# THE ROLE OF IN-DEPTH MOTORCYCLE ACCIDENT STUDIES IN THE REDUCTION OF ACCIDENT TRAUMA

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## ABSTRACT

This paper examines the real and potential contribution of in-depth motorcycle accident investigation studies to the reduction of motorcycle accident trauma.

Firstly, this paper will describe the results of a 5-year in-depth accident investigation study of 100 serious and 197 fatal motorcycle accidents in and around Birmingham, England. The paper includes a description of the accident investigation procedures and presentation of selected accident and injury data. Specific emphasis is given to the performance, or potential of protective devices.

Secondly, the usefulness of such in-depth accident data in the evaluation of existing protective devices and the identification of other counter-measures including injury prevention programmes is considered.

The paper includes commentaries on such associated matters as the feasibility of comparing the results from different accident samples and the level of effort involved in in-depth accident studies.

Finally, specific recommendations are made regarding the most fruitful direction for future motorcycle accident research.

## INTRODUCTION

Road traffic accidents result in immeasurable pain and suffering and inordinately high financial costs. Accident studies are undertaken to learn more about these costly and injury producing events. Accident data is seen as the key to isolating problem areas and to identifying or evaluating ways to prevent the accident or to eliminate their injury-producing consequences.

Fundamental to the development of an appropriate injury prevention measure is an understanding of the nature of the problem; who is involved, how, in what circumstances and with what consequences. The characteristics of the population to be protected needs to be defined, for example, their age, sex, size, whether rider or passenger. The circumstances surrounding the injury event must be ascertained; the type of collision, the crash configuration, the nature of the striking or impacting object, the severity of the crash event. The frequency and precise nature of injuries sustained by the different body regions must be identified.

Any countermeasure or protective system must not only be technically feasible, it must be acceptable to the consumer, the manufacturer and the legislator or the politician. The protective system must be cost effective, in terms of savings through injury reduction. The money spent in the development and implementation of the protective system must also stay within "acceptable" manufacturing and consumer budgets.

The solution cannot be developed in isolation. It may be developed to address a specific problem, but ultimately it will be used in a variety of crash configurations. A solution or countermeasure which accommodates the scatter of human responses in real accidents and the influence of other conditions will inevitably be a compromise. The aim must be to achieve the best balance of all these variables to provide optimal protection.

It is obviously important to ensure that the protective system works before living humans depend on it. To this end, there are design rules and performance test procedures to determine whether or not the countermeasure provides the prescribed level of protection.

Design rules specify the physical properties or geometry of certain components of vehicle structures and protective devices. They often depend on subjective interpretation, and typically fail to consider the performance of components in crash circumstances.

In contrast, performance tests examine the behaviour of protective systems or other vehicle structures in crash loading conditions. Unlike design rules, the performance tests are not design restrictive, and theoretically encourage more realistic solutions for optimal crash protection. Performance tests examine the behaviours of specific components in isolation or the entire safety system.

Motorcycle safety can also be assessed by measuring the performance of an anthropometric dummy during a specific crash event. Such a global approach seems a good means of evaluating the performance of protective systems in the real world. It presupposes, however, that the input crash conditions, the dummies and recording devices, are capable of simulating and measuring human responses in real accidents. It further assumes that the correct injury tolerance levels have been specified.

Standards describing evaluation test procedures may be mandated via formal laws to exert some control over the development and implementation of protective systems and other vehicle structures.

The ultimate test of any protective system must be the ability to prevent or reduce injuries in a range of collision conditions. This requires very detailed and critical examination of the performance of protective systems in actual accidents. At the same time, the effects of the protective system can be assessed for populations and circumstances other than those for which it was developed originally.

This brief paper examines the real and potential contribution of in-depth motorcycle accident investigation studies to the reduction of motorcycle accident trauma.

One such study was conducted at the University of Birmingham in England. It involved the in-depth study of 100 serious and 197 fatal motorcycle accidents in rural and urban areas around Birmingham.

The primary findings of this study are presented below. The usefulness of such in-depth data in the evaluation of existing protective devices and the identification of other counter-measures is evaluated. Results from different accident studies are also considered.

## THE BIRMINGHAM MOTORCYCLE ACCIDENT STUDIES

### Methodology

During 1977-1982, an in-depth study of fatal and serious motorcycle accidents was undertaken at the Accident Research Unit of the University of Birmingham. The broad aims of the research were to characterize motorcycle accidents specifically in terms of the injuries sustained by the riders, the protection afforded by current helmet designs and the potential of other protective devices.

Accident investigation was initiated one to two days after the accident. The collection of data included a visit to the accident scene, examination of the involved vehicles, extrapolation of injury data from medical and pathology reports and examination of the helmets. Following the completion of data collection on each accident, the entire accident sequence was reconstructed, primarily to identify the sources of the rider's injuries and the levels of violence associated with identified impacts.

The 197 fatal motorcycle accidents studied in-depth were identified through established police and medical records and a random sample were subsequently selected for in-depth investigation. The accidents involved 205 fatally injured riders and 36 surviving riders. Representing 62% of all motorcycling fatalities in the study area, the in-depth sample was a good representation of all such accidents nationally.

The sample of 100 seriously[1] injured riders was selected from casualties seeking hospital treatment to overcome the known under-reporting of motorcycle accidents to the police. The study area was based on the catchment areas of the Royal Shrewsbury and Selly Oak Hospitals, which respectively serve rural and urban communities.

Hereafter, unless otherwise indicated, it can be assumed that varying totals reflect missing data. Percentages were calculated using known values only.

### Results - Fatal Study

#### The Riders:

In 44 (22%) of the 197 accidents there were passengers. All the motorcycle drivers and 68% of the passengers were male. The majority of riders were younger than 30 years with 50% aged between 17-19 years.

#### The Motorcycles:

A breakdown of the engine size for all "motorcycles" is given in Table 1. Fairings were fitted to 14 (7%) motorcycles. Different configurations of engine and leg "protective" guards were fitted to 46 (24%) of the case vehicles.

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[1] *The definition of serious was adopted from that used in national road accident statistics, viz "An injury for which a person is detained in hospital as an in-patient, or any of the following injuries whether or not he is detained in hospital: fractures, concussion, internal injuries, crushings, severe cuts and lacerations, severe general shock requiring medical treatment, injuries causing death 30 or more days after the accident."*

**Table 1: Engine Size of Motorcycles In Fatal Sample Compared With Motorcycles Licensed Nationally**

| | Sample | | Licensed Motorcycles (in thousands)* | |
|---|---|---|---|---|
| | N | % | N | % |
| Moped | 18 | | | |
| < 50 cc | 6 | 12 | 458 | 38 |
| 51 - 150 | 18 | 9 | 336 | 28 |
| 151 - 200 | 28 | 14 | 126 | 11 |
| 201 - 250 | 75 | 38 | 136 | 11 |
| 251 - 500 | 22 | 11 | 67 | 6 |
| >500 | 30 | 15 | 71 | 6 |
| TOTAL | 197 | 99 | 1194 | 100 |

*1978 national data

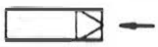
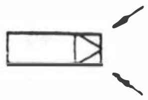
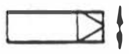
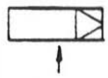
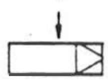
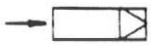
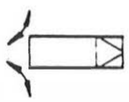
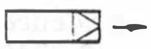
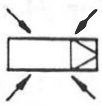
**The Accidents:**

In 108 accidents, the motorcycle struck at least one other vehicle. The motorcycles did not come into contact with any other motorized vehicle in 84 accidents; the so-called "single vehicle accident". In 5 cases it was not established whether another vehicle had been involved in the accidents.

In 90 (84%) of the multiple vehicle accidents, the motorcycles were upright with the riders in position at the time of the impact. The configuration for these accidents are presented in Table 2. Typically the impact with the "other" vehicle was the source of the fatal injuries.

In the 84 single vehicle accidents, impact with a fixed off-road object was the primary source of injury in 75% of the 69 cases for which this information was firmly established. Of the 37 fatalities still on their motorcycles at the time of these impacts, a lamp standard, telephone pole or tree was the main impact for 25 (78%) of these drivers and 4 (80.0%) passengers.

**Table 2: Accident Configuration by Type of Vebicle Struck for Fatal Motorcycle Accidents Where Motorcycle was Upright at Time of Impact**

| Accident Configuration | Type of Vehicle Struck Motorcycle | Car | LGV | HGV | PSV | > 1 Vehicle | Total |
|---|---|---|---|---|---|---|---|
|  | 1 | 14 | 2 | 3 | - | 1 | 21 |
|  | - | 7 | - | - | - | - | 7 |
|  | 2 | 4 | - | 1 | 1 | - | 8 |
|  | 1 | 5 | 1 | 3 | - | - | 10 |
|  | - | 8 | 1 | 1 | - | - | 10 |
|  | - | 2 | 4 | 10 | - | 1 | 17 |
|  | - | 1 | 1 | - | 1 | 2 | 5 |
|  | - | - | - | 1 | - | - | 1 |
|  | - | 9 | 2 | - | - | - | 11 |
| TOTAL | 4 | 50 | 11 | 19 | 2 | 4 | 90 |

**The Injuries:**

Of the fatalities, 146 (72%) died instantaneously or shortly after the accident. A further 18 (9%) died within 6 hours of their accidents. There were 10 riders who were run over. These riders are excluded from the following analyses.

**Table 3: Body Region of Fatalities With Highest or Equal Highest AIS**

| | AIS | | | | | |
|---|---|---|---|---|---|---|
| Body Region | 3 | 4 | 5 | 6 | N | % Drivers |
| Head | 1 | 5 | 85 (19) * | 17 (2) | 108 (21) | 46 |
| Face | 1 | 0 | 0 | 0 | 1 | 0 |
| Neck | 0 | 1 | 3 | 10 (1) | 14 (1) | 6 |
| Upper Limbs | 0 | 0 (1) | 0 | 0 | 0 (1) | 0 |
| Chest | 1 | 5 | 44 (5) | 10 | 60 (5) | 25 |
| Thoracic Spine | 0 | 0 | 1 | 0 | 1 | 0 |
| Abdomen | 1 | 1 | 44 (4) | 0 | 46 (4) | 19 |
| Pelvis | 3 | 0 | 0 | 0 | 3 | 1 |
| Lower Limbs | 3 | 1 (1) | 0 | 0 | 4 (1) | 2 |
| Total | 10 | 13 (2) | 177 (28) | 37 (3) | 237 (33) | 99 |

* Passenger data in parenthesis

Only 4 riders were not wearing helmets, even so there was a high incidence of severe head injuries. Head injuries rated as AIS >=4 were reported for 142 (74%) of the fatalities. There was a high incidence of basal skull fracture, observed for 84 of the 100 casualties with skeletal head injury AIS >2.

A fracture and/or dislocation of the cervical spine was observed in 23 (11.9%) cases. There was no indication that neck injuries were related to the presence or design of the helmet. The true incidence of cervical spine injuries may have been higher as in cases of instantaneous death, the cervical spine is typically only examined externally.

After head injuries, injuries to the chest and abdomen predominated. The outstanding feature of the chest injuries is the high incidence of severe internal injuries without any skeletal chest injuries. This was true for 65 (51%) of the internal chest injuries rated higher than AIS 2.

There were 100 (52%) riders who suffered abdominal injuries rated AIS >2. There were 12 drivers and 2 passengers who sustained one or more pelvic fractures. Impacts with the riders' own machine were isolated as the primary causes of abdominal injuries in only

3 cases. However, the contribution of the motorcycle itself to abdominal and pelvic injuries is probably higher. For example, five fatalities who suffered pelvic fractures were "in-position" motorcycle drivers involved in frontal collisions. A paucity of detailed information on soft tissue injuries sustained by this group of fatalities prevented more conclusive comments.

There were 66 (34%) cases of lower limb fractures; resultant fat embolism causing the deaths of 4 of these riders.

**Protective Systems:**

It was established that 67 of the 201 helmeted riders who were fatally injured lost their helmets during the accidents. This represents 43% of those cases for which the post-accident helmet status was firmly established. In 29 cases, helmet loss was attributed to thermoplastic shell fracture or retention system overload. In 4 cases the rider had failed to secure the retention straps correctly. The reasons for loss of the remaining 33 helmets were not immediately apparent, however, there must always be some doubt as to the fit and security of the helmet prior to the accident.

It was obvious in many cases the loads applied to the helmets were greater than that which any structure of limited thickness could be expected to reduce to a tolerable level. There were no reported head injuries for 26 (30%) of the riders whose helmets were known to have stayed on. Full examination of 15 of their helmets showed at least 11 of the riders had sustained a direct head impact, confirming the potential effectiveness of helmets.

**Results - Serious Injury Study**

In terms of rider and accident epidemiology, the in-depth serious sample is a good representation of all riders seriously injured in the study area. During the study period of 19 months, there were 573 such riders. This total "population" was identified through both hospital and police records. Selected from known hospital admissions only, the in-depth sample reflects the more seriously injured riders in comparison to the total "population".

**The Riders:**

The in-depth sample of 100 seriously injured riders were injured in 96 accidents. As in the fatal sample, young solitary male drivers predominated. Of the 100 seriously injured riders, 92 were operating the motorcycle. There were 6 seriously injured female casualties, 4 of whom were operating the motorcycle.

**The Motorcycles:**

A breakdown of the size of the motorcycles in the serious sample compared to national license data is given in Table 4.

**Table 4: Engine Size of Motorcycles In Serious Sample Compared to National License Data**

| | Sample | | Licensed Motorcycles (in thousands)* | |
|---|---|---|---|---|
| | N | % | N | % |
| Moped | 8 | | | |
| < 50 cc | 1 | 10 | 472 | 35 |
| 51 - 150 | 24 | 26 | 402 | 29 |
| 151 - 200 | 14 | 15 | 131 | 10 |
| 201 - 250 | 27 | 29 | 187 | 14 |
| 251 - 500 | 6 | 6 | 81 | 6 |
| >500 | 14 | 15 | 98 | 7 |
| TOTAL | 94 | 101 | 1371 | 101 |

*1981 national data

**The Accidents:**

There were 60 (63%) multiple vehicle accidents and 36 (38%) single vehicle accidents. The motorcycle was essentially upright with the riders in position in 51 (85.0%) of the multiple vehicle accidents. The on-impact vehicle configurations for these accidents is given in Table 5.

The road was identified as the primary injury-producing impact in 17 (47%) of the single vehicle accident cases. In 8 (22%) accidents, the riders were still astride their machines at the time of the primary impact. In 7 of these cases the impact was with an off-road object.

**The Injuries:**

The ISS was calculated for all casualties; 51% were rated with an ISS >5. An ISS > =9 was calculated for 61% of riders injured in multiple vehicle accidents compared to 33% for riders in single vehicle accidents.

There were 23 casualties who received outpatient treatment only. Of the 77 inpatients, 41 (53%) were retained in hospital for 1 week or more. Of the casualties with a highest AIS < =2, 73% were discharged from inpatient care within 1 week. In comparison, only 23% of casualties with highest AIS >2 had been discharged from inpatient care within 1 week.

Injuries to the legs, arms and head predominate. A compilation of the highest AIS for individual body area is given in Table 6.

**Table 5: Accident Configuration for Serious Multiple Vehicle Accidents Where Motorcycle Upright at Time of Accident**

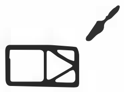
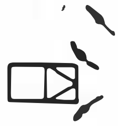
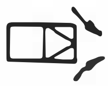
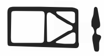
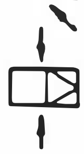
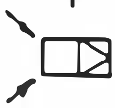
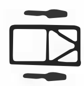
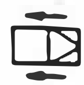
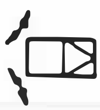
| Accident Configuration | Car | Other Vehicle | Total |
|---|---|---|---|
|  | 5 | 0 | 5 |
|  | 2 | 0 | 2 |
|  | 3 | 1 | 4 |
|  | 1 | 1 | 2 |
|  | 5 | 2 | 7 |
|  | 5 | 0 | 5 |
|  | 3 | 0 | 3 |
|  | 6 | 1 | 7 |
|  | 1 | 0 | 1 |
|  | 3 | 3 | 6 |
|  | 6 | 1 | 7 |
|  | 1 | 1 | 2 |
| TOTAL | 41 | 10 | 51 |

**Table 6: Body Regions of Seriously Injured Riders With Highest or Equal Highest AIS**

| | AIS | | | | | | |
|---|---|---|---|---|---|---|---|
| Body Region | 1 | 2 | 3 | 4 | 5 | N | % Drivers |
| Head | 1 | 19 (2) * | 1 | 1 (1) | 1 | 23 (3) | 20 |
| Face | 1 | 3 | 0 | 0 | 0 | 4 | 4 |
| Neck | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| Upper Limbs | 2 (1) | 16 (1) | 10 | 0 | 0 | 28 (2) | 25 |
| Chest | 0 | 0 | 3 | 1 | 0 | 4 | 4 |
| Abdomen | 0 (1) | 1 | 2 | 1 | 0 | 4 (1) | 4 |
| Pelvis | 0 | 2 | 0 | 0 | 0 | 2 | 2 |
| Lower Limbs | 1 | 21 (1) | 26 (2) | 0 | 0 | 48 (3) | 42 |
| TOTAL | 5 (2) | 63 (4) | 42 (2) | 3 (1) | 1 | 114 (9) | 102 |

* Passenger data in parenthesis

**Implications of the Accident Findings**

The Birmingham field accident data highlighted areas for further injury reduction, for example:

The pattern and severity of injuries differ markedly between fatalities and seriously motorcyclists.

The fatalities typically sustained fatal injuries to more than one body region. Fatal head injuries predominated. The chest and abdomen were the next two most frequently injured body regions. In comparison, the seriously injured casualties typically sustained a serious injury to only one body region, most frequently serious injuries associated with long-term disability.

It is likely that the use of fatal accident statistics will underestimate the real effectiveness of the systems designed to protect specific body regions. Similarly, the potential for the prevention of fatal injuries in motorcycle accidents is relatively small compared to non-fatal accidents.

The Birmingham accident data highlighted some shortcomings of existing helmets which, through links with standards and legislative bodies, led to improved helmet designs. Even so, fatal impacts are often beyond the protective capabilities of current helmet design.

Significant neck injuries are not a feature of helmeted survivors or deaths.

## DISCUSSION

### Police Records:

In most non-fatal accidents, the information collected on police records is of limited detail. Typically police records describe only the overall circumstances of the crash, the accident location and provide brief descriptive data on the accident victims and their injuries.

There are two other shortcomings of police data. Firstly, accident data based on police reports significantly underestimate the true incidence of injury-producing accidents. Secondly, the usefulness of police accident data may be restricted by the validity of the data which depends heavily on road user and witness statements.

### Hospital Records:

Hospital data provide a better basis for identifying the true incidence of injury-producing accidents. Regrettably, however, the circumstances of the accident and identification of the type of road user is neither routinely nor reliably recorded. Another problem is the lack of well-defined levels of injury severity, although the Abbreviated Injury Scale was developed in recognition of this need.

The application of the AIS using existing records is often hampered by poorly documented injuries. The precise nature and location of injuries to different body regions is often elusive. In more serious accidents, lesser injuries may not even be reported.

### Coroners' Records:

Detailed and highly reliable accident data is typically collected on all fatal accidents through the efforts of special police accident investigation teams. Their findings together with autopsy results are available through coroners' records. A post-mortem is conducted on all fatal accident victims, however, the level of injury detail varies considerably.

### Limitations of Existing Records:

In summary, existing accident records do provide basic data on motorcycle accidents involving hospitalized casualties and police reported accidents.

The representativeness of these samples is not, however, clearly defined. Available data bases do not include all accidents. Accidents not reported to the police or involving casualties who do not seek hospital treatment are overlooked. Priorities identified through existing records may not be true for all accidents.

The contribution of existing accident records is further limited by the meagre and unreliable nature of the data collected.

This limitation extends to the potential contribution of existing records in other areas, namely trend analysis and the assessment of legislative change. Data from existing records may be confounded by the influence of more than one change in road user characteristics, vehicle type, and/or the traffic environment. The influence of new regulations must be examined through parallel exposure studies. At present the only exposure data routinely recorded and available are the types and numbers of vehicles registered for road use.

**Limitations of In-Depth Studies:**

The primary aims of the Birmingham studies were to determine the collision and injury characteristics of a population of fatal and serious motorcycle accidents; to quantify the contribution of motorcycle mechanical defects; to examine the accident performance of helmets and eye-protectors; and to consider the potential of other protective devices.

If field accident studies are to contribute to the development of optimal crash protection, the data must be reliable and sufficiently detailed to promote a greater understanding of the mechanisms of injuries in real accidents.

Even so, the usefulness of field accident data in the evaluation of proposed protective systems or legislation is finite.

A good example is the contribution of the Birmingham in-depth studies in the evaluation of the draft UK specification for leg protection. The data can be used to examine the circumstances in which leg protectors, built to this specification, might be deployed. As such, the potential benefit of the leg protectors on specific types of leg injuries may be assessed. Field accident data cannot, however, be used to determine the influence of the proposed design on the riders' motion. Changes to the overall pattern of the riders' injuries cannot be anticipated. In isolation, field accident data cannot be used to determine what will happen in circumstances outside the design criteria, e.g., when the motorcycle drops during cornering.

It is also true, that at the end of the in-depth studies some of the data was found to be superfluous. Global in-depth studies have traditionally involved the collection of comprehensive data in the inherent belief that it may have some unforeseen future use. In practice, data collected in those areas not directly pertinent to the primary research aims tends to be too generic or incomplete to address other specific safety issues.

## RECOMMENDATIONS FOR FUTURE STUDIES

**Future Use of Existing Records:**

Hospital and police accident records should be compatible and routinely combined for national statistics. The collection and documentation of data internationally should follow a common format. Standardization of accident reporting methods would facilitate the pooling of results for analysis of larger samples and comparisons between different data banks.

The reliability of existing records should be encouraged with reporting agencies collecting only that data which is specific to their expertise, e.g., injury severity should be confined to hospital records. Information on the use of protective equipment should be documented only where there is physical evidence of correct usage.

Input from insurance records should be considered to identify accidents not included in official police or hospital records.

One of the biggest failings of accident studies is the paucity of data on non-injury producing accidents. The contribution of this population to the overall accident/injury pattern is typically overlooked, e.g. the potential effect of new countermeasures on this population is rarely considered. Insurance records may go some way to addressing this shortcoming.

Accident studies based solely on existing records should determine the degree of any under-reporting before identifying specific problem areas or assessing legislative change.

Registration figures with independent exposure data should become part of the official national accident statistics.

**Future Use of In-Depth Studies:**

The ultimate measure of success of any study must be its contribution to the reduction of accident trauma either directly or indirectly through the introduction or revision of appropriate safety regulations.

The immediate contribution of the Birmingham in-depth studies was realized through direct input to the British Standards Institute helmet standard technical committee. The study of helmet performance in real accidents identified shortcomings in current helmet standards and subsequently supported the introduction of appropriate amendments to address these specific problems. Direct and timely input of the field accident data into the standards bodies proved effective.

The introduction of other research findings through regulatory or standards committees was less successful. The problem of poorly abraded and tinted faceshields was only partly addressed at that time by the eye protector standards committee. The need for helmet recall was lost in ill-defined recall procedures.

These examples highlight the need for the agencies supporting the research to facilitate or instrument the early utilization of the accident data to effect necessary regulatory changes.

Detailed data must not only be reliably collected, it must be collected for a precise and recognized reason.

The large scale collection of data which characterizes global in-depth studies is expensive and of relatively limited future value. Concentrated efforts and financial support are more effectively directed into short term target research studies with ongoing and direct input to legislative or safety standard authorities.

The experience and knowledge of past work can be used to guide future work. The studies might well follow the traditional in-depth accident methodology with, however, tighter control on the data collected.

**The Use of Future Accident Data:**

The true potential of field accident data can best be realized by:

1. Use existing records in conjunction with exposure data to identify and prioritize problem areas, and to characterize the target populations.
2. Conduct specific in-depth studies to look at mechanisms and circumstances of injury.
3. Develop potential countermeasures.
4. If countermeasure is a physical device, evaluate the device in crash tests using a realistic dummy, within and outside, the original design/performance criteria.
5. Examine the likely influence of the countermeasure on the user population and exposure trend.
6. Before, during and after the introduction of the device monitor the accident and injury trends through existing records.

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