Injury Severity and Causation Factors of Motorcyclists in Traffic Accidents in comparing Drivers of Motorcycle and All Kinds of Motorized Two-wheelers

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content

• Introduction of research methodology
• Analysis frame and data
• Accident and Injury situation
• Accident Causation
• Conclusions
• Improvements for more safety
Technical University Dresden

Medical University Hannover

methodology

2000 accidents annual

By order of
Federal Highway Research Institute BAST
Automotive Research Association FAT
Description of sampling

Representative Data Sampling on Scene

**Methodology**

Random selection

Selection criteria

Weighting process

No personal decision for selection of case!

All kind of traffic accidents with injured person!

Comparison to national or regional statistics!
Description of sampling methodology

What to do on scene?
Kind + Location + Severity

Injury documentation

MAIS 2
AIS-Head 2
AIS-Arms 2
AIS-Legs 2

Commotio Cerebri  AIS 2
Laceration Head right frontal  AIS 1
Fracture of head of radius right  AIS 2
Rupture left crucial ligament  AIS 2

methodology
GIDAS - German In-Depth Accident Study

3020100207
Kompression fracture 5th thorax vertebra

Luxation Daumen right

PASSAT VK 20 km/h
DUCATI VK 40 km/h
Vrel 46 km/h

MAIS 2
Motorcycle driver
38 y. m.

3020100207
Human # Machine # Environment

- "Human“ → **Group 1**, human cause factors (Seven Steps)
- „Machine“ → **Group 2**, factors from the technical nature of the vehicle
- "Environment“ → **Group 3**, factors from the range of the infrastructure and nature

**ACASS methodology**
The causes of traffic accidents can be found in three different areas: **Human factors**, technical factors form the vehicle and factors from the infrastructure or environment presented in three groups of the system.

The human factors consist of **seven categories (7 Steps)**

Chronological sequence of basic human functions from the perception, the judgment of the perceived situation to the resulting operation.

- **Group 1: Human factors**
  - (1) Information access
  - (2) Observation
  - (3) Recognition
  - (4) Evaluation
  - (5) Planning
  - (6) Selection
  - (7) Operation

Each category consists of **specific criteria** which specifies the factor within the category.

- (1) Wrong expectation
- (2) Misjudgement of others
- (3) Misjudgement of own vehicle

Solely the human factors allow to further categorize the chosen criteria with **specific indicators**.

- (1) Own speed
- (2) Veh.-dynamics/behaviour
- (3) Braking, Accelerating

**Code of 4 numbers**

**ACASS methodology**
Multiple causation-codes for each accident participant are possible:

1st Code: [ ] [ ] [ ] [ ] [ ] [X] Comments box

2nd Code: [ ] [ ] [ ] [ ] [ ] Comments box

... 

5th Code: [ ] [ ] [ ] [ ] [ ] Comments box

- **Causation factors codes possible per accident participant**
- **Source of information** Numbers 1 to 9 how the information was obtained
- **Doubts concerning the reliability of the coded information**
- **Comments to explain the selected code**

**ACASS methodology**

Recording of accident causation data in GIDAS
The analysis!

- Data selection
- Kind of injuries
- Frequency of injured body areas and severity grades
- Impact loads
- Accident situation and causation factors
Motorized Two Wheelers

- Mofa, Moped, Mokick, light motorcycle
- Motorcycle, Scooter
### GIDAS 1999-2011

- **n=24,013 cases**
- **n=23,033 participants**
- **n=44,348 motorcycle participants**

#### STATUS
- **not complete** n= 715
- **no reconstruction** n= 265

#### Participation
- **car** n=27,209
- **truck** n= 2,690
- **coach, tram** n= 890
- **bicycle** n= 6,897
- **pedestrian** n= 3,074
- **others** n= 114

#### Zweirad
- **unknown, quad** n= 29
- **no cyclist** n= 2

#### Unknown
- **MAIS** n= 162
- **head injuries** n= 31
- **helmet** n= 386

### GIDAS 2008-2012

- **Hannover**
  - **n=4,798 cases**
  - **n=4,314 participants**

#### STATUS
- **not complete** n= 444
- **no reconstruction** n= 40

#### Participation
- **truck** n= 504
- **coach, tram** n= 116
- **bicycle** n= 1,598
- **pedestrian** n= 512
- **others** n= 26

#### Driver
- **no cyclist, quad** n= 454

### Data:
- **all motorcyclists** n= 2,864
- **motorcyclist (> 125 ccm)** n= 1,406
The situation of Injury Severity in Germany for Motorcyclists (n=2864)

Severely injured

11.9% MAIS 3+

GIDAS 2013, Unfälle von 2000 bis 2012
For Comparison!

Belted Car Occupants (n=21,668)

GIDAS 2013, Unfälle von 2000 bis 2012
Relative Speed in motorcycle accidents

- alle mot. Zweiräder (n=2501)
- Motorräder (n=1277)

% cumulative

Relative speed [km/h]
maximum injury severity grades

- moped 25 (n=91)
  - MAIS 3+: 3.3%
  - MAIS 2: 27.5%
  - MAIS 1: 64.8%
  - MAIS 0: 4.4%

- moped (n=943)
  - MAIS 3+: 7.5%
  - MAIS 2: 23.3%
  - MAIS 1: 65.1%
  - MAIS 0: 4.1%

- up to 125 ccm (n=415)
  - MAIS 3+: 8.8%
  - MAIS 2: 26.3%
  - MAIS 1: 60.3%
  - MAIS 0: 4.6%

- > 125 ccm (1415)
  - MAIS 3+: 16.3%
  - MAIS 2: 26.8%
  - MAIS 1: 50.8%
  - MAIS 0: 6.1%
Injury severity and power-weight ratio

- GIDAS
- German In-Depth Accident Study

<table>
<thead>
<tr>
<th>Power-weight ratio [kg/kW]</th>
<th>MAIS 3+</th>
<th>MAIS 2</th>
<th>MAIS 1</th>
<th>MAIS 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 (n=376)</td>
<td>4,8</td>
<td>55,0</td>
<td>48,7</td>
<td>25,3</td>
</tr>
<tr>
<td>4-8 (n=600)</td>
<td>10,5</td>
<td>27,2</td>
<td>22,3</td>
<td>25,6</td>
</tr>
<tr>
<td>9-12 (n=158)</td>
<td>11,4</td>
<td>25,3</td>
<td>25,3</td>
<td>27,2</td>
</tr>
<tr>
<td>13-20 (n=268)</td>
<td>9,0</td>
<td>23,1</td>
<td>61,9</td>
<td>57,6</td>
</tr>
<tr>
<td>21-30 (n=355)</td>
<td>11,6</td>
<td>25,6</td>
<td>58,6</td>
<td>23,1</td>
</tr>
<tr>
<td>&gt;30 (n=215)</td>
<td>5,1</td>
<td>22,3</td>
<td>68,4</td>
<td>25,3</td>
</tr>
</tbody>
</table>
collision types of all motorcycles (n=2,848)

<table>
<thead>
<tr>
<th>Collision Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>5.4%</td>
</tr>
<tr>
<td>Type 2</td>
<td>9.9%</td>
</tr>
<tr>
<td>Type 3</td>
<td>6.8%</td>
</tr>
<tr>
<td>Type 4</td>
<td>21.1%</td>
</tr>
<tr>
<td>Type 5</td>
<td>8.2%</td>
</tr>
<tr>
<td>Type 6</td>
<td>3.9%</td>
</tr>
<tr>
<td>Type 7</td>
<td>44.7%</td>
</tr>
</tbody>
</table>

Note: The percentages sum up to more than 100% due to rounding and the fact that some categories might overlap or not be mutually exclusive.
coll. types and injury severity grade of all motorcyclists

- All types of motorcycles:
  - Type 1 (n=153):
    - MAIS 3+: 10.4%
    - MAIS 2: 30.1%
    - MAIS 1: 58.8%
    - MAIS 0: 0.7%
  - Type 2 (n=282):
    - MAIS 3+: 17.8%
    - MAIS 2: 28.7%
    - MAIS 1: 52.1%
    - MAIS 0: 1.4%
  - Type 3 (n=195):
    - MAIS 3+: 14.3%
    - MAIS 2: 24.6%
    - MAIS 1: 58.5%
    - MAIS 0: 2.6%
  - Type 4 (n=602):
    - MAIS 3+: 11.4%
    - MAIS 2: 22.6%
    - MAIS 1: 63.8%
    - MAIS 0: 2.2%
  - Type 5 (n=233):
    - MAIS 3+: 12.5%
    - MAIS 2: 25.3%
    - MAIS 1: 60.5%
    - MAIS 0: 1.7%
  - Type 6 (n=112):
    - MAIS 3+: 6.3%
    - MAIS 2: 20.5%
    - MAIS 1: 68.7%
    - MAIS 0: 4.5%
  - Type 7 (n=1271):
    - MAIS 3+: 10.8%
    - MAIS 2: 26.7%
    - MAIS 1: 53.5%
    - MAIS 0: 9.0%

- Collision types:
  - Type 1: Head-on collision
  - Type 2: Side impact
  - Type 3: Rear-end collision
  - Type 4: Angle collision
  - Type 5: Over-crossover collision
  - Type 6: Multiple vehicle collision
  - Type 7: Other collisions
GIDAS - German In-Depth Accident Study

Collision types for motorcycles > 125 ccm (n=1,406)

<table>
<thead>
<tr>
<th>Collision Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>3.9%</td>
</tr>
<tr>
<td>Type 2</td>
<td>9.1%</td>
</tr>
<tr>
<td>Type 3</td>
<td>6.4%</td>
</tr>
<tr>
<td>Type 4</td>
<td>20.3%</td>
</tr>
<tr>
<td>Type 5</td>
<td>7.9%</td>
</tr>
<tr>
<td>Type 6</td>
<td>3.6%</td>
</tr>
<tr>
<td>Type 7</td>
<td>48.8%</td>
</tr>
</tbody>
</table>

Motorcycles > 125 ccm
Collision types and injury severity motorcyclists

Motorcycles > 125 ccm

<table>
<thead>
<tr>
<th>Kollisionstypen</th>
<th>MAIS 3+</th>
<th>MAIS 2</th>
<th>MAIS 1</th>
<th>MAIS 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>type 1 (n=55)</td>
<td>3.6</td>
<td>29.1</td>
<td>67.3</td>
<td>0.0</td>
</tr>
<tr>
<td>type 2 (n=128)</td>
<td>2.7</td>
<td>29.7</td>
<td>46.0</td>
<td>1.6</td>
</tr>
<tr>
<td>type 3 (n=90)</td>
<td>2.2</td>
<td>28.9</td>
<td>59.1</td>
<td>1.7</td>
</tr>
<tr>
<td>type 4 (n=286)</td>
<td>1.7</td>
<td>23.8</td>
<td>52.3</td>
<td>1.8</td>
</tr>
<tr>
<td>type 5 (n=111)</td>
<td>1.8</td>
<td>26.1</td>
<td>70.0</td>
<td>8.0</td>
</tr>
<tr>
<td>type 6 (n=50)</td>
<td>6.0</td>
<td>16.0</td>
<td>45.5</td>
<td>10.3</td>
</tr>
<tr>
<td>type 7 (n=686)</td>
<td>15.9</td>
<td>28.3</td>
<td>4.5</td>
<td>10.3</td>
</tr>
</tbody>
</table>

GIDAS - German In-Depth Accident Study
injury severity head with and without helmet

<table>
<thead>
<tr>
<th>Injury Severity Grade</th>
<th>With Helmet (n=2725)</th>
<th>Without Helmet (n=139)</th>
<th>Reduction of Injury Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIS 0</td>
<td>80.0</td>
<td>72.7</td>
<td>34%</td>
</tr>
<tr>
<td>AIS 1</td>
<td>7.6</td>
<td>11.5</td>
<td>22%</td>
</tr>
<tr>
<td>AIS 2</td>
<td>9.0</td>
<td>11.5</td>
<td>21%</td>
</tr>
<tr>
<td>AIS 3+</td>
<td>3.4</td>
<td>4.3</td>
<td></td>
</tr>
</tbody>
</table>
injured body regions of drivers vs. type of motorcycle

frequencies of injured body regions

- **moped**
  - Up to 125 ccm
    - n=415
    - Frequencies:
      - Head: 16.1%
      - Neck: 9.9%
      - Trunk: 26.7%
      - Arms: 35.5%
      - Hands: 4.9%
      - Legs: 10.1%
      - Feet: 29.3%
      - Total: 73.5%
  - > 125 ccm
    - n=1415
    - Frequencies:
      - Head: 19.9%
      - Neck: 9.8%
      - Trunk: 9.4%
      - Arms: 12.3%
      - Hands: 12.3%
      - Legs: 22.9%
      - Feet: 8.6%
      - Total: 67.2%

- **moped 25**
  - n=91
  - Frequencies:
    - Head: 44.0%
    - Neck: 53.8%
    - Trunk: 44.1%
    - Arms: 47.3%
    - Hands: 53.8%
    - Legs: 53.8%
    - Feet: 53.8%
    - Total: 53.8%

- **n=943**
  - Frequencies:
    - Head: 33.0%
    - Neck: 5.5%
    - Trunk: 21.5%
    - Arms: 22.9%
    - Hands: 47.5%
    - Legs: 72.0%
    - Feet: 72.0%
    - Total: 72.0%
### Frequencies of Injured Body Regions

<table>
<thead>
<tr>
<th></th>
<th>With Protective Clothing</th>
<th>Without Protective Clothing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AIS 1</td>
<td>AIS 2</td>
</tr>
<tr>
<td>Head</td>
<td>37.6%</td>
<td>46.4%</td>
</tr>
<tr>
<td>Neck</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thorax</td>
<td>58.6%</td>
<td>24.7%</td>
</tr>
<tr>
<td>Upper Ext. Total</td>
<td>75.8%</td>
<td>20.9%</td>
</tr>
<tr>
<td>Upper Arm</td>
<td>47.8%</td>
<td>42.0%</td>
</tr>
<tr>
<td>Elbow</td>
<td>99.4%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Lower Arm</td>
<td>42.9%</td>
<td>49.3%</td>
</tr>
<tr>
<td>Hand, Joint</td>
<td>87.9%</td>
<td>12.1%</td>
</tr>
<tr>
<td>Abdomen</td>
<td>55.8%</td>
<td>25.0%</td>
</tr>
<tr>
<td>Pelvis</td>
<td>75.3%</td>
<td>16.7%</td>
</tr>
<tr>
<td>Lower Ext. Total</td>
<td>70.8%</td>
<td>16.8%</td>
</tr>
<tr>
<td>Upper Leg</td>
<td>41.5%</td>
<td>6.5%</td>
</tr>
<tr>
<td>Knee</td>
<td>86.2%</td>
<td>13.4%</td>
</tr>
<tr>
<td>Lower Leg</td>
<td>59.9%</td>
<td>29.7%</td>
</tr>
<tr>
<td>Foot, Ankle Joint</td>
<td>69.9%</td>
<td>27.8%</td>
</tr>
</tbody>
</table>

### Injured Body Regions Only

- 100%
trend of injury severity grades of all motorcyclists

- 1985-1993 (n=655)
- 1994-2002 (n=866)
- 2003-2011 (n=1196)

MAIS 0: 8.1%
MAIS 1: 44.6%
MAIS 2: 26.1%
MAIS 3+: 21.2%

MAIS 1: 54.3%
MAIS 2: 26.1%
MAIS 3+: 14.8%

MAIS 1: 64.0%
MAIS 2: 23.1%
MAIS 3+: 8.4%
injury severity grades of motorcyclists (cycle > 125 cm³)

- MAIS 0:
  - 1985-1993: 9.4%
  - 1994-2002: 5.6%
  - 2003-2011: 4.7%

- MAIS 1:
  - 1985-1993: 42.1%
  - 1994-2002: 50.7%
  - 2003-2011: 58.2%

- MAIS 2:
  - 1985-1993: 26.9%
  - 1994-2002: 26.9%
  - 2003-2011: 23.9%

- MAIS 3+:
  - 1985-1993: 21.6%
  - 1994-2002: 16.8%
  - 2003-2011: 13.1%

Note: MAIS stands for Maximum Abbreviated Injury Scale.
GIDAS 1999-2011
n=24,013

Used for active safety analysis

Hannover 2008-2012
n=4,798

cases
n=4,314
participants
n=8,324

cars n=4,939
motorcycles n=629

motorcyclist
n=5,114

excluded
STATUS
not complete n= 444
no reconstruction n= 40

participation
truck n= 504
goat, tram n= 116
bicycle n= 1,598
pedestrian n= 512
others n= 26

driver
no cyclist, quad n= 454

car n= 4,569
motorcycle < 125 cm³ n=260
motorcycle > 125 cm³ n=285

active safety
Quotient of „causers of accidents“ and „all accident participants“ for different types of age groups

- All road users (n=503590)
- Riders of powered two-wheelers (n=24039)

Driver’s Age [years]
Distribution of accident causation groups
Comparing passenger cars with light and heavy motorized two-wheelers

- Car (n=3012)
- Motorcycle <125ccm (n=179)
- Motorcycle >125ccm (n=193)

Human: 97.7%
Machine: 91.1%
Environment: 19.6%
Composition of ACAS-code exemplarily for Group 1 (human factors)
Distribution of human causation categories
Comparing passenger cars with light and heavy motorized two-wheelers

- Car (n=2942)
- Motorcycle <125ccm (n=163)
- Motorcycle >125ccm (n=177)

Information access
Information admission
Information evaluation
Planning
Operation

GIDAS Hannover 2008-2012
Verteilung der bewussten Regelverstöße bei mot. Zw. > 125 ccm

<table>
<thead>
<tr>
<th>Beschreibung des Einflussfaktors</th>
<th>ACAS-Code</th>
<th>Häufigkeit</th>
<th>%-Anteil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Überhöhte Geschwindigkeit</td>
<td>14022</td>
<td>34</td>
<td>68%</td>
</tr>
<tr>
<td>Falsches Überholen</td>
<td>14023</td>
<td>10</td>
<td>20%</td>
</tr>
<tr>
<td>Falsches Abbiegen</td>
<td>14024</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Abstandsunterschreitung</td>
<td>14025</td>
<td>2</td>
<td>4%</td>
</tr>
<tr>
<td>Regelwidrige Benutzung des Verkehrsweges</td>
<td>14027</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Andere</td>
<td>14028</td>
<td>2</td>
<td>4%</td>
</tr>
</tbody>
</table>

Beispiel Überhöhte Geschwindigkeit (14022) (30110683)

**Motorrad:** Suzuki GSX-R750  
**Fahrer:** Männl., 29 Jahre, Schwerverletzt MAIS 3

Der Motorradfahrer befuhr die Straße "Hermann-Ehlers-Allee" mit hoher Geschwindigkeit. Er wollte bremsen, da die LZA auf Rot stand, dabei verlor er die Kontrolle über sein Krad und rutschte gegen die LZA und verletzte sich schwer.
Injury severity distribution for different categories of human causation factors of PTW riders

<table>
<thead>
<tr>
<th>Category</th>
<th>MAIS 3+</th>
<th>MAIS 2</th>
<th>MAIS 1</th>
<th>MAIS 0</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No causation factor (n=173)</td>
<td>43.7%</td>
<td>56.3%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Information access (n=22)</td>
<td>5.9%</td>
<td>44.1%</td>
<td>47.8%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Information admission (n=72)</td>
<td>3.5%</td>
<td>19.4%</td>
<td>36.2%</td>
<td>40.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Information evaluation (n=107)</td>
<td>11.2%</td>
<td>56.1%</td>
<td>31.7%</td>
<td>1.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Planning (n=111)</td>
<td>8.1%</td>
<td>54.9%</td>
<td>36.9%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Operation (n=69)</td>
<td>14.7%</td>
<td>59.4%</td>
<td>25.8%</td>
<td>0.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

- MAIS: Modifikationsäquivalenter Index Score
Injury severity distribution for different categories of human causation factors for riders of motorcycles (>=125 ccm)
Conclusions

- Motorcyclists highly protected
- MAIS 1 of 60 to 65%
- Wearing helmets motorcyclists only 19.9% suffered head injuries.
- Effectiveness of the helmet confirmed
- Reduction of head injuries AIS 1 to minus 34% and AIS 2 to minus 22% and severe head injuries AIS 3+ to minus 21%.
Conclusions

• Severe injuries AIS 3+ are particularly often in association with a high risk of bone injuries of the cervical spine and the lower extremities.

useful solution

• usage of protective clothing with protectors
• use of padded machines
• development of special leg protectors (Otte, 2002)
• reduction of severely injured motorcyclists of nearly 50% over the time period of more than 20 years

Accidents caused by a failure of information admission (e.g. the rider misses to see a relevant road user due to a wrong focus of attention) of the rider of a PTW resulted in visibly higher shares of MAIS 2 had MAIS 3+ injuries than failures from the other categories
• failures in the Information evaluation related to a misjudgment of the behavior or speed of the own vehicle (in about 20% of the cases).

• PTW have a high incidence of accident causes from the subcategory of intentional breach of rules.

• riders of motorcycles (≥ 125 ccm) have an incidence of over 40% from the subcategory which is mostly related to excessive driving speed.

• Another source of accident causes which is specifically high with PTW (23.3% for light motorcycles, 17.5% for motorcycles but only 7.2% for cars) is the handling failures, in wrong braking or over braking
Parameter analysis
Influence on injury severity AIS

<table>
<thead>
<tr>
<th>Effect</th>
<th>DF</th>
<th>Wald Chi-Square</th>
<th>Pr &gt; ChiSq</th>
</tr>
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Improvements

• Speed reduction helps avoidance of accidents and reduction of injury severity!
• Earlier Information of oncoming conflict-situation helps for avoidance strategies
• High safety standard is given for motorcyclists
• The acceptance of safety measures is not so much existing for others PTW
• Helmet is shown high effectiveness, if using the integral helmet design
• Protective clothes gives effectiveness against soft tissue injuries, higher using rate should be realized
• motorcycle drivers should be better educated and trained
• More attention for driving assistance especially for older drivers
• Information on special behavior of PTW as education of other traffic participants i.e. car-truck-drivers
• Thank you very much for your attention