsentwicklung bewusst in Richtung optimaler Verzögerung des Gestürzten geleitet wird. Durch die kürzeren Rutschwege verringert sich in direkter Folge die Gefahr von Aufprällen an Bäumen, Leitplanken oder anderen Hindernissen im Straßenverkehr. Die maximal mögliche Verzögerung ergibt sich aus der Grenze, ab der kein stabiles Rutschen des Verunglückten mehr stattfindet, sondern der Fahrer zu purzeln beginnt. Nach wird eine mittlere Verzögerung zwischen 0,7 g und 1,1 g empfohlen.

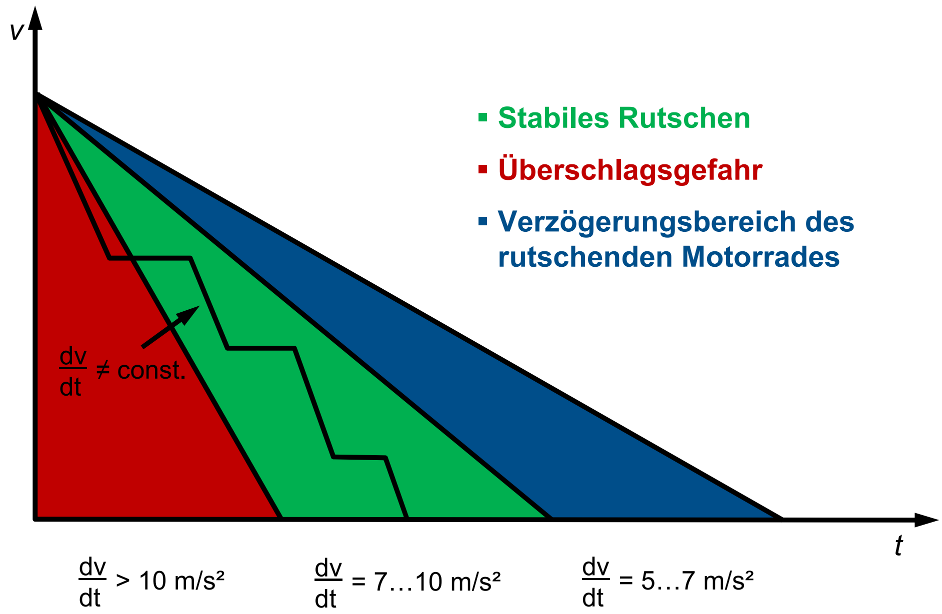

Abbildung 9. Verzögerungsbereiche

Weiterhin bleibt jedoch die Verwendbarkeit der Fahrbahnkachel zu klären. Aus Gründen der leichter handhabbaren Fertigung soll zukünftig von der Nutzung einer Asphaltfahrbahnkachel abgesehen werden und ausschließlich auf Zementbeton als Fahrbahnwerkstoff zurückgegriffen werden. Dieser hat sich zudem in Voruntersuchungen über die Nutzungsdauer als beständiger hinsichtlich seines Lochbildungsverhaltens herausgestellt. Die Änderung des Reibwertes über die Nutzungsdauer der Fahrbahn stellt einen Schwerpunkt aktueller Arbeiten am Testverfahren dar. Die Verwendung einer nach Straßenbaunorm ZTV Beton 1997 gefertigten Zementbeton-Fahrbahn auf einem Schwester-Prüfstand hat sich seit über 15 Jahren bewährt und stellt daher eine vielversprechende Alternative dar.

5 Entwicklungswerkzeug

Während das Darmstädter Verfahren zur Anwendung innerhalb der Prüfnorm denkbar einfach konfiguriert werden kann – Lochbildung und mittlere Verzögerung sind mit einfachster Messtechnik festzustellen – bieten zuvor beschriebene Überarbeitungen ein großes Potential zu Detailuntersuchungen des Materialverhaltens.

Als Beispiel sei der erwartete Reibwertverlauf einer handelsüblichen Lederkombi genannt: Deren Lackierung bedingt einen sehr niedrigen Reibwert zu Beginn des Rutschvorgangs. Ist diese oberste Schicht abgetragen, sodass das Leder selbst über die Fahrbahn rutscht, erhöht sich der Reibwert des Probenmaterials deutlich. Vor allem bei Tests aus höheren Geschwindigkeiten entstehen über den Rutschvorgang höhere Temperaturen. Führen diese zu Verhärtungen des Leders, fällt der Reibwert schließlich wieder ab. Abbildung 10 stellt dieses Verhalten schematisch dar.

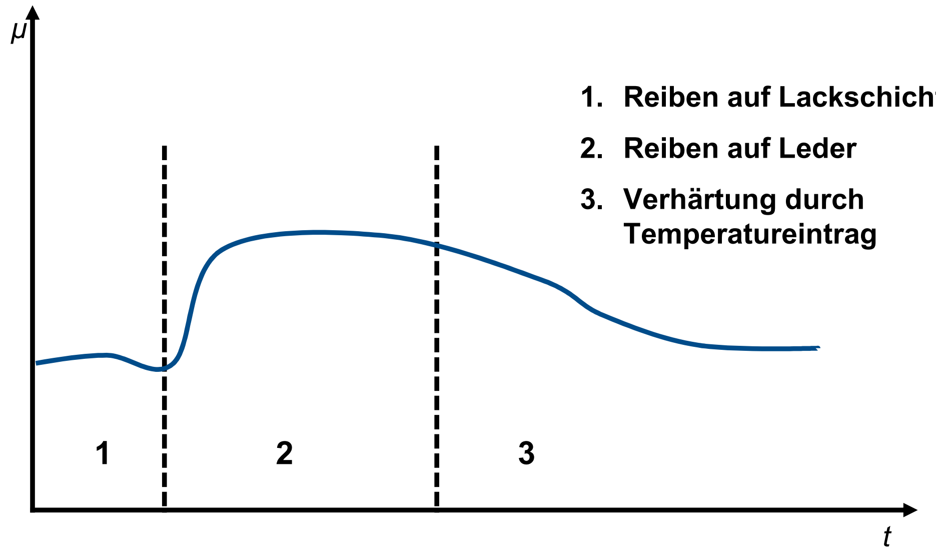

Abbildung 10. Erwarteter Reibwertverlauf einer lackierten Leder Probe

Abbildung 11 zeigt den gemessenen Verlauf des Reibwertes in Abhängigkeit des Rutschweges sowie den Geschwindigkeitsverlauf. Mit einer Geschwindigkeit von 109,1 km/h (bei gewünscht 110 km/h) kommt die Probe in Kontakt mit der Zementbeton-Fahrbahn. Der Rutschweg beträgt 51,54 m und die Rutschdauer 3,53 s.

Abbildung 11. Gemessener Reibwertverlauf einer lackierten Lederprobe, v_0 = 109,1 km/h

Beim Vergleich der beiden Abbildungen fallen direkt die starken Unterschiede zwischen erwartetem und gemessenem Reibwert-Verlauf ins Auge. Dafür kommen mehrere Begründungen in Betracht:

- Die große Reibwertspitze zu Beginn der Messung ist auf eine Kraftüberhöhung beim Aufprall der Proben zurückzuführen. Diese tritt ebenfalls im Realunfall auf und erhöht folglich den Realitätsbezug des Verfahrens. Gleichzeitig verstärkt sie jedoch die resultierende Verzögerung und verfälscht somit den unter Annahme konstanter Flächenpressung errechneten Reibwert.
- Der zu Beginn des Rutschvorgangs auf die Fahrbahn aufgebrachte Lack wirkt im weiteren Verlauf des Tests zu stark schmierend und reduziert folglich den gemessenen Reibwert im mittleren Bereich der Messung.

Einen Vergleich dieser Messung mit einer zweiten Messung bei auf 60 km/h reduzierter Startgeschwindigkeit zeigt Abbildung 12. Darin ist der Reibwert der Proben über der Rutschgeschwindigkeit aufgezeigt.

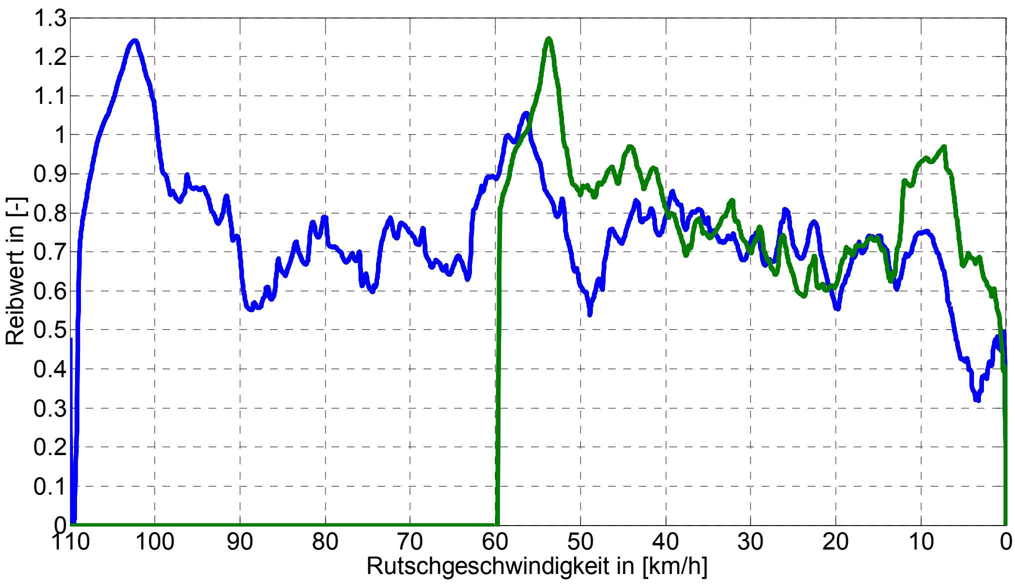

Abbildung 12. Variation der Startgeschwindigkeit

Erneut ist die Reibwertspitze zu Beginn beider Rutschvorgänge deutlich zu erkennen. Nach dem Abklingen der aufprallinduzierten Normalkraftschwankungen zeigt sich jedoch eine sehr gute Übereinstimmung beider Kurvenverläufe. Die Differenzen, welche gegen Ende der Messungen auftreten, könnten die Folge leichter Lochbildung bei dem Test aus höherer Startgeschwindigkeit sein.

Das dynamische Materialverhalten kann in Abhängigkeit von der Körperregion, in der das Material zum Einsatz kommt ein unterschiedliches Idealverhalten aufweisen. So sollten beispielsweise Regionen, die nach dem Aufprall auf die Fahrbahn einen großen Einfluss auf die Bremswirkung besitzen (z.B. Gesäß, Oberschenkel, Schultern, Rücken, etc.) – unabhängig von weiteren Größen wie zum Beispiel der Schlagdämpfung – einen konstant hohen Reibwert und damit gute Verzögerungswerte erzeugen (Verlauf 1 in Abbildung 13). Ein Nachlassen des Reibwertes, wie ihn Verlauf 2 zeigt, ist dabei einem ansteigenden Verlauf, wie ihn Verlauf 3 zeigt, zu bevorzugen, da dieser zu Beginn des Rutschvorgangs – also bei noch hohen Rutschgeschwindigkeiten – bessere Verzögerungswerte erzielt. Sollte jedoch zu Beginn des Rutschvorganges ein ähnlich hoher Reibwert wie in Verlauf 1 oder 2 an der Handschuhfläche auftreten, könnte der Fahrer beim Aufdrücken der Handballen auf die Fahrbahn die auftretenden Reibkräfte ggf. nicht mehr abstützen. Somit wird es dem Gestürzten erschwert, das Rutschen mit Hilfe der Hände zu stabilisieren. An dieser Stelle wäre also ein zunächst niedriger Reibwert zu wünschen, der jedoch im Verlauf des Rutschvorgangs kontinuierlich ansteigt (Verlauf 3 in Abbildung 13). So kann der Gestürzte die Bremswirkung erhöhen, sobald er kontrolliert über die Fahrbahn rutscht.

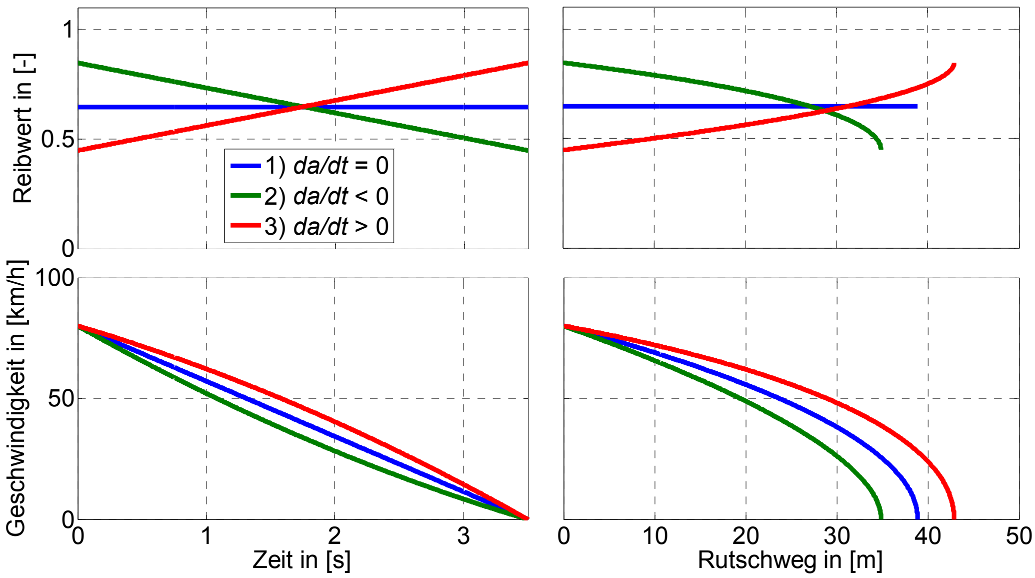

Abbildung 13: Unterschiedliche Materialverhalten bei gleichen Mittleren Reibwerten μ_t (Modellrechnung)

Die Verläufe 1 und 3 zeigen einen weiteren Vorteil der kontinuierlichen Datenauswertung auf: Bei den früher durchgeführten Prüfungen konnten lediglich die mittleren Verzögerungen über die Rutschzeit t_{rutsch} oder den Rutschweg s_{rutsch} bestimmt werden:

$$\mu_t = \frac{v_0}{g \cdot t_{rutsch}} \text{ oder } \mu_s = \frac{v_0^2}{2 \cdot g \cdot s_{rutsch}}$$

Zum einen unterscheiden sich beide Mittelwerte aufgrund des nicht konstanten Verzögerungsverlaufes voneinander. Es muss also stets festgelegt werden, welche Referenz zur Mittelwertbildung herangezogen wird und weshalb. Zum anderen erreichen alle drei gezeigten Reibwertverläufe gleiche Mittelwerte über die Zeit, obwohl sie fraglos ein gänzlich unterschiedlich zu bewertendes Reibverhalten aufweisen. Aufgrund dieser Problematik liegt ein weiterer Entwicklungsschwerpunkt auf der Generierung neuer Kennwerte, die eine Bewertung des Materialverhaltens unter Betrachtung des Verwendungszwecks ermöglichen.

Trotz der geschilderten Problematik hinsichtlich der Fahrbahnkonstanz besteht zum Darmstädter Verfahren hinsichtlich Realitätstreue und Reproduzierbarkeit der Ergebnisse aktuell keine Alternative. Die zuvor gezeigten Betrachtungen sind derzeit allein mit diesem Verfahren durchführbar. Andere bekannte Verfahren weichen in der Regel nicht nur deutlich stärker vom Realunfallgeschehen ab, sondern erzeugen zudem Kennwerte, die höchstens indirekt relevant für Motorradfahrer-Schutzbekleidung sind. Für die Entwicklung zukünftiger Schutzbekleidung bietet das Darmstädter Verfahren somit besonders großes Potential.

6 Fazit / Ausblick

Das Darmstädter Verfahren für Schutzkleidungsprüfung – im speziellen der Abriebversuch – zeichnet sich durch einen realgetreuen Testablauf hinsichtlich des Motorradunfallgeschehens aus. Bereits bei der Verwendung einfachster Messtechnik können mehrere Kennwerte generiert werden, die relevant für das Realunfallgeschehen sind. Dabei hebt es sich besonders durch die zusätzliche Betrachtung des Reibwertes von anderen Verfahren hervor.

Die in diesem Dokument aufgezeigten Überarbeitungen am Rutschsimulationsprüfstand schaffen einen großen Mehrwert gegenüber dem bisherigen Prüfablauf. Die genannten mechanischen Arbeiten am Prüfstand verbessern die Ergonomie, erhöhen die Effizienz und ermöglichen neue Testszenarien. Die erneuerte Messtechnik schafft die Möglichkeit zur dynamischen Betrachtung des Materialverhaltens.

Diese Vorteile kann das Verfahren jedoch nur dann sinnvoll nutzen, wenn ein gleichbleibendes Reibverhalten der Testfahrbahn – sowohl während eines einzelnen Testlaufes, als auch über die Lebensdauer hinweg – gewährleistet werden kann. Daher sind weitere Untersuchungen der Fahrbahnkachel hinsichtlich Betonzusammensetzung sowie Reinigung und Abnutzung unabdingbar.

Sobald diese Voraussetzungen geschaffen sind, hat das Darmstädter Verfahren für Schutzkleidungsprüfung die Anforderungen erfüllt, um in der europäischen Prüfnorm verwendet zu werden und damit einen Beitrag zur Entwicklung sicherer Motorradfahrer-Schutzbekleidung zu leisten.

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The technology of Multistrada D-Air® motorcycle with airbag

Die Technologie der Multistrada D-Air®

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Abstract

Ducati launched in 2014 the Multistrada D-Air® model, featuring a fully integrated, intelligent system of sensors wirelessly connected to Ducati Apparel airbag jackets by Dainese. Marking a ‘world's first' in the motorcycle industry and combining the innovative designs from two famous Italian brands, the new Ducati model takes a significant step forward in two-wheel safety.

Combining the expertise of both Ducati and Dainese, the intelligent passive safety system uses sensors built into the Multistrada's existing electronics to constantly understand the vehicle's dynamic situation and deploying only when subjected to a genuine accident scenario, considerably reducing the risk of injury upon impact.

The technology of Multistrada D-Air® motorcycle with airbag

The Multistrada 1200 S Touring D|air

Ducati introduces the Multistrada 1200 S Touring D|air model, featuring an integrated, intelligent safety system wirelessly connected to Ducati Apparel D|air® airbag jackets by Dainese. Marking a ‘world’s first’ in the motorcycle industry and combining the innovative designs from two famous Italian brands, the new Ducati model takes a significant step forward in two-wheel safety.

The cooperation of expertise between Ducati and Dainese has produced an intelligent system that uses sensors built into the Multistrada 1200 S Touring’s electronics to constantly understand the vehicle’s dynamic situation, deploying only when subjected to a genuine accident scenario. The Multistrada D|air® system completes the data analysis and airbag deployment inside both the rider and passenger jackets in just 45 milliseconds, considerably reducing the risk of injury upon impact.

The Ducati D|air® is the first production motorcycle with an integrated jacket airbag system to complete the necessary tests for certification by Germany’s rigorous TÜV SÜD, the association responsible for defining the standards for wearable airbags. Ducati’s premiere of the technology, developed with Dainese, further underlines the Italian motorcycle manufacturer’s commitment to enhanced safety, already represented by their Ducati Safety Pack consisting of multi-level ABS, traction control and power-controlling Ride-by-Wire.

The Ducati Multistrada D|air®, which is also equipped with Ducati’s semi-active Skyhook suspension, will be available in European Ducati Dealerships from May 2014 onwards along with the D|air® Street jackets.

Multistrada D|air® Street technology

Now common place in the automotive world, the airbag remains the most effective passive safety system. A really effective motorcycle airbag for street use, however, must have a deployment time of less than 80 milliseconds in order to provide adequate protection to the rider against the impact of another vehicle. Until now, this system simply did not exist.

Ducati's Multistrada D|air® system is designed to deploy in just 45 milliseconds, protecting the rider and passenger's body exposed to impact by absorbing the forces with an airbag expertly built into the jacket by Dainese. The airbag system is capable of split-second inflation without hindering the rider and intelligent enough to understand the difference between a potentially dangerous accident and a low-speed incident, or the motorcycle simply falling over.

This intelligence comes from a sophisticated algorithm, which manages data delivered from two triple-axis accelerometers fixed to the left and right fork bottoms of the Multistrada's front suspension and an additional two rear triple-axis accelerometers mounted in the D|air® Electronic Control Unit (ECU) positioned under the seat. When the sensors detect a potentially dangerous crash scenario, an algorithm is triggered which takes just 25 milliseconds to decide if airbag deployment is necessary or not. If deployment is necessary the D|air® ECU onboard the Multistrada, which is continuously in bi-directional radio contact between the system and the Dainese jackets, initiates and completes airbag inflation in just 20 milliseconds, a total of 45 milliseconds from the start of impact.

The system adds just 1kg to the Multistrada and the only visual difference to the model is the addition of an extra LED display on the main instrumentation that constantly provides the system's active status. The horizontal display is divided into three sections with illuminated displays from left to right for "Rider", "D|air" and "Passenger". Designed to provide reassurance to the user, both the green-coloured Rider and Passenger sections illuminate constantly to confirm that the rider's and passenger's airbag jacket is connected (paired) with the D|air® system and ready for use. The system is programmed to warn the user of a jacket system error by flashing slowly and will flash faster if the jacket has failed to connect to the system after 30 seconds of key-on. The central yellow light remains off when the system is active and ready for use, but will illuminate constantly to warn of a low battery in the airbag jacket or a D|air® system error.

The original round, dot-matrix part of the Multistrada's instrumentation is utilised to display information for rider and passenger airbag battery levels in addition to airbag jacket scheduled maintenance reminders.

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Multistrada D|air® airbag deployment scenarios

The system's intelligence is able to recognise the main scenarios in which the Multistrada D|air® must deploy its airbag jackets. Those scenarios include: a) the vehicle's frontal impact into another object, b) collision impact into the side of a vehicle side or rear impact from another vehicle and c) when control is lost and the motorcycle is sliding on its side. In this last scenario, the airbag deploys ready to provide protection against the rider or passenger sliding into an obstacle.

By recognising these scenarios, the system avoids to deploy during non-dangerous incidents, such as aggressive sport riding, losing balance while manoeuvring at low speed or the motorcycle simply falling over while parked.

Multistrada D|air® Street jacket by Dainese

The Ducati D|air® Street jacket (not included with motorcycle) is designed for long-range touring and provides maximum protection and comfort by introducing the D|air® airbag technology with GORE-TEX® membrane. In addition to the D|air® Street airbag system, which is powered-on with a slide switch built into jacket, the garment is equipped with shoulder and elbow protectors and a Wave back protector inside a waterproof and breathable GORE-TEX® fabric with detachable thermal lining. The highly innovative system is designed, developed and patented by Italian manufacturer, Dainese S.p.A., a world leader in the field of protective clothing for motorcyclists.

The garment incorporates two high-pressure, three-dimensional, 12 litre structural airbags inflated by two 'cold' technology gas generators integrated into the jacket lining. The three-dimensional airbag structure provides a controlled, high-pressure expansion that assumes a pre-formed shape designed to wrap around and protect the rider's body. The jacket, which weighs just 1.5kg more than an ordinary jacket, feels exactly the same as a conventional garment, while achieving maximum impact absorption with minimum bulk.

The D|air® Street jacket reduces impact energy transmitted to the body by up to 72% compared with a back protector and up to 89% compared with a chest protector. This substantially enhances back, collarbones and chest protection in addition to limiting the 'tilting' of the wearer's head in relation to the neck, by reducing excessive helmet movement while 'tumbling' during an accident.

The D|air® Street jacket's integral system, which requires a maintenance check every 24 months starting from its first connection (pairing) with the Multistrada D|air®, is powered by a battery pack charged via a USB connection built into the garment, from which a 5 hour charge will guarantee 30 hours of autonomy. The D|air® jacket maintenance reminders and battery levels are clearly communicated to the rider via the Multistrada's instrumentation.

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The Multistrada 1200 S Touring D|air

The brand new D|air® system is fully integrated into the highly acclaimed Multistrada 1200 S Touring, the multi-tasking motorcycle that features confidence-inspiring electronics, including the advanced Ducati Skyhook Suspension (DSS).

The D|air® introduction continues the Multistrada adventure with a long list of fascinating and high-tech features that enhance the model's reputation for industry-changing innovation, including the second generation Testastretta 11° DS engine and the Bosch ABS 9ME braking system with full Riding Mode integration.

Combining ground-breaking design and unprecedented technology, the Multistrada's Sport, Touring, Urban and Enduro Riding Modes enable a truly enjoyable and customisable riding experience separated by just one click. The four-bikes-in-one concept makes instant adjustment to power and torque delivery in addition to electronic adjustment of suspension settings, traction control, ABS and Ducati Skyhook Suspension, instantly transforming the Multistrada to suit its rider and environment with precision.

Hailed as a true 'game-changing' motorcycle, the Multistrada 1200 S Touring has attracted all types of riders by removing the borders between motorcycle categories. With the latest 150hp Testastretta 11° DS engine, a class-leading dry weight of just 207kg* and the application of advanced ergonomics, the Multistrada is not only powerful and playful, but also a comfortable and versatile adventure on two wheels. The eight-level DTC and three-level ABS of the Ducati Safety Pack (DSP) is now in addition to the innovative new D|air® system, further underlining Ducati's focus on performance safety.

Dressed in Ducati red, the early entry 2015 Multistrada 1200 S Touring D|air comes fully equipped with additional side luggage, heated grips and centre stand and will be available in European Ducati dealerships from May 2014 onwards.

*New Multistrada 1200 S Touring D|air model

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