**PISa**

**Powered Two Wheeler Integrated safety**

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<tbody>
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Executive Summary

This report is the D3 deliverable of the PISa project which is associated with Work package 2: User needs and requirements – Task 2.1.2: Literature review.

In developing an integrated safety system (ISS) for powered two wheelers (PTW) it is important that it is ‘needs-driven’ in terms of:
- What accident scenarios need to be addressed,
- What technologies best meet these needs and
- What rider/driver factors need to be considered in relation to the above two aspects to ensure an optimal solution.

The first point above is addressed in the D2 deliverable report: Powered two wheeler Integrated Safety (PISa): Review of current PTW accident data.

The second and third points are addressed within this document as it contains a discussion of potentially suitable technologies for application to a PTW ISS as well as an overview of the relevant rider/driver factors. More specifically:
- Sections 1-4 provide the background to the PISa project and the context of the literature review.
- Section 5 identifies existing motorcycle technologies which may have a role to play within an ISS and also technologies from four-wheeled vehicles which may be at least conceptually, if not technologically, transferable.
- Section 6 discusses pertinent rider/driver issues such as age, gender, behaviour, vehicle usage, etc. and provides guidance on interface design in terms of cognitive psychology theories and Human-Machine Interface (HMI) standards and best practice.
- Section 7 relates to gender issues associated with the project and reports this in connection with: PTW type, PTW usage, accident involvement, injury severity and trends/forecasts.

For ease in reading the document, each of the above sections is preceded by a summary which together act as sign-posts to key information within the report. The remainder of each of these sections contains the detailed information obtained from various sources which is collated under pertinent headings.

The conclusions section (Section 8) summarises the findings of the technologies and rider/driver issues sections and illustrates how the information may be applied in the context of the PISa project. A tabulated summary of this, for easy reference within future work packages of the project, is provided in Section 9.

The authors would like to acknowledge the contributions provided be the partners of the PISa Consortium.
TABLE OF CONTENTS

1 Introduction 5
   1.1 Background 5
   1.2 Integrated approach 5

2 PISa project 7
   2.1 Project details 7
   2.2 Project aim 7
   2.3 Project structure 7

3 Work package 2 9
   3.1 Work package details 9
   3.2 Work package aim 9
   3.3 Work package structure 10

4 Task 2.1.2 – Literature 12
   4.1 Task details 12
   4.2 Task aim 12
   4.3 Task structure 12
   4.4 Summary of the major studies 12
      4.4.1 APROSYS 13
      4.4.2 MAIDS 14
      4.4.3 SafetyNet 15
      4.4.4 TRACE 15
      4.4.5 Stefan et al 2003 15
      4.4.6 Bayly et al - MONASH University – Intelligent Transport Systems and Motorcycle Safety - 2006 15

5 Technologies 17
   5.1 Summary 17
      5.1.1 Analysis of safety devices currently implemented on PTW’s 17
      5.1.2 Analysis of IS devices currently implemented in other transport forms 18
      5.1.3 Conclusions 19
   5.2 Role of advanced safety features 19
   5.3 Analysis of safety devices currently implemented on PTW’s 19
      5.3.1 Introduction 19
      5.3.2 Crash helmets 20
      5.3.3 Cervical spine brace 24
      5.3.4 Rider clothing 24
      5.3.5 Rider airbag 26
      5.3.6 Motorcycle airbags 27
      5.3.7 Leg protectors 30
      5.3.8 Enclosed PTW – BMW C1 31
      5.3.9 Braking systems 33
      5.3.10 Roll stability 36
      5.3.11 Conspicuity Enhancement 37
      5.3.12 Intelligent Speed Adaptation (ISA) 40
      5.3.13 Adaptive/active Lighting 41
5.3.14 Emergency lighting 42
5.3.15 Vision Enhancement 42
5.3.16 Inter-vehicle communication systems 43
5.3.17 Pedestrian detection systems 45
5.3.18 Curve speed warning 46
5.3.19 Impact sensing cut-off 46
5.3.20 Vehicle diagnostics 46
5.3.21 Alcohol interlock 46

5.4 Analysis of IS devices currently implemented in other transport forms 46
5.4.1 Sensors 47
5.4.2 Warning Systems 51
5.4.3 Driver Assistance Systems 53
5.4.4 Pre-Crash and Crash Devices 59
5.4.5 Cooperative Systems 59
5.4.6 Risk Detection Systems 61

5.5 Prioritisation of safety devices 65
5.5.1 Prioritisation criteria 65
5.5.2 Prioritised list of ITS for motorcycles 66

6 Rider / driver issues 70
6.1 Summary 70
6.1.1 Use of PTWs 70
6.1.2 Age and gender 70
6.1.3 Rider characteristics 71
6.1.4 Use of braking systems 72
6.1.5 Cognitive psychology theories 73
6.1.6 HMI 74
6.1.7 Driver issues – ‘Looked-but-failed-to-see’ 75
6.2 Use of PTW 76
6.2.1 The role of the PTW 76
6.2.2 PTW manoeuvres 76
6.3 Age and gender 77
6.3.1 Age and gender 77
6.3.2 Age only 78
6.4 Rider characteristics 80
6.4.1 Behaviour 80
6.4.2 Motivations and attitudes 84
6.4.3 Experience 87
6.5 Use of braking systems 87
6.5.1 The role of braking in accidents 87
6.5.2 Problems in brake use 87
6.5.3 Need for training 88
6.6 Cognitive psychology theories 89
6.6.1 Functions of Attention 89
6.6.2 Controlled vs Automatic Processing 90
6.6.3 Serial vs Parallel Processing 91
6.6.4 Basic Mechanisms of Timesharing 91
6.6.5 Practical Theories 91
6.7 HMI 93
6.7.1 Guidelines/principles 93
## Gender issues

### Summary

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1.1 Introduction</td>
<td>106</td>
</tr>
<tr>
<td>7.1.2 Rider gender</td>
<td>106</td>
</tr>
<tr>
<td>7.1.3 PTW type</td>
<td>106</td>
</tr>
<tr>
<td>7.1.4 Usage</td>
<td>106</td>
</tr>
<tr>
<td>7.1.5 Accident involvement</td>
<td>106</td>
</tr>
<tr>
<td>7.1.6 Injury severity</td>
<td>107</td>
</tr>
<tr>
<td>7.1.7 Trends and forecasts</td>
<td>107</td>
</tr>
<tr>
<td>7.2 Introduction</td>
<td>107</td>
</tr>
</tbody>
</table>

### References

| 7.4 The Governments Motorcycling Strategy 2005 (UK) | 108 |
| 7.5 Huang & Preston (2004) | 108 |
| 7.6 MAIDS study | 108 |
| 7.7 De Lapparent M (2006) | 109 |
| 7.8 Motorcycle Industry Fact Sheet 2005 | 109 |
| 7.9 Valent et al 2002 | 110 |
| 7.10 Stefan et al 2003 | 110 |

## Conclusions

### Technologies

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1.1 What safety devices are currently implemented on PTW’s and how do they perform?</td>
<td>112</td>
</tr>
<tr>
<td>8.1.2 What IS devices are currently implemented in other transport forms and how do they relate to PISa?</td>
<td>115</td>
</tr>
</tbody>
</table>

### Rider and driver issues

<table>
<thead>
<tr>
<th>Sub-section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.2.1 What are the aspects of PTW use which PIocrates may need to support?</td>
<td>116</td>
</tr>
<tr>
<td>8.2.2 What age and gender of rider need to be accommodated by IS systems?</td>
<td>117</td>
</tr>
<tr>
<td>8.2.3 What aspects of rider behaviour may be pertinent to PIocrates?</td>
<td>117</td>
</tr>
<tr>
<td>8.2.4 What can be learnt from the usability of braking systems?</td>
<td>117</td>
</tr>
<tr>
<td>8.2.5 What guidance is there to assist in IS system design?</td>
<td>118</td>
</tr>
<tr>
<td>8.2.6 Driver issues – ‘Looked-but-failed-to-see’</td>
<td>119</td>
</tr>
</tbody>
</table>

## Summary of D3 findings for future work packages

### References

| 9. | 120 |

| 10 | 128 |
1 Introduction

1.1 Background
Currently, almost 40,000 persons are killed every year on EU roads. About 6,500 of them are drivers and passengers of Powered Two Wheelers (i.e. motorcycles, mopeds). Motorcycle or moped travel carries a risk of death per kilometre travelled 20 times higher than for car travel. PTW accidents now represent a major subject for road safety in Europe. The safety of vulnerable road users, including motorcycle and moped riders, is one of the priorities of the European Community as stated in the White Paper on Transport Policy 2002-2010 and underlined by the Council of Ministers in June 2003.

Developing countries have a much lower level of motorization and the road usage pattern is significantly different from those of developed ones, primarily due to the low income levels. The proportion of PTW's in these countries is extremely high and the traffic usage patterns are very complex. In India, for instance, PTW's account for about 80% of the domestic automotive sales. This means that these countries are exposed to a much higher level of road accident risk. Typically about 39% of the annual 336,000 road traffic deaths in South East Asia are PTW users. India's automotive policy (2002-2010) has given a major thrust to improving the road infrastructure, which is abysmally poor in comparison to growth of traffic. The traffic has been steadily growing at a rate of 7 – 10 % per annum. While this will largely help in decongesting the roads and reducing the probability of accident occurrence, the motor vehicle rules are being continuously improved in enhancing the design of vehicles for safety. In line with these objectives, the Indian government has recommitted itself in promoting research and development activities towards advancement of vehicle designs.

Both mopeds and motorcycles have some special characteristics which directly or indirectly contribute to their relatively high number of accidents. The fact that they are single track vehicles means that the rider has difficulty controlling the vehicle, in particular when cornering or braking, and even more so in emergency situations. A small frontal area contributes to the problems of the perception of mopeds/motorcycles by other road users. The small size of a moped/motorcycle and their low weight in relation to their engine performance provide opportunities to their riders for behaviour which is different from car drivers. The absence of bodywork means that riders of a moped/motorcycle have little or no protection against collision impact. The lack of protection of riders of mopeds and motorcycles can only partly be compensated by wearing a helmet (which reduce the risk of a fatality by half) or other protective clothing.

1.2 Integrated approach
An integrated safety approach, combining accident avoidance and injury prevention technologies, in the field of road vehicle safety is advocated strongly nowadays. However, current research and technology development is mainly focussing on

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1 In the EU-15 member states and about 47.000 per year in EU-25.
passenger cars. There is a clear need for innovative safety systems for PTW’s, integrating preventive, active (i.e. primary) and passive (i.e. secondary) safety aspects, as well as human-machine-interface (HMI) aspects.

PISa will develop and use new technologies to provide integrated safety systems for a range of Powered Two Wheelers, which greatly improve primary safety and can link to secondary safety devices: the systems will be reliable and fail-safe.
2 PISa project

2.1 Project details

The project details are shown in Table 1 below.

<table>
<thead>
<tr>
<th>Proposal full title</th>
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</tr>
</thead>
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<tr>
<td>Proposal Acronym</td>
<td>PISa</td>
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<tr>
<td>Research topic addressed:</td>
<td>Activity code: FP6–2005-Transport-4</td>
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<td></td>
<td>Research domain 4.13: Developing integrated safety systems which are reliable and fault tolerant (preventive, active and passive) taking into account human-machine interface concepts focusing on the system implementation.</td>
</tr>
</tbody>
</table>

2.2 Project aim

The aim of the PISa project is to develop and implement ‘reliable and fail-safe ‘ integrated safety systems for a range of Powered Two Wheelers, which will greatly improve the performance and primary safety (handling and stability) and can link to secondary safety devices. PTW’s are single track vehicles, which means that the rider has a more difficult vehicle to control in relation to a car, in particular when cornering or braking, and even more so in emergency situations. Only a few (high-end) motorcycle brands are fitted with ABS and (partly) combined braking systems. Optimization of the PTW brake performance will reduce the impact speed in case an accident cannot be avoided and this will directly reduce the fatality rate and injury level.

Within the project PTW’s will be fitted with integrated safety systems to demonstrate the potential of such systems to reduce the incidence and severity of up to 50% of PTW accidents. The specification of components of such safety systems will be defined from relevant accident mechanisms and rider assistance functions identified and from identification of existing technologies and safety systems in cars. The systems will take human reaction to information, warning and support systems into account.

The system components include sensors, a PTW state estimator, logic control, warning devices, and advanced/intelligent actuators within brakes and suspensions elements to assist the rider. Specific sensors and actuators will be developed and integrated into an operational safety system for PTW’s to allow for driver warning and assistance and to improve handling and stability, to be innovative and beyond current state-of-the-art. The developed systems will be implemented in PTW’s and evaluated by executing road and track tests and performing simulations. The cost savings in terms of reduction in accidents and injuries will be related to the costs of fitting the integrated safety systems to PTW’s.

2.3 Project structure

The project structure is illustrated in Figure 1 below.
Figure 1: Structure of the PI Sa project
3 Work package 2

3.1 Work package details
The project details are shown in Table 2 below.

<table>
<thead>
<tr>
<th>Work package number</th>
<th>WP 2</th>
</tr>
</thead>
<tbody>
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<td>Work package title</td>
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<tr>
<td>Work package dates</td>
<td>Start: Month 1  Completion: Month 9</td>
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<td>Person months</td>
<td>36.5 PM</td>
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<td>Work package leader</td>
<td>LU VSRC</td>
</tr>
</tbody>
</table>

3.2 Work package aim
The activities proposed in WP2 are planned to make efficient use of existing data and information where it exists and collect some new information where it does not. With this in mind, WP2 will use the analysis outputs from other projects, which have used existing motorcycle accident statistical data. Whilst this is not an ideal situation, the limitations of national accident datasets (with regard to the detail of motorcycle accidents and their causation) means that to undertake further analysis of this data is unlikely to yield the level of detail that is required for this study. These existing analyses will be used to inform, determine and prioritise, at a statistical level, the accident risks, scenarios and causations in which integrated safety systems are considered likely to make a positive contribution to safety. Emphasis will instead be placed on the review of existing on-scene in-depth motorcycle accident datasets, which have been collected with sufficient detail about the accident causes, circumstances and outcomes for this study. From the review of these datasets, cases will be selected for each of the accident scenarios and the cases will be analysed in detail. In addition video footage of the accident sites, rider’s perspectives and road user behaviour at junctions will be analysed. New information about rider’s experiences, expectations and behaviours will be collected and analysed. This body of information will be used both to understand all of the relevant issues and to determine and prioritise the potential for active and integrated safety solutions. The detailed in-depth cases will also be prepared for use by subsequent WP’s for the evaluation of the systems under development. A brief review of state-of-the-art knowledge will identify knowledge, issues and techniques that will inform the process of prioritising the integrated safety solutions and which will be usefully employed in the subsequent development, implementation and evaluation phases of the project.

Once these activities have been undertaken the information can be consolidated and consideration will be given to the situations in which sensor systems are considered likely to make a positive contribution to PTW accident avoidance or injury mitigation. Potential integrated safety solutions/interventions will be identified for each scenario and these will be prioritised in terms of injury severity, frequency and potential for improvement the systems. For those scenarios and systems selected as priorities for further development the rider assistance functions will be determined and the user requirements for these will be derived. Initial consideration will be made of the Human-Machine-Interface (HMI) requirements. Finally, there will be a consolidation of
the findings from all of the tasks and an agreement about which suggestions and recommendations are taken forwards from WP2.

3.3 **Work package structure**

The structure of the work package is illustrated in Figure 2 overleaf.
### WORK PACKAGE 2: USER NEEDS AND REQUIREMENTS

#### 2.1 ACCIDENTOLOGY (L=VSRC)

**2.1.1 Statistics**  
Mon 1-3  D2 Report  
Review existing European databases.

#### 2.2 RELEVANT SCENARIOS (L=LMU)

**2.2.1 In-depth accident cases**  
Mon 1-7  D10 Report  

**2.2.2 Junction video analysis**  
Mon 1-7  D11 Report  
Background factors. Risk assessment issues.

**2.2.3 User interface**  
Mon 1-7  D12 Report  

#### 2.3 DERIVED RIDER ASSISTANCE FUNCTIONS (L=VSRC)

**2.3.1 Matrix of scenario interventions**  
Mon 1-9  D13 Report  
Scenario (severity, frequency, improvement potential) – safety functions – safety solutions/interventions. Pre-crash/crash/post-crash. Cost, viability, etc.

**2.3.2 Scenario prevention priorities**  
Mon 1-9  D14 Report  
Use matrix to provide functions and systems according to benefits.

**2.3.3 Derived driver assistance functions**  
Mon 1-9  D15&16 Report  
For prioritised scenarios, determine rider assistance functions and derive user requirements.

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**Figure 2: Structure of work package 2**
4 Task 2.1.2 – Literature

4.1 Task details
The task details are shown in Table 3 below.

<table>
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<th>2.1.2</th>
</tr>
</thead>
<tbody>
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<tr>
<td>Work package dates</td>
<td>Start: Month 1  Completion: Month 3</td>
</tr>
<tr>
<td>Deliverables</td>
<td>D3 Report</td>
</tr>
</tbody>
</table>

4.2 Task aim
To undertake a review of existing literature relating to both motorcycle safety (accident causation, rider behaviour, rider performance, etc) and active safety developments in other vehicles (specification, HMI issues, evaluation, etc) will be undertaken. This will be to identify knowledge, issues and techniques that may inform the process of prioritising the integrated safety solutions and which may be usefully employed in the subsequent development, implementation and evaluation phases of the project. In addition information about future trends in motorcycling (such as rider age, mileage, motorcycle characteristics, etc) will be identified and considered, as they may have a bearing on the appropriateness of the various possible integrated safety systems and the effect of their introduction in the new PTW models.

4.3 Task structure
The literature relating to accident data is reported within Deliverable 2 to complement the activities of Task 2.1.1. Statistics which are also reported within D2. This report focuses on two elements:

- Technologies – What technologies are available
- Rider issues – What rider factors may interact with the above two aspects – Age, gender, attitudes, experience, etc.

4.4 Summary of the major studies
Whilst the information in the major studies summarised below pertains mainly to Task 2.1.1 Statistics and are reviewed within Deliverable 2, elements of them are relevant to this task and so the summaries have been included for reference. Other studies were referenced in addition to these although it should be noted that whilst there is a substantial body of knowledge regarding motorcycle safety in Western world, there are only a few such studies in Singapore and other rapidly developing economies. Hence whilst this review has attempted to look broadly, and data from developing countries, where available and relevant, has been included; most of the reported data is skewed to Europe, Japan, USA and other developed countries. Quddus et al (2002)
4.4.1 APROSYS

Overview

World-wide, vehicle safety experts agree that significant further reductions in fatalities and injury numbers could be achieved by deploying appropriate passive (or crash) safety strategies. APROSYS is mobilizing and integrating the European scientific & technological expertise for the development of new technologies for the protection of road users in all relevant accident conditions. Its stated aims are:

- To improve passive safety for all European road users in all relevant accident types and accident severities
- To increase the level of competitiveness of the European automotive industry
- To improve efficiency by adopting an Integrated Approach

The objective of SP4 which relates to Motorcycle accidents are given as:

- Identification of the main accident scenarios for motorcyclists
- Injury characterization for motorcyclists in the selected accident scenarios
- Proposal of a new test procedure for rider-infrastructure interaction
- Guidelines to design motorcyclist friendly roadside infrastructure
- Design concepts for innovative motorcyclist protective equipment

APROSYS SP4: Motorcyclists: Accident National Data (Deliverable AP-SP41-0001-C)

The main objective of this deliverable D4.1.1 ‘Motorcyclists: National Accident Data’ is to identify the main accident scenarios involving motorcycles and mopeds, taking into account not only the frequency of the accidents but also the severity. Thus, only fatal and serious accidents are considered in most of the queries presented in the report. A few variables that could be found in all the databases have been selected to distinguish the different accident scenarios.

This report is focused on the analysis of national accident databases using the last accident data available from Germany, Italy, The Netherlands and Spain. Some general figures from each country and a brief analysis of the circumstances of the accidents are presented. Last, the main accident configurations based on a few specific variables are identified for the analysed countries.


This report focuses on PTW to car impacts and wishes to identify the main accident causation parameters, main accident scenarios and PTW user kinematics. The aim is to describe the main parameters so that these can be used to improve PTW user clothing. This report comprises two sections: Literature review and in-depth accident analysis.
4.4.2 MAIDS

In total PTW’s rider casualties in Western Europe declined by 25% from 1980-90, and by another 20% until 1995. However, since then, the trend stopped. When considering the safety issue, the main problem PTW industry has to face is the lack of detailed statistical data on motorcycle accidents. At present European statistical coverage of motorcycle accidents is insufficient and not harmonised, and causation data and analysis of a full range of standardised parameters are lacking. (http://www.acembike.org/html/maids.htm)

Considering the fact that, improved motorcycle accident causation data are required for targeting remedial action by all stakeholders of the PTW transport mode, ACEM undertook the development of a project dealing with in-depth studies of motorcycle accidents. Motorcycle Accident in Depth Study (MAIDS) project aims at providing a harmonised system for the accident data collection and analysis at European level. (http://www.acembike.org/html/maids.htm)

In order to better understand the nature and causes of PTW accidents, the Association of European Motorcycle Manufacturers (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 Organisation for Economic Co-operation and Development (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. (ACEM – MAIDS 2004).

A total of 921 accidents were investigated in detail, resulting in approximately 2000 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. (ACEM – MAIDS 2004).

To provide comparative information on riders and PTW’s that were not involved in accidents in the same sample areas, data was collected in a further 923 cases. The collection technique was specifically developed to meet the circumstances of this study and is commonly referred to as an exposure or case-control study. This exposure information on non-accident involved PTW riders was essential for establishing the significance of the data collected from the accident cases and the identification of potential risk factors in PTW accidents. For example, if 20% of non-accident involved PTW’s in the sampling area were red, it would be significant if 60% of those PTW’s involved in an accident were reported to be red, suggesting that there is an increased risk of riding a red PTW. On the other hand, if none of the PTW’s in the accident sample were red, it would be an interesting finding, needing further study. (ACEM – MAIDS 2004).

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4 “MAIDS references are quoted with the permission of ACEM. Avenue de la Joyeuse Entrée B - 1040 Brussels. tel. + 32 (2) 230 97 32. acembike@acembike.org”
4.4.3 SafetyNet

In 2001 the European Commission adopted a target of reducing (road) fatalities by 50% within a decade and identified several areas where it could make a direct contribution within the constraints of subsidiarity. The target was reaffirmed in 2003 in the Road Safety Action Programme that provided further detail about actions it planned to introduce. A key element in the Programme concerned the development of a new European Road Safety Observatory to gather data and knowledge to inform future safety policies. The development of the Observatory was to be undertaken by the Sixth Framework funded project “SafetyNet”.

(http://www.erso.eu/safetynet/fixed/SafetyNet%20paper%20for%20PRI%20conference%202006.pdf)

The Observatory will support all aspects of road and vehicle safety policy development at European and national levels. It will make new proposals for common European approaches in several areas including exposure data and Safety Performance Indicators. It will extend the CARE database to incorporate the new EU Member States and will develop new fatal and in-depth accident causation databases. It will also develop new statistical methods that can be used to analyse combined macroscopic and other data.

(http://www.erso.eu/safetynet/content/safetynet.htm)

4.4.4 TRACE

The TRACE project, which comprises the two themes of Integrated Safety and eSafety, stresses that the development of Intelligent Transport Systems in vehicles or on roads (and especially in the safety field) must be preceded and accompanied by a scientific accident analysis encompassing two main issues:

- The identification and the assessment among the possible technology-based safety functions of the most promising solutions (in terms of lives saved and accidents avoided) that can assist the driver or any other road users in a normal road situation or in an emergency situation or, as a last resort, mitigate the violence of crashes and protect vehicle occupants, pedestrians, and two-wheelers in the case of a crash or rollover.

- The determination and the continuous up-dating of the aetiology, (i.e. the causes of road accidents and injuries) and the assessment of whether the existing technologies or those under development actually address road users' real needs, as inferred from accident and driver behaviour analyses.

http://www.trace-project.org/trace_template.html

4.4.5 Stefan et al 2003

Stefan et al (2003) looked at the road safety of PTW's to assess the applicability of the CARE-Database in comparative accident research across Europe. The CARE-Database uses data from 14 European accident databases: Austrian, Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden and the UK but for more detailed analysis the IRTAD database was used. This does not have German or Irish data so these countries were excluded from further analysis. The analysis does not distinguish between types of PTW. The data used in the study was from 1991-2001.

4.4.6 Bayly et al - MONASH University – Intelligent Transport Systems and Motorcycle Safety - 2006

The aim of the study was to identify existing and emerging Intelligent Transport Systems (ITS) that have the potential to enhance motorcycle rider safety. The study comprised a
literature review and expert consultations which indicated that there are very few commercially available ITS specifically for motorcycles, although there are existing and emerging technologies in other vehicle applications that are of relevance to motorcycle safety. All the technologies identified were ranked according to their theorised improvement to motorcycle safety.
5 Technologies

5.1 Summary
The aim of the review is to identify technologies which may have a role to play in an integrated safety system for motorcyclists in the future. The review is split into two sections:
- Analysis of safety devices currently implemented on PTW’s
- Analysis of IS devices currently implemented in other transport forms

5.1.1 Analysis of safety devices currently implemented on PTW’s
The review first discusses motorcycle-focused safety systems which are either currently employed, realised on concept vehicles or the subject of research and which have the potential to be used within an integrated safety system. This covers:

Crash helmets
Protection – Discusses research relating to the safety performance of crash helmets and identifies areas for improvement.
Advanced technologies – Discusses additional, non-protective functions for crash helmets including head-up displays and rear-view cameras.

Cervical spine brace
This section discusses the recent developments in cervical spine protection.

Rider clothing
This section covers the role of conventional protective clothing in injury mitigation and discusses the recent safety advancement of inflating jackets.

Airbags
This section covers the development of motorcycle airbags discussing their areas of application and benefits.

Leg protectors
This section discusses the role of leg protectors, their design, research into their benefits and recommendations for future developments.

Enclosed PTW – BMW C1
This section discusses the addition of an aluminium space frame forming an integral safety cell, seat-belts and a crumple zone to a PTW and outlines the claims and investigations into the potential safety benefits of these additions.

Braking systems
This section discusses the complexity of braking, the different systems available including Automatic Stability Control and Brake Assist and recommendations for improvements to future designs.

Roll stability
This section discusses a system which alerts the rider when a pre-determined lean angle during cornering has been reached thereby advising them against further lean and possible roll-over.

Conspicuity enhancements
This section discusses the factors which can enhance motorcycle conspicuity and shows examples of their application to motorcycles.

ISA
This section discusses an ISA system developed for motorcycles describing its functioning and the HMI methods used to advise, warn and support the rider.

**Adaptive/active lighting**
This section discusses the development of active lighting systems to accommodate the various angles of inclination and adaptive lighting to accommodate safer transition through bends and curves during night riding.

**Emergency lighting**
This section discusses the Xtreme Beam lighting system which automatically activates a safety strobe when the motorcycle is on its side.

**Vision enhancement**
This section discusses developments in identifying and presenting information to the motorcyclist concerning objects on the road ahead and behind.

**Inter-vehicle communications**
This section discusses technologies available which will permit vehicles to communicate with one another providing each other with information concerning speed, direction, etc. Such information is used for junction navigation, avoidance of an accident scene, etc.

**Pedestrian detection systems**
This section discusses systems used to detect pedestrians whose movements may be in conflict with the course of the PTW.

**Curve speed warning**
This section discusses systems which warn the rider of the presence and nature of an upcoming curve thereby providing assistance in its safer negotiation.

**Impact sensing cut-off**
This section discusses systems which automatically disable fuel and electrical systems in the event of an accident.

**Vehicle diagnostics**
This section discusses vehicle diagnostic systems which monitor and advise the rider of the status of the tyres.

**Alcohol interlock**
This section discusses the functioning of a device to prevent use of the motorcycle while intoxicated.

5.1.2 Analysis of IS devices currently implemented in other transport forms
Following the review of motorcycle-focussed systems, IS devices which are currently found on other forms of transport are discussed. These cover:

**Sensors**
The functioning and application of different sensors is discussed including: vision enhancement, lane detection, collision detection and inner space sensors.

**Warning systems**
Different warning systems and their applications are discussed including: acoustic, visual and force feedback.

**Driver assistance systems**
Driver assistance systems support the driver in a specific function once their intentions have been clearly identified. Such systems include: Anti-Lock Braking, Electronic Stability Control,

**Pre-crash and crash devices**

These systems aim to maximise the passive protection available to drivers and other road users using sensors to optimise settings prior to impact. These systems include: Automatically closing windows, Auto-repositioning seats, Reversible pre-tensioners for seatbelts and Auto-inflatable seat cushions for lateral support.

**Cooperative systems**

Cooperative collision warning systems (CCW) are based on vehicle-to-vehicle wireless communications which provide warnings or situation awareness displays to drivers based on information about the motions of neighbouring vehicles.

**Risk detection systems**

The risk detection device collects the inputs from the sensing devices, identifies the risk factors and elaborates the responses of the other IS devices, using decision algorithms. Such systems cover a range of risk scenarios including: Lane Departure/Avoidance Systems, Collision Avoidance Systems, Road Surface Monitoring Systems, Pre-collision Systems, Driver Vigilance Systems and Pedestrian Protection Systems.

5.1.3 Conclusions

In summary the review shows that in the current state of technological advancement:

- Established technologies still have the potential for improvement e.g. leg protectors,
- New technologies are being successfully introduced e.g. air bags,
- There is the potential for cross-over from car technologies for use in motorcycle applications.

5.2 Role of advanced safety features

- ‘The number of motor cycles range from about 2% of personal vehicle population in the US to above 6% in Germany. The potential ITS safety market that will service to reduce motorcycle incidents has not yet been explored by the ITS community. ITS products to improve motorcycle safety could have a significant market potential, specially for collision avoidance with other vehicles and roll over incidents of motorcycles’. (Thirumalai undated)

5.3 Analysis of safety devices currently implemented on PTW’s

5.3.1 Introduction

- PTW sector is slowly accepting the introduction of innovative safety devices.

- The two main research projects on PTW IS are Japanese, as response to the Advanced Safety Vehicle project proposed by Japanese Ministry of Transport: Honda ASV and Yamaha ASV. These projects are developing several devices, including:
  - Active headlight;
  - Airbag system;
  - Vision enhancement devices;
  - Inter-vehicle communication system;
  - Conspicuity enhancement devices.

which will be discussed below along with other relevant devices
5.3.2 Crash helmets

Protection

- Although crash helmets are effective in reducing accident severity, head injuries are still a prevalent form of serious or fatal injury as demonstrated within Deliverable 2 concerning accident statistics. Therefore improvements to crash helmet safety may form a relevant part of PISa. For instance, Huang and Preston (2004) state that past a critical impact speed to the helmet (13 mph), which is likely to occur in real life accident situations, helmet use reduces the severity of head injuries at the expense of increasing the severity of neck injuries. Therefore future designs may incorporate features which extend protection according to the crash circumstance.

- Within MAIDS it was found that 0=90.4% of PTW's riders wore helmets. Approximately 10% of these came off during the accident due to improper fastening or damage during accident. Generally the helmets were found to be effective in reducing the severity of head injuries (ACEM 2004)

- An unhelmeted motorcyclist is 40% more likely to have a fatal head injury and 15% more likely to incur a disabling head injury than a helmeted motorcyclist (Huang & Preston, 2004)

- Helmets reduce the likelihood of death by 29% for all motorcycle crashes (Huang & Preston, 2004).

- A study by Bachulis et al found that unhelmeted riders were 10 times more likely to require craniotomy (surgical incision through the skull) than their helmeted counterparts (Runge 1997).

- A US study collected prehospital motorcycle crash data from the National Highway Traffic Safety Administration’s General Estimates System database from 1994-2002 relating to 1,854 unhelmeted and 3,474 helmet patients. This was combined with data concerning hospital admission rates for riders and helmet use and hospital discharge data from the National Trauma Data Bank. The study found that compared to helmeted riders, unhelmeted riders were:
  - more often pronounced dead at the scene (8% v 4%)
  - significantly more likely to be transported to hospital (79% v 74%)
  - more likely to be admitted to hospital (40% v 33%)
  - were associated with higher hospitalisation costs ($12,353 v $8,735) (Eastridge et al 2006)

- Based on 197,608 motorcycle crashes/year with 69,163 unhelmeted riders, the differential healthcare economic burden between helmeted and unhelmeted riders is $250,231,724/year (Eastridge et al 2006)

- A study by Coben et al (2007) in the US of comparisons of motorcycle-related hospitalisations across states with differing helmet laws found that motorcyclists in states without universal helmet laws are more likely to die during hospitalisation, sustain severe traumatic brain injury and be discharged to long-term care facilities.

- Based on data from the Fatality Analysis Reporting System (FARS), the National Highway Traffic Safety Administration found that between 1995-2004 crash helmet use varied from 52 to 57%. In 2004, for those fatally injured, non-use was 66% in States without universal helmet laws and 15% in those with (Shankar and Verghese 2006)

- Mandatory crash helmet use in resisted in some US states since it is considered that whilst helmet use may mitigate against injury, it may increase crash involvement if riders are impeded in seeing and hearing traffic. Research into this issue was
commissioned by NHSTA who concluded that there was an overall benefit to helmet use. (NHSTA 1997)

- International studies show that crash helmet use compliance is lowest in southern (European) countries (Stefan et al 2003)

- In Taiwan, legal compulsory helmet wearing was enforced in 1997 leading to a 1/3 reduction in head trauma and a 42% reduction in cranial operations. However injury mortality remains high particularly for those aged 34 years and less (Lin, J et al 2006)

- Within Europe, the COST327 programme stated that head injuries cause some three-quarters of all fatalities to motorcyclists (within Europe), while about one quarter of all injured riders suffer a head injury. COST 327 was formed to investigate in detail, motorcyclists' head and neck injuries and to propose a specification for future testing of motorcycle helmets in Europe. Upon completion of the project, such a specification was developed which, if implemented, is confidently expected will ‘lead to a reduction of 20% of all AIS 5/6 head injury casualties to AIS2-4. In addition it is likely that many AIS 2-4 casualties would be reduced to AIS 1 although it is not possible to quantify this’ (Chinn et al 2001).

- COST 357 (also known as PROHELM), which was established in July 2005 and is due for completion in November 2009, is investigating Accident Prevention Options with Motorcycle Helmets. Whilst previous research confirms the safety benefits of crash helmets, aspects such as minimising distraction due to noise or thermal discomfort, maximising useful visual information, and providing the necessary air exchange have not been addressed. In addition the crash helmet could play a role in optimising the visibility, or conspicuity, of the PTW-rider combination, since it is generally the highest visible point and can be seen from all sides. The focus of the project is therefore to identify how the cognitive abilities of PTW-riders are influenced by the helmet construction, and how the cognitive abilities of other drivers could be influenced. The project covers: cognitive aspects of accidents, Head thermophysiology, CO2 and O2 concentrations, Noise, Helmet ventilation, Vision and Conspicuity. To date, outputs available through the web site cover:
  - CO2 and O2 concentrations in integral motorcycle helmets – This reported on CO2 concentrations when stationary and for speeds of 50 km/h or more.
  - Facial warming and tinted helmet visors - This reported on changes in the heat load on the face as a function of motorcycle helmet visor configuration (normal and tinted). It was found that head load was greatly reduced for moderate tinting levels. The optical transmission properties of the visor configurations largely explain the results. The results suggest that visors optimized for infrared rejection would likely be perceived as an improvement.

- Within the APROSYS (Advanced Protection Systems) project, a sub-theme relates to Motorcycle accidents and one aspect of this covers an analysis of the different injuries that can be sustained by the motorcyclists who have been involved in an accident as well as an investigation into the performance of current protective equipment developed for riders in real accidents. With respect to helmets this sub-topic concludes that ‘All studies agree on the protective effectiveness of helmets, and there are no evidences of negative, collateral effects due to the use of such devices. Most of the head injuries come from impacts on the chin area, sustaining the use of full facial coverage helmet (so-called integral) vs. open face (so-called jet). Neck and spinal injuries are not so common, while helmet ejection (roll-off) appears as being still too frequent, although the retention system improved a lot in the recent years. Reason may be found in incorrect operation of the fastening buckle or wrong choice of the helmet size’. It further states that the ‘Comfort of safety helmets could well be
improved by increasing air-flow inside the liner (ventilation) and in the mean time reducing wind noise (great cause of rider’s fatigue) without endangering signals perception. Special attention should be paid to the sizing system to achieve what could be called a custom-fit liner’ (APROSY D414 2006).

• Further research into helmet design is ongoing e.g Research by Shuaeib et al (2007) into the use of expanded polypropylene (EPP) in achieving multi-impact protection performance as well as improved ventilation.

**Advanced technologies**

• Helmet mounted display – The aim is to provide the rider with relevant information with reduced effort and minimal distraction enabling timely responses to the road situation. A mini projector inside the helmet projects information onto a ‘combiner’ screen focused to 1.2m. The combiner screen overlays the projected information over the real visual scene hence a focal shift opposed to a physical shift is needed to attend to the different information sources - Refer to Figure 3 (Gotoh et al undated). The information which can be displayed covers conventional dashboard display information such as fuel level, speed, etc and can be extended to cover additional vehicle and road status information and warnings (Bayly et al 2006).

![Figure 3: Helmet mounted display (Gotoh et al undated)](http://www.sportvue.com/store/product.php?pid=17)

Commercial systems are available such as Veypor’s Sportvue HUD which was developed for racing use (Bayly et al 2006) – Refer to Figure 4 below.

![Figure 4: Helmet mounted HUD by Veypor](http://www.sportvue.com/store/product.php?pid=17)
It is also feasible for crash helmets to incorporate a rear view camera to capture the road scene behind the rider and project this to the top of visor above the directly viewed forward road scene. Such a system is produced by Reevu – Refer to Figure 5 (Bayly et al 2006).

http://www.reevu.com/what_you_see.asp

**Figure 5: Crash helmet with integrated rear view projection by Reevu**

- Visibility improving helmet – The aim is to improve visibility by reducing fogging during cold and rainy conditions. Two methods have been developed:
  - Peltier element method – A dehumidifying unit using electronic cooling (Peltier) elements is installed on the motorcycle to generate and blow dehumidified air onto the shield thus preventing fogging – Refer to Figure 6.

![Figure 6: Peltier cooling method (Gotoh et al undated)](image)

- Double-shield heater method – Batteries are used to heat the shield which combined with hydrophilic film combine to prevent fogging – Refer to Figure 7.

![Figure 7: Double-shield heater method (Gotoh et al undated)](image)
5.3.3 Cervical spine brace

- BMW in collaboration with KTM has developed a cervical spine protection system which aims to reduce the risk of injury to the neck, cervical spine, spinal cord and collar bone in the event of a serious fall. The prototype, which is made of carbon fibre, damping material and titanium is intended to reduce injuries resulting from: hyperflexion, hyperextension and lateral hyperflexion (overflexion of the head when forced forwards, rearwards and sideways respectively) as well as from axial loading (compression of the spinal column due to the effect of force on the helmet) – Refer to Figure 8.

http://www.gizmag.com/go/4782/

Figure 8: BMW/KTM servical spine protection system

- The Leatt-Brace, a Neck Brace System designed to help prevent potentially devastating motor sport injuries to the cervical spine (neck), which is related to the system described above is being distributed in Australia, New Zealand and the UAE. Production allocations are also being made for distribution in North America, European Union and South Africa. The initial production run is of medium sized neck braces. (Leatt 2006 http://www.pr.com/press-release/24241). The system sells for between US$395-995 (http://www.leatt-brace.com/faq.asp#17)

5.3.4 Rider clothing

- This review shows the role of rider clothing in injury reduction, identifies its weaknesses and reports on recent developments.
- Under European law, ‘protective clothing’ can only be so designated if it provides the levels of protection specified in relevant regulations (de Rome and Stanford undated).
- The MAIDS study reported that 55.7% of PTW rider and passenger injuries were to the upper and lower extremities, the majority being minor in nature. Appropriate clothing was found to reduce such injuries (ACEM 2004)
Within the APROSYS (Advanced Protection Systems) project, a sub-theme relates to Motorcycle accidents and one aspect of this covers an analysis of the different injuries that can be sustained by the motorcyclists who have been involved in an accident as well as an investigation into the performance of current protective equipment developed for riders in real accidents. With respect to clothing the study indicates:

- That consideration of protection, ergonomics and comfort are all pertinent to the evaluation of rider protective clothing.
- That whilst protective clothing cannot guarantee the reduction of injuries in all accident conditions it can be stated that this helps to prevent injuries due to abrasions and lacerations, and reduces the risk of wounds becoming contaminated. A decrease in the severity of sprains and fractures is obtained with the use of protectors (APROSYS D414 2006).

Whilst protective clothing can assist the rider with comfort, fatigue, dehydration and some injury affects – gravel rash, friction, exhaust pipe burns, stripping of skin and muscles, torn or severed ligaments, some broken bones and wound infection, it is likely to offer little benefit in high impact crashes (de Rome and Stanford undated)

A report by the European Experimental Vehicles Committee in 1993 (de Rome and Stanford undated) concluded that protective clothing is less effective in reducing injuries associated with:
- severe bending, crushing and torsional forces to the lower limbs,
- Massive penetrating injuries to any part of the body,
- High energy impacts to chest and abdomen causing injuries through shock waves and severe bending forces

Schuller et al (1986) in de Rome & Stanford (undated) found that the wearing of motorcyclist clothing:
- prevents/reduces 43% of skin and soft tissue injuries
- prevents/reduces 63% of deep and extensive injuries
- reduced permanent physical disability by 40%
- improved the time taken to get back to work/school by 20 days
- reduced hospitalisation times by 7 days.

Otte et al (2002) in de Rome and Stanford (undated) found that the same level of injury was incurred at lower speeds for non-use of protective clothing than those who did use such clothing (80% at <50km/h without protective clothing compared to 80% at <60km/h with protective clothing). This is reflected in leg injuries e.g. 40% versus 29% injury free between 31-50km/h and it was found that high boots offer significant injury protection.

Otte et al (2002) in de Rome and Stanford (undated) also found that impact reduces the occurrence of complex fractures in favour of the more treatable simple, closed fractures.

Research into protective clothing conventionally focuses on selecting/developing materials which balance abrasion and tear resistance against manoeuvrability, temperature control and comfort. In Europe, the traditional (and better performing products) are leather-made however this material is less suitable for warmer climates (de Rome and Stanford undated)

An alternative approach to clothing design is to shield the rider from the impact of a crash by improving energy absorption, bending resistance, penetration ability and crush resistance (de Rome and Stanford undated)
In Australia, twenty years worth of accident data indicates that the most common and serious injuries are to the legs, but legs, feet and hands are less likely to be protected (de Rome and Stanford undated).

### 5.3.5 Rider airbag

- A number of systems have been developed in which the airbag is applied to the rider’s clothing rather than the motorcycle.

- Dainese, a protective sports clothing maker in Vicenza, Italy, employs a different activation method. An electronic computer, powered by a re-chargable battery and mounted on the motorcycle, monitors the bikes physical motion and communicates by wireless radio transmission with a receiver in the D-Air vest processing data up to 3,000 times second. If the computer senses pre-specified pre-collision activities, such as sudden deceleration force about ten times that of gravity, the D-Air vest is automatically remotely activated. Each of the three bladders can inflate in as little as 30 milliseconds and maintains the pressure for 20 seconds to assist in subsequent impacts. The vest design was supported by the $500,000 development of a crash test dummy and costs $800-$1,000.

- The Eggparka (shock-buffer protection jacket) is triggered when a release switch is activated through the separation of components brought about by the rider disengaging from the machine over a predetermined distance. This causes the small carbon dioxide (CO2) gas cylinder (which is hidden inside the jacket) to release gas into the inner liner of the jacket, inflating bladders around the neck, back, and waist within 0.9 second thus adding protection by acting as a “buffer” to absorb the shock of impact – Refer to Figure 9 and Figure 10.

- There are different versions of the product hence its variation in weight from 2.5 – 5 pounds.
  - The P-Type and the O-Type Eggparka are the smallest and lightest using the smallest cartridges (60 cc)
  - The EP-Type is the standard Eggparka, with a full size (100 cc) cartridge.
  - The HP-Type combines one of the lighter vests with the 100 cc cartridge.

(http://www.edgereview.com/ataglance.cfm?Category=Edge&ID=20)

![Figure 9: Activation of the Eggparka system](image)
Figure 10: Inflation of the Eggparka

- A similar system is used by MotoAir, Taiwan, which additionally states that:
  - It uses 30-60cm (12-18 inches) in the joining coiled able to allow dismounting with the device still attached.
  - It takes in the order of 8-12kg (17-26lbs) of force to activate the airbag (so walking away from the bike while plugged in is unlikely to result in activation).
  Refer to Figure 11.


Figure 11: The MotoAir rider airbag

- A comprehensive range of products can be found at http://www.hit-air.com/english/lineup/index.html

5.3.6 Motorcycle airbags

- The APROSYS literature review stated that airbags may be very beneficial in motorcycle accidents but it needs to be ensured that they reduce rider kinematics.

- The role of airbags is to reduce rider injury in frontal collisions by controlling the rider’s trajectory and reducing velocity (Finnis 1990 in Elliott et al 2003)
• Tests in the early 1990s showed that full restraint was not possible above a speed of 30 mile/h, though reducing the rider’s velocity and controlling his trajectory could still be beneficial (Elliott et al 2003)

• In the mid-1990s, research was undertaken by the Transport Research Laboratory (TRL) in the UK into the development and testing of a purpose built motorcycle airbag restraint system whose objective was to protect the rider in approximately head-on impacts to the motorcycle into stationary and moving vehicles. The system was evaluated for a standard motorcycle with a single 50th percentile rider in the normal seating position travelling at 48 km/h head on into the side of a stationary vehicle. Among the findings was that:
  - Bespoke design, optimisation and manufacture of the system against a specific machine was critical to its success. The methods used with the TRL study were: analysis of existing data, computer simulation, system design and construction, static fire tests, sled tests and full scale impact tests.
  - Based on the full-scale impact test results analysed to date, the dummy was successfully arrested by the airbag with a reduction in kinetic energy of between 79% and 100%.
  - The neck results for the dummy were significantly less than the tolerance values representing a major advancement over previous research.
  - Based on full scale impact test data and the motorcycle rough ride and misuse results, it is possible to design a system with a fire time which meets the constraints imposed by total airbag deployment time.
  - Based on cost calculations defined in ISO DIS 13232 as applied to the five pairs of ISO tests in the programme, it was shown that the airbag system reduced these costs by 80%.
  - The system should employ an air bag capacity of 90 litres located in the rear of the fuel tank and a hybrid (gas with chemical charge) inflator.
    (Elliott et al 2003)

• Honda, Yamaha and BMW have studied motorcycle airbag systems. They investigated shape, dimension, displacement and triggering characteristics of the airbag, in order to obtain the best results in impact mitigation.

• BMW has developed ultrasound technology devices to monitor the position of the rider during the impact. In this way it is possible to inflate the airbag in the right moment and in the correct way.

• Research was undertaken by Honda of the effect of airbags within their Gold Wing, large touring motorcycle. It was found that:
  - The airbag was beneficial in four cases, harmful in two cases and had little or no effect in three cases.
  - The main benefits and risks presented by the system were to the head and neck. In both cases the benefits were shown to outweigh the risks, although by a reduced margin for the neck injuries. However due to stiffer flexion and extension of the Hybrid III MATD dummy the benefits may be underestimated.
  - When the injury cost model was applied, it again showed that injury benefits outweighed the risks.
    (Elliott et al 2003)
• Honda has implemented a motorcycle airbag system, refer to Figure 12, constituted by four crash sensors mounted on the front fork legs, an electronic control unit (ECU) and the airbag module for its top class touring motorcycle Gold Wing. The ECU analyses the signals from the crash sensors to determine whether or not to inflate the airbag. Honda airbag in a horizontal section has a V shape in order to protect the rider even if he is not perfectly aligned with the motorcycle.

• Honda airbag is principally designed to mitigate the consequences for the driver when the motorcycle hits the side of a car. In this kind of collision the airbag deploys like a car airbag, except that there is not a retain system for the driver. For this reason Honda airbag is much bigger than a normal car airbag. In different kinds of accident Honda airbag is not supposed to deploy, because its effectiveness has not been demonstrated.

• More detailed information concerning the system's research, development, components and functionality are given at: http://world.honda.com/MotorcycleAirbag/.

Figure 12: Honda motorcycle airbag

• Yamaha in May 2006 presented its third-generation ASV airbag equipped motorcycle – Refer to Figure 13. It incorporates a “back-plate and multi-chamber” airbag system designed to simultaneously hold the lumbar section of the rider in place and mitigate the impact of a collision. This airbag system is designed to retain the driver's lumbar region on the motorcycle in case of frontal impact, to avoid the collision between the driver's head and the other vehicle. But in different accidents this kind of airbag is not useful either, e.g. when the motorcycle falls on one side. In those cases the deployment of the airbag would be even dangerous.
5.3.7 Leg protectors

- Lower limb protectors work by protecting the space occupied by the rider’s legs against intrusion in the event of an accident. Such protection may take the form of a bar, crash bar or other structure such as a fairing. Research concerning leg protectors is summarised below and suggests that there may be benefit from their inclusion within an integrated system.

**Crash bars**

- The strength of such structures is key to their performance, and in the absence of an appropriate standard, many were considered to be inadequately designed (Pegge and Mayse 1980 (in Elliott et al 2003). Studies by Craig et al (1983) who reported on the poor protection offered by crash bars fitted to 21% of patients motorcycles and by Ouellet (1987) who investigated 131 accidents involving crash bars on motorcycles, confirmed the lack of protection offered (referenced in Elliott et al 2003). However Nairn (1993) stated that in approximately 50% of accidents involving serous leg injury, severity could be reduced through the use of leg protection (Huang & Preston 2004).

**Fairings**

- Tests from the mid-1980s onwards on protective fairings, whereby energy-absorbing components are located within the fairing, have shown mixed results. A study by the International Motorcycle Manufacturers Association (IMMA) found that leg protection increased the net risk of head and leg injuries although later design improved on this performance. In 1998, further investigations by IMMA following the ISO13232 specifications pointed to overall disbenefits of leg protection as did a computer analysis of 200 accident configurations reported by Kebschull et al. 1998 (Elliott et al 2003). In 1999, Wang & Sakurai undertook a study into the development and verification of a computer simulation model of motorcycle to vehicle collision dynamics using MADYMO and found that leg protectors fitted to the motorcycle can have harmful consequences to the riders head in some crash configurations. However Otte (1998) in an analysis of 258 motorcycle/car collisions found that injury severity to the legs was reduced in those instances where there was a fairing and that there is little impact on injury levels for the head and thorax (Elliott et al 2003).

- A more recent study by TRL assessed leg protection in accordance with ISO13232. The assessed configurations, representative of high injury levels to the rider’s head and legs, were:
  - motorcycle travelling at 30 mile/h and impacting the front door of a stationary car at 90 degrees
- motorcycle travelling at 30 mile/h and impacting the front wing at zero degrees (offset front)

The results showed that:

- The leg protection device reduced the Head Injury Criteria (HIC) value substantially in all comparative cases (with and without the leg protection) except one where the HIC was very low for both cases.

- Leg injury measures were also reduced when using the leg protection device, except for the 90° side impact configuration where the OPAT dummy with injury indicating legs was used.

- Using the ISO injury cost calculations, there was shown to be an overall reduction by 42% when leg protection devices were employed.

- In addition, neck injury level measures (not within the scope of the ISO cost calculation) were dramatically reduced when leg protection was used.

(Department for Transport Website)

**Design recommendations**

- Design recommendations for leg protection include:
  - Mitigation against the direction of force against the riders leg and the loading of that force (Elliot et al 2003)
  - Coverage of the foot to the front and side (Otte 1994 in Elliott et al 2003)
  - Elimination of compression effects (Otte 1994 in Elliott et al 2003)
  - Frontal protection to the tibia by an energy absorbing element which should not retain the rider to the machine (Otte 1994 in Elliott et al 2003)

**5.3.8 Enclosed PTW – BMW C1**

**Concept**

The BMW C1 aimed to combine the convenience of a PTW with the safety of a car – Refer to Figure 14. It was claimed that in a head-on collision, the protection offered by the C1 was comparable to that of a European compact car and as such the rider did not need to wear a crash helmet (http://en.wikipedia.org/wiki/BMW_C1). Different versions were available including the C1-200 which was classified as a motorcycle under UK law hence requiring a full motorcycle licence to ride, whilst the C1-125 was classified as a scooter and so could be ridden by a car driver after the one-day Compulsory Basic Training (http://www.kevinboone.com/mc-c1-200.html).
Figure 14: The BMW C1 Enclosed PTW

Safety features

A number of safety features combine to provide the improved safety of the C1 over other PTWs. These include:

- **An aluminium space frame forming an integral safety cell** – The frame comprises side bars in the shoulder area to prevent sideways slip of the rider as well as intrusion into the area occupied by the rider (Elliott et al 2003). The frame extends over the riders head in a double roll bar formation to join the front of the vehicle where it takes the form of side-pillars to the windscreen. This frame, which complies with the FMVSS 216 roof crush test, and the suspension configuration help to ensure a specific, staggered absorption of energy in the event of a head-on collision (http://www.motorcycle.com/mo/mcbmw/c1.html).

- **Seat-belts** – These take the form of two three-point lap and diagonal seat belts, that comply with ECE-R14 (Elliott et al 2003), which are used in a cross-over formation to secure the rider in position, thus preventing sub-marining as well as contact of the riders head with the ground (http://www.bmwworld.com/models/concepts/c1.htm).

- **Crumple zone** – This is provided at the front of the vehicle where energy is absorbed by deformable front mudguard unit panels (http://www.carenthusiast.co.uk/shows/bmw_3.htm).

- **Crash helmet** – Due to the combined performance of the above safety features, it is claimed that a crash helmet does not need to be worn.

Safety assessment


- **Impact tests**

  The impact tests used the following six configurations:
  - Two were in accordance with ISO 13232,
  - Two were into the rear of a car,
  - One was into a rigid barrier
  - One was into the side of the car with the C1 also carrying a pillion passenger.
For impacts frontal to the C1, the results indicate that:
- The HIC (Head Injury Criterion) was always well below the human tolerance,
- The neck momentum was reduced by about 50% compared with measurements from a dummy on a conventional two wheeler and the neck force was similar.
- The chest and hip strain were higher than for a conventional machine but these were similar to what is expected from a belted occupant and were well below human tolerance levels.
- The lower extremities, leg forces, were very low and only about 1/12th of the values normally measured for a two-wheeler.

For impacts into the side of the C1, similar results were found although the hip measurements were greater, they were still below recommended tolerance levels. Head contact with the ground did not occur in these tests although it was thought to be possible.

**Computer simulation**

The computer simulation investigated all seven of the ISO 13232 configurations with respect to HPC (analogous to HIC), head acceleration and GAMBIT (Generalised Acceleration Model for Brain Injury Tolerance) for both the C1 and a conventional scooter. The results indicated that in all configurations these measurements were very much lower for the C1 than for a conventional scooter.

**Marketability**

Whilst the concept was sufficiently promising for the vehicle to go into production and 10,614 units were sold in 2001, production ceased the following year due to lack of sales (http://www.bmwworld.com/models/concepts/c1.htm). Whilst the German, French and Spanish authorities allowed an exception to the helmet law for C1 riders (http://www.carenthusiast.co.uk/shows/bmw_3.htm), the UK authorities did not which potentially limited the product appeal and reduced its market exploitation.

5.3.9 **Braking systems**

**The complexity of braking**

- Brake use by a rider is a complex process which needs to account for:
  - Large load transfer from rear wheel to front wheel during braking
  - Separate controls for front and rear brakes
  - Wide variation in the proportion of each brake effort required on different surfaces to give optimum performance. (Donne & Watson 1985).

- Further complexities arise when the brakes are applied whilst cornering or changing direction since the machine has to be inclined to accommodate the resultant level of centrifugal generated. This causes a sideways force of the tyre against the road which is proportional to the mass of the machine with rider, the speed and the curve radius. If the grip is low and the cornering force requirement is high, braking performance may be compromised. If the braking requirement is increased whilst cornering, instability can occur. (Donne & Watson 1985). If the brakes are applied too harshly, the brakes may lock leading to skidding which may cause the machine to become unstable and capsize (Huang & Preston, 2004). If insufficient brake force is applied, an unnecessarily long stopping distance will result (Donne & Watson 1985).

**Linked / Combined Braking Systems**
• Fries et al (1989) found that braking is most effective, in terms of stopping distance, if front and rear brakes are used properly together. Use of the rear brake only resulted in a longer stopping distance.

• Linked or Combined Braking Systems aim to minimise ineffective braking by applying pressure to both wheels even if only one brake control was applied (Bayly et al 2006).

• Nishimoto et al (1991) assessed a Combined Braking System in which hand and foot systems simultaneously applied front and rear wheel braking. One configuration, in which rear braking force was adjusted to prevent 'hopping' and the front wheel was designed to lock before the rear wheel, resulted in higher than average decelerations compared to a conventional braking system and enabled novice riders to brake more efficiently than experienced riders using conventional systems.

• Based on rider response times to two motorscooter brake configurations, Carter (2000) found that a hand lever front brake/hand lever rear brake was equal to or better than the conventional hand lever front brake/foot pedal rear. They acknowledged that for PTW with a hand operated clutch, the dual hand lever control system may not be feasible unless the clutch control was changed.

• Hagstotz & Ludsteck (1995) conducted braking trials with a number of motorcyclists in southern Germany and found that when riders used:
  - Their own bikes (which had conventional brakes), they often locked their wheels and lost stability,
  - A linked system, there was some wheel-locking,
  - The ABS system, braking was carried out much more safely.

• Mortimer (2002) conducted studies in the 1980s using experienced and novice riders braking in both wet and dry conditions. He found that:
  - Riders using linked braking systems obtained greater deceleration compared to the foot brake alone
  - There was not greater tendency to lock the wheels and skid using linked brakes than separated brakes
  - Most participants, who had no prior experience of integrated brakes, preferred the integrated braking system.

**Anti-lock braking systems**

• The purpose of anti-lock brakes is to prevent wheels from locking and so reduce incidences of loss of control, skidding and falling, thus enabling riders to brake with maximum effectiveness. The ABS monitors the rotational speed of the wheels and releases the braking force if the wheels begin to lock (Bayly et al 2006). The benefits of ABS are the reduced stopping distances in dry, wet and icy conditions (Huang & Preston, 2004). Studies comparing test track performance with real world accidents suggest that the benefits may not be as extensive as first thought. (Elliott et al 2003). Further research into their effectiveness is required.

• A study for the UK Department for Transport investigated the accident involvement and damage levels incurred by BMW motorcycles imported and sold since 1990 i.e. those known to have ABS. The study found that ABS has the potential to reduce the number of accidents but this is not being fulfilled. Lack of knowledge of the system’s fitment to the bike and its workings were considered to be partly responsible especially in relation to the increased accident risk for older men and women (Department for Transport).

• Due to low frequencies in the accident and exposure samples and some questions regarding the validity of the ABS counts in the exposure sampling, no meaningful conclusions related to advanced braking systems could be made (ACEM 2004).

• Compared to automotive sector, only recently some motorcycle brands such as Honda, Yamaha, BMW, Ducati, Piaggio have introduced anti-lock braking system
(ABS) on top level models, even if ABS can be very useful for almost everyone and on every motorcycle. In fact many tests have shown that ABS permits a reliable hard brake without increasing significantly the minimum braking distance, either for expert drivers. ABS and airbag are still considered the maximum level of safety devices mounted on series PTW’s.

Figure 15: Components of the ABS system of BMW

• BMW Motorrad’s new Integral ABS technology has been developed independently of previous systems employed. Due to advancements in both hydraulic and electronics technologies, functionality has been enhanced whilst the system architecture has been reduced in complexity. The result is ‘supreme stopping power and very short stopping distances even without electrical power assistance for the brakes’ (http://www.webbikeworld.com/BMW-motorcycles/bmw-abs-asc.htm).

Automatic Stability Control

• Automatic Stability Control is an additional and complementary assistance function to ABS. ASC prevents the rear wheel from spinning in an uncontrolled manner when accelerating hard, and thus avoids any loss of grip or stability which could lead to the wheel spinning out of control http://www.webbikeworld.com/BMW-motorcycles/bmw-abs-asc.htm). This is the first system in the world to control driven wheel spin on a production motorcycle and is being introduced as an option on touring models in the BMW K and Boxer (R) Series motorcycles (BMW 2006). Refer to Figure 16.


Figure 16: Diagram to show the hydraulic and electrical network for its anti-lock brake system and automatic stability control
**Brake Assist**

- These systems, which work in conjunction with ABS, maximise the braking potential of the vehicle and reduce stopping distances in an emergency. Under emergency braking, the braking pressure of the front and rear wheel brakes is assessed and automatically adjusted through the application of additional hydraulic pressure, such that the maximum pressure is applied subject to the wheels locking. This system has been applied to the Yamaha ASV-2 Model 1 as shown in Figure 17 below. (Bayly et al 2006).

![Diagram of Yamaha ASV-2 Model 1 with Brake Assist system]


**Figure 17: Brake Assist system by Yamaha**

**Recommendations**

- Eberspächer (1991) recommends the adaptation of brake technology to include brakes only operated by one control, automatic co-ordination between front and rear wheel braking and an appropriate anti-lock system.
- Based on interviews and braking trials with a number of motorcyclists in southern Germany, Hagstotz & Ludsteck (1995) conclude that the ideal brake system would be one which combined ABS and linked brakes and had only one control (a hand brake).

**5.3.10 Roll stability**

- These systems assess the speed and vertical positioning of the motorcycle and advise the driver/rider if there is opportunity for a roll over to occur. This function is included within the Xtreme Beam system which is predominantly designed to activate a warning beacon if the motorcycle rolls over. The system can be calibrated to alert the rider, through a red flashing logo displayed to the rider, that they have reached a predetermined lean angle during cornering thereby cautioning against further lean and potential roll-over ([http://www.xtremebeam.com.au/index.htm - Refer to interactive heading](http://www.xtremebeam.com.au/index.htm)) (Bayly et al 2006).
5.3.11 Conspicuity Enhancement

- Deliverable 2 showed that most PTW-other vehicle accidents are due to the actions of the other driver who frequently ‘fails to see’ the motorcyclist. Among the solutions posed to this is improved conspicuity. This aspect was discussed directly within the MAIDS project which found that the effect of the background on PTW conspicuity was positive in 7.5% of the multi-vehicle cases and negative in 14.4% of cases. (ACEM 2004). Conspicuity may have a role to play within an integrated system and the research below can be used to support this. For instance, if a rider is on a priority road and approaching a junction at which a car is waiting to turn, a future system may be able to detect the onset of forward motion by that vehicle and activate enhanced conspicuity features such as a flashing light.

- A study reported by the UK Home Office Scientific Development Branch (Harrison 2006) reported on the development of a high conspicuity livery for police motorcycles – Refer to Figure 18. Based on 374 questionnaire responses from police riders and a small number of accident records it was found that: the priority function for the livery was improved conspicuity (more important than recognition or image) and needed to be effective at 100m, on most types of roads, during daytime (and to a lesser extent dusk) and to front and rear of the motorcycle.

Figure 18: Recommended format for UK national police motorcycle livery

- In developing a livery to address these requirements, the following human factors principles were followed:
  - Increase luminance contrast
  - Increase colour contrast
  - Maximisation of the motorcycle’s size (or apparent size)
  - Strengthening the shape or pattern recognition
- Employing changes of state

**Increase luminance contrast**
- Use steady headlight flanked by running lamps in mirrors
- Use materials which are both fluorescent (to improve daytime contrast) and retro reflective (improve night-time contrast)
- Retro reflective materials should be positioned where they are most likely to be picked up in other vehicles' headlamps
- Retro reflective materials are less effective on the front of the motorcycle since their effect is lost within the headlamp beam
- (Note: The MAIDS study found that for 24.2% of accidents, the headlight of the PTW was switched off which was likely to have been a contributing factor. (ACEM 2004))
- (Note: Based upon a review of research into motorcycle accidents covering several countries over a long period of time, Huang and Preston (2004) concluded that daytime running headlights are an important primary prevention measure)
- (Note: Yamaha has developed a new surface finishing technology which is phosphorescent. If the motorcycle is kept outdoors during the daytime the film becomes charged and emits a dim light for about an hour after dusk – Refer to Figure 19).

![Yamaha electric scooter series EC-02 with “Film-on Graphics” phosphorescence finish](http://www.tmcnet.com/usubmit/2006/04/19/1586067.htm)

**Figure 19: Yamaha electric scooter series EC-02 with “Film-on Graphics” phosphorescence finish**

**Increased colour contrast**
- The human eye is most receptive to wavelengths in the yellow-green part of the spectrum hence the clothing and livery is predominantly (fluorescent) yellow.
- (Note: This is similarly supported by Huang and Preston (2004) who stated the importance of the colour and fluorescence of the vehicle and rider to improved conspicuity)
- (Note: The MAIDS study found that dark rider clothing decreased conspicuity in 13.0% of all accidents (ACEM 2004)
Maximisation of the motorcycle’s size (or apparent size)

- Use of a single colour (fluorescent yellow) renders the motorcycle a single block of colour and increases its perceived size hence assisting its visibility
- Extend this effect by including the rider through the use of fluorescent yellow clothing and a fluorescent yellow or white crash helmet
- Fluorescent colour should be used high up on the motorcycle/rider to assist their detection in traffic i.e. over tops of cars and through windows.
- The use of a fluorescent yellow screen was rejected for operational reasons

Strengthening the shape or pattern recognition

- Identification of a vehicle can be assisted by emphasising its shape e.g. the box-shape contour markings on the rear of trucks.
- Identification can also be achieved through learnt associations which are less intuitive than those based on shape outlining. This may be implemented through a unique lighting configuration which is relevant to just one vehicle type – Refer to Figure 20.
- This relates to research commissioned by the Honda Research Institute to Wako Research Center and the Asaka R&D Center which found that the human brain has a strong response to oblique lines and facial patterns (especially to the eyes). For this reason ASV3 motorcycle has a new face design which resembles a human face with oblique eyes and one mouth.

Employing changes of state

- Movement or changes in state, such as a flashing light, are good for attracting attention in the visual periphery and so can improve conspicuity.

- Speed and distance estimation – Honda has developed a new front design for ASV3 motorcycle in order to enhance the conspicuity of the vehicle. An important problem concerning the conspicuity of the motorcycles is that they have only one light source (or two light sources very close to each other). For this reason it is difficult to determine the speed and the distance of the motorcycles during the night. Honda has mounted on its ASV3 motorcycle two sets of high-intensity LED lights at different
heights in order to achieve a higher level of visibility. A couple of LED are mounted near the ground, on the front fork legs, to improve the distance assessment. Another high-intensity LED is mounted on the top of a structure which rises from the back of the vehicle. The two sets of lights are quite distant from each other in order to help the assessment of the speed of the vehicle. Refer to Figure 21.

![Figure 21: Long design of the Honda ASV3 for night conspicuity enhancement](image)

5.3.12 Intelligent Speed Adaptation (ISA)

- As part of a UK Department for Transport research project into Intelligent Speed Adaptation, a demonstration motorcycle was developed and then trialled with invited parties for feedback. GPS is used to inform an onboard computer of the location of the motorcycle from which the legal maximum speed for that location can be determined. This legal maximum is then compared with the motorcycles actual speed and if this is in excess, then the system is activated. A display advises the rider of the limit and once the system is activated warning lights, mounted by the screen flash to alert the driver as does an audible tone transmitted through ear plugs. If the rider fails to respond by reducing their speed to meet the legal requirement, then vibrating pads at the rider’s thighs are activated as a means for encouraging the rider to comply. Should this fail to bring about the desired response, then the throttle will automatically start to reduce power to the engine until the specified limit is reached whereupon control will be returned to the rider. This system therefore follows a logical progression from rider information to rider warning and ultimately rider support. In addition, provision has been made to supply the rider with power when needed, such as when overtaking, by means of a temporary off-switch. (http://www.network.mag-uk.org/EVSC/campaign/evsc1.html)

![Figure 22: The ISA motorcycle](image)

http://www.network.mag-uk.org/EVSC/campaign/evsc1.html
• In the UK, the House of Commons Transport Committee (2007) recommend that this technology is progressed further for motorcycles, particularly with respect to limiting the speed of the more powerful motorcycles

5.3.13 Adaptive/active Lighting

• Suzuki, through its Advanced Safety Vehicle (ASV), have re-designed motorcycle lighting to take advantage of the high illumination headlamps increasingly used within cars. Difficulties in transferring application arose from the optical rotation experienced by the motorcycle headlamps as it banks at intersections and curves – Refer to Figure 23. Using a vehicle speed sensor, an angular velocity sensor and a stepper motor, the optical axis of the light is controlled to maintain a parallel position to the ground.

![Figure 23: Adaptive lighting (Gotoh et al undated)](http://www.yamaha-motor.co.jp/global/news/2000/11/15/asv2-02.html)

• Similarly, Yamaha have developed an active headlight whose task is to provide better illumination, during night-riding, on curves. With conventional lighting, when the motorcycle inclines on a side to round a curve, the light pattern projected by the headlight on the road changes its shape. As a consequence, the enlightenment of the road on the trajectory of the motorcycle is drastically reduced. Active headlight addresses this problem since its motorized headlight is capable of a longitudinal-axis rotation which can compensate the roll movement of the vehicle on curves and so maintain the correct light pattern on the road. Refer to Figure 24 and Figure 25.

![Figure 24: Yamaha active headlamp – Areas of illumination](http://www.yamaha-motor.co.jp/global/news/2000/11/15/asv2-02.html)
• However, a simple longitudinal-axis rotation cannot be sufficient to obtain a good illumination of the road, because the headlight is still aligned with the tangent of the curve, while it should point into the curve. An alternative solution for the movement of the active headlight might have the potential to significantly improve the visibility of the road in dark conditions by additionally addressing this aspect.

5.3.14 Emergency lighting

• The Xtreme Beam lighting system is a safety strobe located beneath the rear of the motorcycle which is activated when the motorcycle’s tyres loose contact with the road and it is on its side causing a high contrasting amber flash (about two a second) to be emitted to the surface below. The manufacturers claim that it is visible from 360° and can run from its own power source for approximately seven hours, thus highlighting the presence of the rider to other roadusers and the emergency services.  

5.3.15 Vision Enhancement

• Honda has developed a vision enhancement device comprising a frontal and a rear camera for its ASV motorcycle. The images of the frontal camera are automatically analysed to detect objects, stop signs and road markings. A panel on the dashboard and an in-helmet audio system provide the driver with synthetic information about approaching vehicles and obstacles on the road – Refer to Figure 26. The system can alert the driver in case of an imminent frontal collision or in case the vehicle is approaching an intersection too fast.
The small rear camera is mounted on the back of the vehicle and its image is presented on a display on the dashboard. This device provides the rider with information about vehicles approaching from the rear that are not easily seen in a rear view mirror – Refer to Figure 27. The disadvantage of this system is that the camera presents a flat image, while mirrors accommodate stereo vision.

5.3.16 Inter-vehicle communication systems

- Inter-vehicle communication systems enable vehicles within sufficient proximity to exchange information about their speed, positioning, heading and vehicle type. This information is conveyed to the driver who is then alerted if a collision is predicted (Bayly et al 2006).
- Suzuki, through its Advanced Safety Vehicle (ASV), have developed a system to inform other vehicle drivers of the presence of a motorcycle in their vicinity. The motorcycle emits weak radio waves which are received by either the front or rear receivers fitted to other vehicles and from which the relative location of the motorcycle can be determined. Refer to Figure 28. This information is conveyed to the driver using a warning signal on the dashboard and a warning tone. Refer to Figure 29.
Honda’s third-generation ASV system exchanges positional data (GPS) and dynamic data (speed, acceleration, yaw rate) between vehicles in order to prevent detection failures with its principal focus on avoiding intersection accidents. When the vehicle has come to a stop the system detects the position of the approaching vehicles, assisting the driver and motorcyclist in determining whether it is safe or not to proceed through the intersection – Refer to Figure 30 and Figure 31.


Figure 30: Motorcycle and automobile communication at crossroads
5.3.17 Pedestrian detection systems

- Pedestrian detection systems aim to detect, using video, laser and/or radar sensors, and warn the driver/rider of the presence of pedestrians in the roadway which have the potential to conflict with their own vehicle. The Yamaha ASV-Model 2 has a pedestrian crossing support system within its Rider Support System, refer to Figure 32, which detects and alerts the motorcyclist to pedestrians at designated crossings.
5.3.18 Curve speed warning

- These systems warn the driver/rider of an upcoming curve providing information such as direction and extent of the curve, road camber, recommended speed, warning concerning current vehicle speed, etc (Bayly et al 2006). Such information may be displayed on roadside signs or within the vehicle. The Yamaha ASV-2 has curve-speed warning within its rider support system, refer to Figure 32 above, which conveys the shape of upcoming curves.

5.3.19 Impact sensing cut-off

- This system can employ a number of methods, such as crash sensors and vapour sensors, to assess the vehicle status and disable fuel and electrical systems in order to prevent the vehicle igniting (Bayly et al 2006).

5.3.20 Vehicle diagnostics

- The Honda ASV-2 contains a vehicle diagnostic system to monitor the status of the tyres in terms of their pressure and temperature through sensors integrated into the tyre valves. If the air pressure within either tyre changes or the temperatures within them become extreme information is sent by radio wave to a vehicle-mounted display (Bayly et al 2006).

5.3.21 Alcohol interlock

- The aim of the system is to prevent riding above the legally prescribed limit. A hand-held, electronic breath-testing device which is wired to the ignition measures the level of intoxication and only allows the vehicle to be started if the result lies within acceptable limits. Even if the vehicle is started, re-checks are undertaken with the potential for preventative actions with pre-warning. Currently such interlocks are being piloted on motorcycles. (Gregoriades 2006)

5.4 Analysis of IS devices currently implemented in other transport forms

- Before discussing the devices currently implemented in other transport forms in more detail, it is worth noting the findings of the Start of the Art report for the Advanced Driver Assistance Systems in Europe (ADASE) project. The State of the Art looked across 37 R&D projects of ADA related systems for road transport, passenger cars, freight transport and public transport. It found:
  - Safety is the main motivation for the R&D and implementation of ADA systems which focus both on accident and severity reduction.
  - Considerations as to the effects on the traffic system, the environment and comfort play a minor role within ADA system development.
  - There is an increasing interest in the development of technologies to support detection, perception and interpretation of the infrastructure and other road users.
  - There is worldwide interest in and R&D into ADA systems.
  - Co-operative systems are emerging worldwide (within vehicles, between vehicles and between infrastructure and vehicles) supporting a need for global standardisation.
• Automotive manufacturers have sustained the greatest efforts to develop IS devices. In particular, in the top class passenger car segment, sophisticated safety devices are considered an important element in advancing such technologies. This is why some brands have created their own safety programs, in order to go beyond the concept of simple active or simple passive safety.

• IS devices are constituted of different devices working together. The elementary devices can be classified into several categories:
  - Sensors;
  - Risk detection systems;
  - Warning devices (HMI);
  - Driving assistance systems;
  - Pre-crash and crash devices;
  - Cooperative systems.

5.4.1 Sensors

• There are many different kinds of automotive sensors. Some of them measure the parameters of the device they are mounted on, whilst more innovative sensors in the automotive segment are supposed to measure parameters through free space (e.g. radar, infra-red sensors) with the intent of providing information concerning the external environment or the passengers' position and posture.

• All kinds of sensors can be adopted for IS goals, in case the data they detect are utilized to provide synthetic information to the other safety devices implemented on the vehicle.

• There are several fields covering the innovative utilization of automotive sensors:
  - Vision enhancement;
  - Lane detection;
  - Pre-collision detection;
  - Inner space monitoring.

Vision Enhancement Sensors

• The aim is to enhance drivers' night-time vision and so improve the safety of night driving. There are two main different kinds of vision enhancement (VE). The first one aims to provide the driver with better images of the outside of the vehicle (e.g. Mercedes Night Vision, Lexus rear camera – Refer to Figure 33. The second kind of VE utilizes the images collected by the sensors to perform an automatic interpretation of the scene (e.g. Mobileye). If no interpretation is performed, VE can not be considered exactly to be an IS device because the images it produces can not interact directly with the other safety devices. In case of image interpretation systems, the information can be shared between the IS devices and the decisional system can use that information to individuate the correct response.
Vision enhancement utilizes principally videos from cameras or infrared technology (IR). There are two kinds of IR:

- Far Infrared Radiation (FIR) (Passive systems) – FIR systems exploit the radiation emitted by any warm object. In the resulting image, warm objects are displayed in white or light grey, while cold objects appear dark. FIR images provide a type of information quite different from the images in the visible spectrum. While such information is not immediately comprehensible by a human observer, the high thermal contrast between the background and the foreground elements have spurred the development of algorithms for automatic detection of cars and pedestrians.

- Near Infrared Radiation (NIR) (Active systems) – NIR sensors detect the radiation reflected by objects in the infrared range which is close to visible light. This requires an active illumination of the scene through NIR light sources. The first NIR application, around 10 years ago, were based on CCD camera as they were becoming highly sensitive, smaller and cheaper. CCD sensors, however, are blinded by oncoming vehicles’ headlamps. The recently developed highly dynamic CMOS sensors are able to reduce blinding effects by exploiting a nonlinear response. Rain or snow does not greatly affect the system performance, while no advantages can be expected in fog. Additionally, NIR sensors offer images that are quite intuitive to the viewers, since the spectrum is close the visibility range of human eyes. This property makes NIR images suited to be displayed directly to the driver. (Bellotti et al 2004)

The first Night Vision system has been introduced in the US market in year 2000 on Cadillac DeVille. It is based on an infrared camera and head-up display to show to the driver a thermal image of the front scene (Saroldi and Bianco 2003) – Refer to Figure 34.
Some systems extend vision up to five times thereby giving the driver increased time to react. As well as informing the driver the system can also be used to initiate automatic action by the vehicle (Gregoriades 2006)

**Lane Detection Sensors**

- Lane detection consists in the localization of the road, the determination of the relative position between vehicle and road and the analysis of the heading direction of the vehicle. (Bertozzi et al 2003)
- Lane detection can be obtained with the computer processing of images from simple cameras positioned behind the windshield or on a side of the vehicle. The dimensions of a lane detection system can be very small. For example Mobileye AWS includes a smart camera and the processing unit packed together in the size of a matchbox.

A few systems are designed to handle lane detection for completely unstructured roads by exploiting the homogeneous colour of the road (e.g. Supervised Classification Applied to Road Following system) (Bertozzi et al 2000). Other systems perform the localization of specific features such as marking painted on the road.
surface, for example Mobileye AWS. Lane detection is possible also at night with only the enlightenment of low beam headlight (e.g. Mobileye).

- As lane detection is based on images caught by a camera mounted on the vehicle, when there is an occlusion of the vision field due to a vehicle too near the camera lane detection can be avoided. Also critical weather conditions, like rain and fog, in many cases avoid image-based lane detection.

**Collision Detection Sensors**

- Collision detection is currently a fundamental task for passive safety devices. For example the airbag system uses the information of the collision detection sensors to decide whether or not to deploy the airbags. Ordinary collision detection devices are based on acceleration measures in different direction and in different locations on the vehicle. But a collision can be detected a few seconds before the impact using radar information (e.g. Honda and Mercedes) or through the processing of images provided by simple cameras (Mobileye). Other predictive sensors include infrared, laser and ultrasonic means to calculate the likelihood of a crash. If such calculations exceed a pre-determined threshold, then a warning will be issued to the driver which may also activate crash avoidance or pre-crash systems as described above. (Gregoriades 2006).

- Mercedes utilizes two different kinds of radars: an 80-degree wide short-range radar with a frequency of 24 gigahertz with a range of 30 metres in front of the car and a narrower 9-degree beam radar with a frequency of 77 gigahertz with a range of 150 metres – Refer to Figure 36 and Figure 37.
• Honda millimetre-wave radar has a range of about 100 metres with a 16-degree arc. The radar device has approximately the size of a cigarette-box. Many other brands utilize a millimetre-wave radar to detect front obstacles, for example Lexus.

• There are short range sensors whose task is to detect imminent collisions, for example a modified millimetre-wave radar of Denso. These devices are positioned principally on the lateral sides of the vehicle.

**Inner Space Sensors**

• Another research direction for vehicle sensors concerns the perception of the inside of the vehicle from which two important topics are emerging:
  - Driver monitoring – The driver monitoring is related to active safety, whose objectives are the on-line analysis of the driver conditions to detect and predict driver’s vigilance degradation and then warn of critical situations. (Boyerie 2001). Driver monitoring can be obtained from measures of the driver's eyelid patterns (eye blink, slow eye closure). To measure eyelid pattern Siemens has developed a non intrusive system based on a distant on-board IR video sensor and image processing. In the future such systems may also be used to activate emergency braking. (Gregoriades 2006)
  - Passenger occupant detection - Passenger occupant detection is more related to passive safety. The massive introduction of airbags in cars has generated new problems related to the detection of the seat occupant. The determination of the presence of somebody/something, located on the seat, and the evaluation of the volumetric occupancy of the passenger in the front part of the cockpit should be useful to perform better operating conditions for new generation airbags. (Boverie 2001).

Siemens has explored different kinds of 3D video sensors to detect the position of passengers and object inside the vehicle. The first one is based on “time of flight” of the light. The method consists of illuminating the scene with ultra-short light pulses synchronized with the opening of the shutter of a CMOS sensor. Each pixel of the sensor measures the distance of one point of the scene, so that the 3D picture is directly available at the output of the camera.

Another kind of 3D reconstruction is stereovision. Stereoscopic vision is based on the principle that depth information can be achieved by triangulation techniques from two images (provided, for example, by two video sensors) with a common part in their field of vision. In automotive applications the sensors should be at least at a distance of 100 mm from each other.

**5.4.2 Warning Systems**

• When a risk is detected by the safety system, this information must be communicated to the driver using acoustic, visual or tactile inputs and hence relates to human-machine interfaces (HMI). Two important features of the input chosen to communicate a risk are the driver's reaction time to that kind of stimulus and the capability of inducing the correct response from the driver. Many automotive warning devices have been implemented and tested and good results can be obtained combining more than a single warning system.
Acoustic Warnings

- The easiest way to warn the driver is to use a simple acoustic warning, for example an alarm sound. In this case the information content of the warning is very low. The driver’s attention level is attained but it is not indicated what to concentrate on, even if it is possible to communicate different levels of warning using different volumes or different sounds. In a more sophisticated system the alarm sound can be directional, so that the driver is informed of the direction of the warning in a very intuitive and fast way. Other systems reproduce sounds which remind of the subject of the warning. For example Mobileye warning system utilizes rumble strip sounds to indicate the crossing of the lane markings.

Visual Warnings

- Visual warnings can have different characteristics: shape, colour, dimension, localization. The first characteristic is the shape: it can have a simple geometrical shape, in cases where there is time to think about it, or a more complex shape, in order to communicate faster the object of the warning. An important characteristic is the localization of the warning: it can be placed on the dashboard or projected on the bottom of the windshield, or even projected in the correspondent point of the windshield, using head-up displays (HUDs).


Figure 38: Acura CMBS (Collision Mitigation Braking System) warning on the dashboard

- The Mobileye safety system displays its visual warnings on a small device mounted on the dashboard and the shape of the warning reminds of the object it is referred to. For example the lane departing warning utilizes a blinking oblique line similar to the marking painted on the side of the road, while the collision warning utilizes a blinking red car – Refer to Figure 39.
Figure 39: Mobileye AWS 4000 - lane departing warning and collision warning

- Alternatively, Mercedes active cruise control displays only a red light on the dashboard to warn about the presence of a slow car ahead. However the system does not need a fast reaction by the driver because speed is automatically reduced.

**Force Feedback Warnings**

- The safety system can also alert the driver with forces or vibrations transmitted through the steering wheel, the pedals or other devices. Force feedback warnings have great potential even if they are not completely exploited in automotive sector. Some of these warnings might not only alert the driver but they could also suggest the correct manoeuvre. For example if the system wanted to alert the driver about a sudden braking of the car ahead it could use a vibration on the throttle pedal in order to induce the driver to throttle back.
- The following devices are currently being studied:
  - Steering wheel vibration e.g. Ford (Kozak et al 2006),
  - Steering wheel torque feedback e.g. Ford (Kozak et al 2006),
  - Pedals vibration and force feedback;
  - Light deceleration of the vehicle with light throttle down or with auto-braking (e.g. Acura).

5.4.3 **Driver Assistance Systems**

- The risk component is often generated by unpredictable factors or their combination, such as the presence of an animal or an object along the street, other drivers’ behaviour, a collision between vehicles and so on. In all these cases it is very difficult for an electronic system to elaborate the appropriate response and the safety system can only warn the driver. But when the system is able to clearly detect the intentions of the driver, a driving assistance function can be provided.

**Antilock Braking System**

- This driver assistance system was first introduced in 1978 as standard fitment in Europe and is now widely adopted on passenger cars. The Antilock Braking System (ABS) prevents the wheels from locking and thus assists in the avoidance of obstacles. Rotational-speed sensors continuously monitor each wheel and as soon as incipient lock-up is detected at a wheel, ABS temporarily reduces the braking pressure at the wheel in question to such a degree that lock-up is prevented. In this way the vehicle remains under control and the stopping distance is usually shortened compared to locked wheels.
Another important safety device mounted on many vehicles is electronic stability control (ESC). The system employed by Bosch is shown in Figure 41 below and is described at [http://www.bosch-experience.com/uk/language1/espabsasr.html](http://www.bosch-experience.com/uk/language1/espabsasr.html). In summary, when faced with sudden obstacles, bends that have been under or over estimated, fast cornering or changing road surfaces, ESP stabilizes the vehicle and reduces the danger of skidding by controlling the braking force on each wheel or eventually controlling the engine and the traction as well. ESP comprises the following components:

- A speed sensor on each wheel;
- A rotational rate sensor which measures the rotations of the car around its vertical axis;
- A lateral acceleration sensor;
- The steering angle sensor to acquire the driver's steering intentions;
- A control unit which decides when and how to intervene.

It is predominantly effective in mitigating against lateral impacts by reducing side-slip angle and maintaining stability. (Gregoriades 2006). The effectiveness of existing systems is evidenced by a study by Audi and Volkswagen. Based on an analysis of data relating to the German In-Depth Accident Study (GIDAS), an assessment of the reduction in sustained injuries due to the introduction of safety-belts, structural enhancements of the vehicle, airbags and ESP found that after safety belts and structural enhancements, ESP made the greatest contribution to injury reduction. It stated that, with respect to accident reduction, the effectiveness of the system has been estimated at about 50% regarding severe accidents and up to 80% in reducing accidents initiated by skidding – in Germany this would mean that 35% of all vehicle occupant fatalities could be prevented. Since vehicles have currently reached a level of passive safety that can only be improved by an inappropriate increase in vehicle weight, Rieger et al (2005) suggest that future safety developments will be driven by accident avoidance rather than injury mitigation.
• Research by Kin et al (2003) demonstrated the increased effectiveness of combining stability control with information from the vehicle’s navigation system. Figure 42 (a) below shows that at a vehicle speed which was at least 20km/h above the speed which would permit the turn to be negotiated, the vehicle deviated more than 1m from the course width of 3.6m despite operation of the stability control suggesting that this alone cannot provide sufficient control in this situation. Figure 42 (b) shows that when the stability control system is combined with the navigation information, data obtained 50m prior to the turn was used to decelerate the vehicle to an appropriate speed to negotiate the turn within the course width. If the system judges that the approach speed is too high, a warning lamp flashes and a warning alarm is sounded. If the driver makes an inappropriate response, the stability system engages deceleration control and, if necessary, under steer control.

![Figure 42: Stability control without and with navigation data (Kin et al 2003)](http://www.bosch-esperience.com/uk/language1/wirktesp.html)

**Brake Assistance System**

• An innovative driver assistance system is the emergency brake assistance system (e.g. Mercedes Brake Assist System BAS Plus, Jaguar Emergency Brake Assist EBA) which aims to reduce crash severity by optimising speed reduction immediately prior to impact. If the IS system detects the risk of a collision and at the same time the driver is braking, the system monitors the force that the driver is applying on the brake pedal and eventually regulates the braking force in order to obtain the highest...
deceleration of the vehicle. It requires a sensor on the throttle and brake control with interface to the brake system. Acura Collision Mitigation Braking System CMBS can undertake an emergency braking manoeuvre to mitigate the impact even independently from the driver, in the case of unavoidable collision.

**Adaptive Cruise Control**

- Many automotive brands have adopted an innovative cruise control system, called ACC (Adaptive Cruise Control). This device can be considered a driving assistance system as it automatically maintains a set speed and distance to the preceding vehicle making adjustments as the situation changes. The driver decides the cruise speed and communicates it to the system with a specific device. The ACC then maintains the desired speed automatically, as long as the road is clear. When a slower vehicle gets in front of the car, the ACC detects it and then slows down the car in order to maintain a certain distance. The sensors used are based on laser radar (lidar) or microwave radar with a maximum detection range of around 100 m. The microwave radar sensors operate in the 76-77 GHz band that has been reserved for automotive obstacle detection applications. ACC calculates the distance as a function of the cruise speed, in order to keep a certain number of seconds of distance from the vehicle which is proceeding. In fulfilling its function it uses both acceleration and braking adjustments, the latter of which is limited to 1/3 of available braking power. This function was firstly introduced in Japan on 1995 based on lidar technology, and in the following years was extended to Europe and to microwave technology. The first introduction in Europe was done by Mercedes in 1999 (Saroldi and Bianco 2003).
- Gotoh et al (undated) report on research by Suzuki within the second phase of the Advanced Safety Vehicle (ASV) project in Japan and state that the experimental car (ASV-2) is able to stop itself in congested traffic.

**Safe following systems**

- The aim of these systems is to support the driver by automatically maintaining distance to the lead vehicle and adapt the vehicle speed if necessary. Such systems are an advancement on current cruise control since they employ additional sensors, warning systems and means of vehicle-to-vehicle or vehicle-to-infrastructure communication. They cover collision warning, collision mitigation, ASS, platooning and stop+go (low speed ACC). They are likely to be more effective in well controlled traffic situations such as motorways. (Gregoriades 2006)

**Automatic Steering**

- In 2003 Eric Rossetter from Stanford University implemented an electronic steering device on a drive-by-wire Corvette. The experimental system was able to keep to the road in a fully automatic way, using dynamic data of the vehicle (lateral and longitudinal accelerations, yaw rate), a high definition digital map and GPS information.

**Lane change assistant**

- The aim of the lane change assistant is to assist drivers in making safe lane change manoeuvres by detecting hazards in the path eg overtaking car in the blindspot. Predictive sensors scan the area around the vehicle and cameras are used for lane recognition and blindspot monitoring. If a hazard is detected, a warning (auditory or visual) is triggered to alert the driver. Future developments include tactile feedback
through steering wheel as well as action to be taken in critical situations. (Gregoriades 2006)

- Such a system has been developed within the PReVENT programme which is a European automotive industry activity to develop and demonstrate preventative safety applications and technologies. As part of PReVENT, the LATERAL SAFE sub-project had the aim of developing safety applications to prevent lateral/rear-related accidents and assist the driver in adverse or low visibility conditions and blind spot areas with a specific objective being to develop a lane change assistant system which has been demonstrated in a limousine car from Bosch. http://www.prevent-lateralsafe.org/ls_demonstration.htm). A similar Highway Lane Change Assistant which uses radar has been developed and trialled by different drivers in different vehicles on German highways. (Ruder et al 2002).

**Intelligent Speed Adaptation (ISA)**

- The aim of these systems is to improve road safety by maintaining a safe speed since speed is a major factor in accident severity. The aim is to develop systems linked to ISA based on satellite positioning or vehicle-infrastructure communications using Dedicated Short Range Communications DSRC which will alert drivers to the speed limit according to current traffic situations. Examples include – intersection support using vehicle-infrastructure communication, curve speed prediction, traffic sign recognition and speed advice depending upon road status. Warning based systems using digital maps are likely to be introduced initially with adaptive versions expected after 2015. (Gregoriades 2006)

**Adaptive lighting**

- The aim of adaptive lighting is to provide greater illumination of the road ahead in the dark through automatic adjustments to accommodate speed, gradient, curves, intersections, high/low beam settings, etc. There are different forms of adaptive lighting including:
  - Dynamic curve illumination - Based on factors such as vehicle speed, steering angle and yaw rate, the changes needed to provide improved illumination of the road ahead are calculated and adjustments made by electronically pivoting the headlight module. In this way the system is able to anticipate bends in the road ahead and alter the vehicle’s light distribution to accommodate them. Such systems are employed by a number of manufacturers including BMW, refer to Figure 43, and Ford who state that their system which uses halogen projector-beam headlamps shifts the light pattern as much as 11 meters left or right in a curve. Ford have also introduced a row of light emitting diodes (LEDs) that stretch around the sides of the headlamp unit which switch on sequentially at a rate and intensity calculated from the degree and speed of the turn to provide extra illumination and then automatically switch off when the curve has been negotiated – Refer to Figure 44.
- Turning light – In a system developed by Audi, an additional headlight is located in the headlamp unit between the dipped and main beam lights. When the dipped beam is on and the vehicle speed is less than 40mph, the turning light is activated when the indicator is used or there is a significant change in steering angle. The light emitted assists the driver by placing more light in the area of the turn. ([http://www.audiusa.com/audi/us/en2/tools/glossary/safety/turning_lights.html](http://www.audiusa.com/audi/us/en2/tools/glossary/safety/turning_lights.html))

- Rear light – BMW has designed a rear lighting system which is designed to reduce the risk of bumper-to-bumper collisions by enlarging the brake area when the driver forcefully applies the brakes. ([http://www.bmwworld.com/technology/lighting.htm](http://www.bmwworld.com/technology/lighting.htm))

**Automated Crash Notification System**

- When a crash occurs, information from the vehicles ignition, acceleration, tilt and shock sensors and also sometimes the airbag, will be used to confirm the occurrence
and then automatically inform the emergency services of when the crash occurred and where it can be found using GPS. Advanced systems can convey the severity and nature of the crash and some provide speakers so that the occupants can communicate directly with the emergency service personnel (Bayly et al 2006).

5.4.4 Pre-Crash and Crash Devices

- These systems aim to maximise the passive protection available to drivers and other road users. When an imminent crash is detected, short range predictive sensors will send signals from active sensors to passive safety systems. There are several devices which are activated before the collision to prepare the vehicle and its passengers for the emergency manoeuvre and the eventual impact, in order to mitigate damages:
  - Automatically closing windows;
  - Auto-repositioning seats;
  - Reversible pre-tensioners for seatbelts;
  - Auto-inflatable seat cushions for lateral support.

- The fatality reducing potential of passive safety measures is almost exhausted (Kopf, 2002). Typical crash devices, such as airbags have been developed in order to exploit all the potentials of an IS system. For example, the latest generation airbags can be inflated at different stages and in different ways, in accordance with the inner space monitoring data, in order to provide a better protection of the passengers. Moreover there are studies concerning pedestrian safety, in particular airbag-based safety systems for pedestrians which have been implemented and tested. These studies show the necessity of detecting pedestrian collisions before the impact, for example using visual detection or radar monitoring.

5.4.5 Cooperative Systems

- A cooperative collision warning system (CCW) based on vehicle-to-vehicle wireless communication has been studied and implemented by the Institute of Transportation Studies of the University of Berkeley, California. The CCW concept provides warnings or situation awareness displays to drivers based on information about the motions of neighbouring vehicles obtained by wireless communications from those vehicles, without use of any ranging sensors. This has the advantages of a potentially inexpensive complement of on board vehicle equipment (compared to ranging sensors that could provide 360 degree coverage), as well as providing information from vehicles that may be occluded from direct line of sight to the approaching vehicle.

- Honda has tested a different cooperative system, inside the ASV3 project. The communication between vehicles intends to warn about the presence of an accident. When an accident occurs the vehicles in a certain range acquire the information about the crash from the cars involved and communicate it to the oncoming vehicles, in order to pre-alert the drivers before they reach the site of the accident.

- CarTALK 2000 started in August 2001 as a three-years European research project focussing on new driver assistance systems which are based upon inter-vehicle communication. The main objectives are the development of co-operative driver assistance systems on the one hand and the development of a mobile ad-hoc radio network as a communication platform with the aim of preparing a future standard on the other hand. CarTALK 2000 defines three application clusters:
- Information and Warning Functions - A vehicle will transmit a warning message when it detects a vehicle breakdown, high traffic density and congestion, or dangerous road surface conditions. This allows an early warning of the driver of following vehicles on the same road – Refer to Figure 45.

**Figure 45: Illustration of CarTALK information and warning function scenario**

- Communication-based Longitudinal Control Systems - Existing Adaptive Cruise Control systems only react on the vehicle directly in front. By integrating communication, these systems may adapt longitudinal control to the traffic in front and can allow anticipating to an early braking manoeuvre when an invisible vehicle beyond the direct predecessor in front (e.g. vehicle 1 in Figure 46 below) is braking.

**Figure 46: Illustration of CarTALK longitudinal control systems scenario**

- Co-operative Assistance Systems - A typical scenario for co-operation is the highway entry and merging scenario. Today, misunderstandings between drivers on the highway and on the entry-lane cause critical situations. By exchanging information up to simple trajectory plans, critical situations can be foreseen and solved by the vehicles themselves. Other examples are inner-city intersection scenarios when the right of way situation is unclear – Refer to Figure 47.
5.4.6 Risk Detection Systems

- The risk detection device is the core part of IS systems. It collects the inputs from the sensing devices, identifies the risk factors and elaborates the responses of the other IS devices, using decision algorithms. Most advanced risk detection systems simultaneously monitor different aspects of the vehicle risk situation and control an integrated response of all the safety devices, with distinct levels of warning. For example Continental has designed a risk detection system called Danger Control Module. For any given situation, this module computes a hazard potential, which reflects the current accident risk. If the hazard potential reaches a defined limit, the danger control module initiates a staged hazard response strategy.

- There are many fields for advanced risk detection systems:
  - Lane departing avoidance system;
  - Collision avoidance system;
  - Pre-collision system;
  - Driver’s vigilance degradation warning system;
  - Pedestrian detection system.

Lane Departing Avoidance Systems

- The lane departing avoidance system utilizes lane detection methods to help the driver to keep the lane. There are two different kinds of lane departing avoidance systems:
  - Autonomous lane keeping systems – Some prototypes of autonomous lane keeping systems acquire the images from a camera, compute the relative position of the vehicle with respect to the lane and then drive actuators to keep the vehicle in the correct position. Other autonomous systems choose the commands to be issued to the actuators directly from the visual patterns detected in the incoming images using neural nets (e.g. Autonomous Land Vehicle In a Neural Net ALVINN). Nevertheless, since the knowledge of the lane position can be conveniently exploited by other driving assistance functions, the localization of the lane is generally performed.
  - Lane departing warning systems – These do not assist the correction manoeuvre, but only notify the driver: when the system detects an imminent lane departure the driver can be alerted in real time through the HMIs. This kind of system is to be preferred in the case of difficult lane detection conditions since a mistake in
recognizing the road position will produce only a false warning instead of a dangerous automatic steering correction. This system was introduced in 2000 in Japan by some car manufacturers and in US on trucks with the ITERIS “Auto-vue” system – Refer to Figure 48 below (Saroldi and Bianco 2003).

![ITERIS “Auto-vue” Lane Warning system](source: www.iteris.com)

**Collision Avoidance Systems**

- **Forward collision avoidance systems** - These systems employ laser or radar sensors which are mounted on the front of the vehicle to monitor the distance from other vehicles in the same lane.

- **Side collision avoidance systems** – The Audi ‘Side Assist’ system uses a radar based detection system to analyse the blind spot region on both sides of the vehicle and monitor the presence of oncoming vehicles. If Audi side assist identifies another vehicle, it informs the driver via an LED light in the exterior mirror – Refer to Figure 49. This is the most intuitive way to communicate to the driver the presence of a vehicle aside, in fact the driver is used to looking at the external mirror to decide whether or not to change the lane. The system gives a warning by emitting a flashing signal via the LED if the driver has activated the turn indicator in preparation for changing lane, but has overlooked another vehicle in the adjacent lane.

Similarly Mitsubishi announced such a system called side-rear warning system in 1998. It utilized a stereo camera system to detect the objects on the side of the vehicle and their speed. The result was shown to the driver with a graphic display panel [http://media.mitsubishi-motors.com/pressrelease/e/corporate/detail429.html, 1998]. The function was the same but the panel was not as intuitive as Audi's mirror.

When the risk of impact is high the collision avoidance system utilizes the highest level of warning to get the driver to try to avoid the impact, eventually undertaking an emergency manoeuvre. For example a loud alarm sound can raise the driver's attention very quickly. Also the pretensioning of the seatbelt can warn the driver efficaciously (e.g. Mercedes Pre-safe system, Acura CMBS). The system can also activate one or more driver assistance systems, if they are available and even pre-collision devices (pre-collision system functions). Driving assistance systems, like brake assistance systems, can be useful in addition to a collision avoidance system. In fact when the system detects the risk of frontal collision and the driver brakes, the system can easily understand the driver's intention and substitute the uncertain driver's braking action with a reliable automatic braking manoeuvre.

Systems which aim to independently take control to avoid an accident situation intervening when there is insufficient time for the driver to respond are expected within the market by 2015. (Gregoriades 2006).

Road Surface Condition Monitoring Systems

These systems use video or laser scanning to monitor the condition of the road surface ahead and alert the driver/rider of abnormalities. These can be combined with ABS, collision avoidance and speed limiting systems to keep the vehicle parameters in line with the road requirements. Roadside beacons may also be the source of such data (Bayly et al 2006).

Pre-Collision Systems

Pre-collision systems are based on two kinds of devices:
- Pre-collision sensors;
- Passive safety devices to be activated before the impact.

Sensors can be the same used for other safety systems, for example long range radar used for collision avoidance systems or adaptive cruise control. Also video recognition can be used to detect an imminent collision. Short range ultrasound systems can be placed inside the doors or in the rear bumper to detect lateral and rear collisions before the impact.
The system analyses the information from the sensors to predict a collision. When an imminent collision is detected the vehicle and the passengers are prepared in order to mitigate the injuries on the passengers. The reversible safetybelt pretensioners make the passenger adhere to the safetybelt and to the seat, in order to reduce the force needed to retain the passenger in case of impact. Moreover the seat can be automatically moved into a vertical position, in order to avoid the damages produced by the safetybelt in case of incorrect position of the passenger. These operations are very useful for the passengers who do not have their attention on the road and might be caught unprepared for the impact (e.g. they might be out of position) with severe consequences.

**Driver's Vigilance Degradation Systems**

All the safety systems require the driver to work properly. Even the brake assistance systems do not intervene if the driver does not brake (with very few exceptions, e.g. Acura CMBS), so the first thing to monitor should be the driver's vigilance level. These systems undertake such monitoring by means of eye movement camera, grip sensors, lane position monitors and driver input devices. If the driver is deemed to be at a sufficiently low level of arousal, the system provides alerts or stimulation and in some cases takes control of the vehicle from the driver (Bayly et al 2006). Siemens has developed a non-intrusive system based on eyelid movements. IR video image sensors placed on the dashboard and an image processing unit acquire the driver's eyelid pattern (eye blink, slow eye closure), which can give information about the driver's vigilance level (Boverie 2001). Also Mitsubishi has developed a drowsiness control system in which the driver's wakefulness is monitored by the steering controls and vehicle behaviour. If necessary, warning sounds, a stimulating fragrance, and vibration of the seat and steering wheel alert the driver (Mimuro et al undated). Vigilance monitor systems would be very useful for integrated safety systems, subject to achieving a good level of reliability, with the possibility of the responses of the safety devices being differently set for different driver's vigilance levels.

**Pedestrian protection**

Pedestrian protection passive systems which sense a human impact and initiate appropriate systems to mitigate against subsequent injury include:

- **Raised hoods** – These systems raise the car hood/bonnet as a means for preventing impact by the pedestrians head with hard, rigid vehicle structures which can cause serious or fatal head injuries. In the system developed by Autoliv, a sensor is placed in the vehicle’s front bumper which sends signals to two steel bellows which are empty. When a pedestrian is struck the bellows are inflated by gas generators within 60-70ms causing them to raise the rear part of the hood by about 100mm thus providing the pedestrians’ head with a deformable surface on impact. This system is also effective in preventing the pedestrian impacting with the lower part of the windshield – Refer to Figure 50. ([http://www.autoliv.com/alv/connect/Home/What+We+Do/New%20Products/Pedestrian%20Protection#](http://www.autoliv.com/alv/connect/Home/What+We+Do/New%20Products/Pedestrian%20Protection#) and [http://www.sae.org/automag/techbriefs/11-2001/page2.htm](http://www.sae.org/automag/techbriefs/11-2001/page2.htm))

- **Pedestrian Protection Airbags (PPA)** – Autoliv’s PPA comprises an airbag located in each of the A-pillars which are triggered by the same sensor as the raised hood system. The aim of the PPA is to complement the raised hood system by protecting pedestrians from head impacts with hard structures around the windshield. ([http://www.autoliv.com/alv/connect/Home/What+We+Do/New%20Products/Pedestrian%20Protection#](http://www.autoliv.com/alv/connect/Home/What+We+Do/New%20Products/Pedestrian%20Protection#) and [http://www.sae.org/automag/techbriefs/11-2001/page2.htm](http://www.sae.org/automag/techbriefs/11-2001/page2.htm))
5.5 Prioritisation of safety devices

Whilst it is not within the remit of this work task to undertake the prioritisation of safety devices for use within PISa, it is appropriate to report on work already undertaken in this area. The work reported here is that undertaken by Bayly et al (2006) of MONASH University.

5.5.1 Prioritisation criteria

- Although the MONASH study prioritised according to safety, it did recognise that there were other criteria which could also have been used. These are reproduced in Figure 51.
5.5.2 Prioritised list of ITS for motorcycles

- Bayly et al (2006) prioritised the ITS they identified on the following criteria and assumptions:
  - Systems considered to have greater safety benefits were positioned higher on the list.
  - Systems which enhance stability, traction or braking were regarded as the most promising since they address performance across a range of situations. They have therefore been ranked higher than those which address one specific issue such as ISA.
  - Active systems were generally ranked higher than passive systems since preventative technologies were considered to have a greater safety-enhancing effect.
- Systems to address unlicensed or intoxicated riding were regarded as priority since they can influence most types of crashes.

<table>
<thead>
<tr>
<th>System</th>
<th>Purpose</th>
<th>Safety benefits</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic stability program</td>
<td>Maintain traction of the vehicle</td>
<td>Loss of control crashes,</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and off-path on curve crashes</td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Linked braking systems **</td>
<td>Maximise braking force</td>
<td>Prevent frontal collisions and running off-road</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>crashes</td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Anti-lock brakes **</td>
<td>Prevent brakes locking</td>
<td>Most relevant to frontal and object collision</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>crashes</td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Brake assist *</td>
<td>Reduce stopping distances in emergency</td>
<td>Most relevant to frontal and object collision</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td>brakes</td>
<td>crashes</td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Intelligent speed adaptation *</td>
<td>Prevent the vehicle exceeding the speed</td>
<td>Prevent speed related crashes</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td>limit</td>
<td></td>
<td>Cooperative</td>
</tr>
<tr>
<td>Inter-vehicle communication *</td>
<td>Prevent other driver failure-to-see crashes</td>
<td>Multiple vehicle crashes, particularly at</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>intersections</td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Curve speed warnings *</td>
<td>Prevent excessive speeds on curves</td>
<td>Off-path, on curve crashes, which account for 17% of</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>all motorcycle crashes</td>
<td>In-vehicle or</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>infrastructure</td>
</tr>
<tr>
<td>Road surface monitoring</td>
<td>Warn riders of abnormalities in road</td>
<td>Reduce running off-road crashes</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td>surface</td>
<td></td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Roll stability **</td>
<td>Warn riders if tilt of motorcycle is too</td>
<td>Off-path, on curve crashes, which account for 17% of</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td>great</td>
<td>all motorcycle crashes</td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Daytime running lights **</td>
<td>Increase motorcycle conspicuity</td>
<td>All multiple vehicle crashes during daytime</td>
<td>Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Automatic crash notification *</td>
<td>Automatically inform emergency services of</td>
<td>Reduce emergency response times</td>
<td>Passive</td>
</tr>
<tr>
<td></td>
<td>vehicle’s location in the event of a crash</td>
<td></td>
<td>In-vehicle</td>
</tr>
<tr>
<td>Feature</td>
<td>Benefit</td>
<td>Category</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
<td>-----------</td>
<td></td>
</tr>
<tr>
<td>Electronic licensing/Smart cards **</td>
<td>Prevent unlicensed riding</td>
<td>Active</td>
<td></td>
</tr>
<tr>
<td>Alcohol detection and interlock **</td>
<td>Prevent intoxicated riding</td>
<td>Active</td>
<td></td>
</tr>
<tr>
<td>Airbag jackets **</td>
<td>Minimise injury to the rider when thrown from the vehicle</td>
<td>Passive</td>
<td></td>
</tr>
<tr>
<td>Airbags **</td>
<td>Prevent the rider being thrown from the vehicle in front-impact crashes</td>
<td>Passive</td>
<td></td>
</tr>
</tbody>
</table>

Systems that are regarded to show indirect safety benefits

<table>
<thead>
<tr>
<th>Feature</th>
<th>Benefit</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward collision warning</td>
<td>Prevent motorcycle striking objects/vehicles in path</td>
<td>Active</td>
</tr>
<tr>
<td>Adaptive front lighting *</td>
<td>Improve visibility of the road when cornering</td>
<td>Active</td>
</tr>
<tr>
<td>Object detection systems (animal, pedestrian etc.)</td>
<td>Warn driver of objects in path</td>
<td>Active</td>
</tr>
<tr>
<td>Vehicle diagnostics *</td>
<td>Warn driver of vehicle system problems</td>
<td>Active</td>
</tr>
<tr>
<td>Advanced driver assistance *</td>
<td>Reduce rider workload</td>
<td>Active</td>
</tr>
<tr>
<td>Navigation systems **</td>
<td>Reduce rider workload</td>
<td>Active</td>
</tr>
<tr>
<td>Driver vigilance monitoring</td>
<td>Monitor alertness and fatigue in rider</td>
<td>Active</td>
</tr>
<tr>
<td>Emergency lighting systems **</td>
<td>Illuminate vehicle after a crash has occurred</td>
<td>Passive</td>
</tr>
<tr>
<td>Helmet mounted display **</td>
<td>Minimise need for riders to take eyes off road</td>
<td>Active</td>
</tr>
<tr>
<td>Rear-view helmet **</td>
<td>Increase riders field of view</td>
<td>Prevent side-swipe and rear-end crashes</td>
</tr>
<tr>
<td>---------------------</td>
<td>-------------------------------</td>
<td>-----------------------------------------</td>
</tr>
<tr>
<td>Impact sensing cut-off systems</td>
<td>Prevent electrical and fuel systems igniting in a crash</td>
<td>Prevent minor injury crashes becoming serious or fatal</td>
</tr>
<tr>
<td>Pop-up bonnet systems</td>
<td>Cushion impact of upper body with car bonnet</td>
<td>Minimise injury in vulnerable road user collisions</td>
</tr>
<tr>
<td>External airbag</td>
<td>Cushion impact of rider with other vehicle</td>
<td>Minimise injury in vulnerable road user collisions</td>
</tr>
</tbody>
</table>

* Have been trialed in motorcycles
** Commercially available for motorcycles
† Commercially available as part of Xtreme Beam system only

**Figure 52: Prioritised list of ITS for motorcycles by Bayly et al (2006)**
6 Rider / driver issues

6.1 Summary
In developing a PTW ISS it is important that it is ‘needs-driven’ in terms of:
- What accident scenarios need to be addressed,
- What technologies best meet these needs and
- What rider/driver factors need to be considered in relation to the above two aspects to ensure an optimal solution.

This section is concerned with the final point above and therefore considers the role of the rider/driver in relation to accident scenarios and the implementation of technological solutions.

6.1.1 Use of PTWs
This section discusses aspects concerning the way in which PTW’s are used.

The role of the PTW
In Europe there is a mix of the use of PTW’s for both leisure and work use. Whilst there is an element of both in most countries, the leisure role is more strongly associated with Austria, Belgium, Italy and The Netherlands and the work use with France, Greece, Portugal, Spain, UK (based on the days of the week of accident occurrence) (Stefan et al 2003). At a global level, there is the view that in the West, motorcycle use may be more recreational, whilst in developing countries it is more commuting or utilitarian travel (Quddus et al 2002). A further difference at this level is the increasing prevalence for pillion passengers (frequently more than one at a given time), in the developing economies. (Milton 1996 and Quddus et al 2002)

PTW manoeuvres
Various studies discuss the increased manoeuvrability of PTW’s in traffic describing the activities undertaken by PTW riders which differ to those undertaken by four-wheeled road users. The study by Clarke et al (2004) suggests that such manoeuvres can be inherently more risky especially when combined with a lack of appreciation by other road users of them.

6.1.2 Age and gender

Age and gender data
According to the OECD (undated), older rider (25-64) fatalities are increasing and they state that recent data, especially from the US, confirms that most people affected by this shift are male riders aged 40+ who have returned to motorcycling, having given up after their teens, who are purchasing more powerful bikes over 1000cc. Other research confirms the prevalence of male riders older than 25 (peak age 31-35 by Clarke et al (2004); Peak age 30-34 with the main increase in fatalities for the 30-49 year group by Broughton (2005), 25-30 by Wick et al (1998) and 26.4±7.2 for Lateef (2002)). However Clarke et al (2004) state a further peak age group at 21-25 whilst Zambon & Hasselberg (2006) found that there was no effect of age on injury severity.

Age only data
The MAIDS study suggests that 18-21 and 22-25 years olds are over-represented in PTW accident statistics whilst those aged 41-55 are under represented. (Other groups were neither under or over represented or there was insufficient data to determine this) (ACEM
2004). From the CARE-Database, Stefan et al (2003) found that across Europe the age of accident involved riders is increasing – for some countries those <30 years still dominate, for other the spread is uniform across age groups. Huang and Preston (2004) note that there has been an increase in the age of rider casualties (between 1982 and 2002, the number of casualties aged 30-39 years rose from 8 to 33%). This is supported by Elliott et al (2003) who also state that fatalities for those aged 30-39 and 40-49 rose by nearly 2.5 times and 1.7 times respectively between 1980 and 1997. Both studies acknowledge the potential of the ‘Return to motorcycling’ rider to be a contributor to these statistics. However a study by Sexton et al (2004) found that increasing age (distinct from experience) significantly influences a rider’s accident liability which falls by 70% between the ages of 17 and 60 and that there was no evidence of those returning to riding after a long break being at greater accident risk.

A further age-related finding was that within Europe, moped riders tend to be younger (less than 25 years (APROSYS 2004) and 58.7% of moped/mofa operators under 21 years (ACEM 2004), whilst motorcycle riders tend to be older (25-35 years (APROSYS 2004) and 88.1% of motorcycle riders over 21 years (ACEM 2004)).

6.1.3 Rider characteristics

General findings

Whilst the MAIDS study provides a couple of insights into rider behaviour, it is a study by Clark et al (2004) which gives a more comprehensive overview. They list a number of behavioural countermeasures which could have made a substantial difference to the outcome of each accident. They conclude that:

- The top three actions that could be taken by motorcyclists to reduce accident rates and/or severity are travelling at an appropriate speed for the conditions, not overtaking near a junction or entrance or travelling slower around a bend.
- For younger riders, who tend to ride smaller PTW's, there appears to be a problem with them either following too close to the vehicle in front or their machines having less effective brakes than larger PTW's.

Horswill and Helman (2001a) found that motorcyclists chose faster speeds than the car drivers, overtook more and pulled into smaller gaps in traffic. (Huang and Preston 2004).

Age/gender

Based on survey data, a study undertaken in Melbourne, Australia, found that age and experience interacted with the following behavioural aspects: Observational skills, approaching intersection, position on roadway, following distance, response to tail-gating, using the horn and dealing with emergency situations.

A study by Chang and Yeh (2007) found the following relationships:

- Disregard of traffic regulations associated with young and male riders
- Negligence of potential risks associated with young riders
- Negligence of motorcycle safety checks associated with young riders
- Increased accident risk due to poor skills especially associated with young, female riders
- Increased accident risk due to reduced experience especially associated with young, female riders

Alcohol
Alcohol involved riders were over-represented in the MAIDS accident population and the unadjusted odds of being involved in an accident when the rider is under the influence of alcohol is 2.7 times greater than when they are not. (ACEM 2004).

Huang and Preston (2004) state that the motorcycle running off the road is the most common type of fatal accident, accounting for 41% of the total. These are often late night, weekend crashes involving a drunken motorcyclist (Preusser et al, 1995).

Alcohol impairment has also been related to speeding and non-use of crash helmets. (Zambon & Hasselberg 2006 and Huang and Preston 2004).

**Motivations and attitudes**

In terms of motivations for riding, a study by Schulz et al (1991) reported in Elliott et al (2003) found three distinct categories of rider:

- Those who bike for pleasure (related to motivations of escapism, hedonism, flow, identification with the bike and socialisation factors),
- Those for whom biking is a fast, competitive sport (related to motivations of dynamic aspects, performance aspects, exhibition riding, thrill seeking and rivalry)
- Those who like to have control over the bike (related to motivations of control beliefs and safety behaviour)

A study by Walters (1982) of 100 in-depth interviews of motorcyclists motivations and attitudes towards riding, also reported by Elliott et al (2003), similarly concluded that there were three main categories of rider: Enthusiasts who rode for pleasure (48%), Practical users (35%) and Irresponsible users (10%). The remaining 7% could not be classified.

Studies by Hobbs et al (1986) and Schulz and Kerwein (1990), in Elliott et al (2003), both stated the belief of some motorcyclists that accident responsibility rests to some extent with other drivers.

A study by Clarke et al (2004) found riders have a relaxed attitude to breaking the speed limit but recognise the significance of riding too fast for the conditions. After speeding, risk-taking activities were the next most cited cause of accidents and was considered to cover: deliberate close following, risky overtaking manoeuvres, ignoring road signals/signs and riding under the influence of alcohol or when tired. The study reports from the literature that age is the most important factor in risk taking stating that young riders are far more likely to be accident involved.

**Experience**

The MAIDS study found that riders with less than six months experience had the greatest risk of PTW accident involvement and that typically more experienced riders are less likely to be the primary contributory factor of an accident. This is corroborated by Sexton et al (2004) who, based on a UK survey of 11,360 motorcyclists, found that riding experience is negatively related to accident liability.

**6.1.4 Use of braking systems**

Evidence from MAIDS, APROSYS and Thom et al (1985) suggests that braking is often employed as a collision avoidance measure but is not always effective. There may be a number of reasons for this including insufficient time for the resultant braking to be effective, incorrect use of the brakes, insufficient force applied, etc. An appreciation of some of the usability aspects of the brakes may inform the design of braking and other systems within PIsa.
Problems in brake use have been identified as:

- Braking strategies which do not employ both front and rear brakes simultaneously,
- Poor practice which carries over from non-emergency into critical situations leading to reduced performance e.g. use of rear brakes only (Mortimer 2002 and Seppard et al 1985 in Huang and Preston 2004)
- Conflicting use of one hand for both throttle and braking control (Thom et al 1985)

Since both accident data and surveys indicate that there is a lack of understanding in how to effectively use the brakes (Hagstotz & Ludsteck 1995 and Fries et al 1989), recommendations have been made for improved rider training to ensure that motorcyclists are able to make best use of the system(s) and the circumstances in which they should be applied (Huang & Preston 2004 and Eberspächer 1991).

The key lesson to learn from this analysis for PISa is that whatever systems are implemented, they need to be as intuitive to use as possible and full consideration should be given to the content and form of training. Guidance in this respect is provided in the following sections.

6.1.5 Cognitive psychology theories

In providing guidance for the appropriate HMI design within PISa, a summary of cognitive psychology theories which discuss ways in which information is processed efficiently is presented as a foundation for future developments.

Since it is important that the interface design for rider IS systems is not distracting and does not overload the rider, appropriate interface design needs to consider a range of factors relating to cognitive processing. Rider attention is a limited capacity resource therefore the interface design should seek to minimise the attentional demands placed on the rider.

Humans process information in either a controlled or automatic mode. Automatic processing is advantageous in that processes will be fast, requiring few resources, thus enabling other tasks to be carried out in parallel. However, the unavoidable nature of automatic processes may be undesirable in situations where an alternative, novel response is required e.g in unintentional acceleration incidents. Parallel processing occurs when two or more information sources/elements are processed simultaneously and so has the obvious advantage of reducing the overall processing time.

Several basic mechanisms which influence how well two or more tasks can be timeshared are discussed: Appropriate scheduling, reduced confusion, task co-operation and reduced competition. In addition, practical theories of timesharing performance are discussed including:

- Multiple resource theory which discusses the reduction in task conflicts by consideration of their – Cognitive stages, input modalities, output modalities and methods of processing.
- Compatibility Principles which consider how the forms of display, response and processing best combine together.
- Proximity Principles which define how best to present two or more information sources for efficient processing.
6.1.6 HMI

Guidelines/principles

One of the main sources of widely-agreed human-machine interface (HMI) guidelines is the ‘European Statement of Principles (ESoP) on the Design of Human Machine Interaction’ the most recent version of which was published in June 2005 by the European Commission.

Whilst the scope of the principles concerns in-vehicle information and communication systems intended for use by the driver while the vehicle is in motion; they are directed to navigation systems, traffic information, etc and not ABS, ESC or ADAS since these are fundamentally different and require additional considerations in terms of Human Machine Interaction. However whilst the ESoP does not directly apply to IS Systems, it does provide some basic principles which are of relevance to PISa.

The ESoP covers:

- Design goals
- Section 3: Information Presentation Principles
- Section 4: Principles on Interaction with Displays & Controls
- Section 5: System Behaviour Principles
- Section 6: Principles on Information about the System
- Recommendations on Safe Use (RSU) 2005 providing guidance for employers, point-of-sale, vehicle hire companies and drivers themselves.

Equivalents to the ESoP exist in the U.S. and Japan.

In addition, NHSTA in the US have produced guidelines for Crash Warning Systems Interfaces (Campbell et al 2007) which cover:

- Chapter 2: General guidelines for CWS design
- Chapter 3: Auditory warnings
- Chapter 4: Visual warnings
- Chapter 5: Haptic warnings
- Chapter 6: Controls used in CWS devices
- Chapter 7: Forward collision warning systems
- Chapter 8: Lane change warning systems
- Chapter 9: Road departure warning systems

Standards

The International Standards Organisation (ISO) has two working groups (WGs) responsible for developing standards for advanced driver technologies. Published Standards and Standards under development are provided for:

- ISO TC22 (Road Vehicles) SC13 (Ergonomics applicable to road vehicles) WG8 (Transport information and control systems, on-board Man-machine interface)
- Working Group Full title: ISO TC 204 (Intelligent transport systems) WG 14 (Vehicle/roadway warning and control systems)

Evaluation methods/measures

The most current reviews of methodological approaches are provided by two 6th Framework IST Programme projects:

- HUMANIST (http://www.noehumanist.org/start.htm)
- AIDE (http://www.aide-eu.org/index.html)
The deliverables of relevance to PISa are:

- HUMANIST deliverable D.2/E.2 (2004), Impact of IVIS on driver workload and distraction: review of assessment methods and recent findings. (Metrics of relevance cover: Lane standard deviation, Time to line crossing (TLC), Time headway, Minimum following distance, Brake response time, Glance duration, Glance frequency and Visual occlusion).
- AIDE deliverable 2.2.5 (2004), Driving performance assessment – methods & metrics. (This covers: speed, lateral position, time to line crossing, headway, brake, steering grip and steering wheel movements as well as an in-depth section on the Lane Change Test).
- AIDE deliverable 2.1.1 (2004), Driving performance assessment – methods & metrics. (This covers methodological issues relating to user-centred design approaches and includes: User mental model and requirements, Usability and acceptance, Workload, Situation awareness. It also assesses environments varying from Laboratory testing to naturalistic driving).

6.1.7 Driver issues – ‘Looked-but-failed-to-see’

This section of the report looks more closely at the actions of other vehicle drivers especially with respect to the ‘Looked-but-failed-to-see’ in order to determine what factors might be applied to motorcycles to assist other drivers in such circumstances.

**Cognitive processing**

The model of processing visual stimuli covers the stages of detection, identification, decision and reaction. ‘Looked-but-failed-to-see’ errors are associated with the first two stages i.e. not seeing the motorcyclist or seeing the motorcyclist and misinterpreting what is being seen. It is the detection stage which is most associated with conspicuity since the more conspicuous an object is the more likely a road user is to detect it.

**Definitions of conspicuity**

In a general sense, visual conspicuity refers to the ability of an object to attract attention and to be easily located, due to its physical properties (e.g., Engel, 1976 in Wulf et al 1989). More precise definitions include:

- ‘Attention’ conspicuity - This refers to an object’s potential to attract attention when it is not specifically being searched for. (Hughes and Cole 1984 in Wulf et al 1989).
- ‘Search’ conspicuity - This occurs when the observer is cued as to some aspect to search for (Hughes and Cole 1984 in Wulf et al 1989). Such precursors may relate to the type of object, when it may appear in the visual field and where.
- Sensory conspicuity – This relates to the physical properties of the object. (Wulf et al 1989)
- Cognitive conspicuity This refers to the interests and experience of the observer. (Wulf et al 1989)

**Factors affecting detection**

A number of factors affecting detection are discussed including:

- The Expectancy phenomenon which postulates that objects not frequently encountered on the road are less likely to be detected. (Australian Motorcycle Council, 1984; Fulton et al, 1980; Nagayama et al., 1975, Wulf et al 1989).
- The cost of detection failures refers to the concept that drivers may pay more attention to vehicles larger than them than to smaller ones due to the greater potential threat that these pose. (Wulf et al 1989).
• Tunnel vision refers to the reduced processing ability generally, and of peripheral vision specifically, due to the increased workload brought about by processing visually complex scenarios e.g. driving in urban traffic. (Mackworth 1965 in Wulf et al 1989).
• The smaller relative size of motorcycles makes them more difficult to detect especially head-on. (Huang & Preston 2004).

Factors affecting identification

• Having detected the motorcycle, the driver must then determine what it is they have detected and its characteristics in order to make an appropriate response. Research suggests that failures can occur at this stage of processing. (Brooks 1988).
• Even if the driver does identify the motorcyclist correctly, they may make incorrect judgements about its rate of approach which may again lead to an unsafe manoeuvre being undertaken.
• Solutions to these types of errors are discussed in Deliverable 2.

6.2 Use of PTW

6.2.1 The role of the PTW

• Within Europe, mopeds are a common form of transport since they are convenient to use, affordable and accessible by a range of the population. Although their engines are limited to a maximum of 50cc, generating speeds of up to 45km/h, they are effectively used in congested cities. They are a popular choice for those starting to engage in independent travel and often provide the foundation to subsequent motorcycle use. (ACEM 2005).

• Using CARE data Stefan et al (2003) have classified PTW use into three types across European countries:
  - Leisure role where there are more accidents at weekends than through the week (Austria, Belgium, Italy and The Netherlands)
  - Everyday use where accidents are predominantly on weekdays (France, Greece, Portugal, Spain, UK)
  - No specific pattern due to low accident figures (Finland, Sweden)

• A survey of 800 PTW riders at motorcycle shows in Germany, Schultz and Koch (1991) found that 47.8% used their bike for mainly leisure purposes and remainder used it half for work and half for pleasure.

• In the West, motorcycle use may be more recreational, whilst in developing countries it is more commuting or utilitarian travel (Quddus et al 2002). This is supported by the Freedonia Group (2005) who state that in the emerging Asian economies motorcycles are viewed as primary family and work vehicles. In industrialized nations, motorcycles are seen as pleasure vehicles.

• Milton (1996) noted that within Singapore in many cases more than two people are carried on a motorcycle and sometimes up to seven may travel together, although pillion passengers are rare in western countries (Quddus et al 2002).

6.2.2 PTW manoeuvres

• The high speed, acceleration and manouevrability of motorcycles provides their riders with opportunities for overtaking and other manoeuvres which present increased accident risk especially in conjunction with young riders. Other drivers contribute to the risk since they fail to appreciate the increased flexibility of PTW’s over four-wheeled forms of transport within the traffic flow. (Clarke et al 2004).
Robertson (2002), in a paper regarding motorcycling and its effects on congestion, describes a range of behaviours specific to PTW's in urban traffic and the manoeuvres made to make journey times shorter. Such behaviours are important to classify as any safety systems introduced must be able to operate within the normal range behaviours of PTW riders. The behaviours identified and described were:

- Moving to the head of a queue of traffic
- Filtering – nearside, offside and centre when the traffic is stationary
- Filtering – nearside, offside and centre when the traffic is moving
- Lane changing behaviour when the PTW moves through streams of traffic that are moving at different speeds to make progress
- Inaction – when the PTW fails to take opportunities to progress using one of the above
- Balking – when progress is impeded by another vehicle placing itself actively or passively in a position to prevent the PTW from making progress
- Wriggling – where the PTW riders move around stationary vehicles/objects that are balking progress. This occurs specifically in stationary traffic and is often characterised by very slow speeds and the PTW often being at least 45 degrees or nearly at right angles to the normal flow of traffic.

However it was noted that this study was undertaken in the UK where there is a low proportion of PTW’s to other road users. The behaviour of PTW riders in other environments where there is a different proportion of PTW to other vehicles may change.

A study by Huang and Preston (2004) found that cruising speeds of motorcyclists are somewhat higher, they overtake more often and they use smaller gaps in traffic. They do, however, not ride closer to the vehicle in front of them than do other road vehicles.

6.3 Age and gender

6.3.1 Age and gender

Based on OECD figures, in 1990 the 25-64 age group represented around 50% of motorcyclists killed rising to 70% in 2000. Refer to Table 4 below. Recent data, especially from the US, confirms that most people affected by this shift are male riders aged 40+. These represent those returning to motorcycling having given up after their teens who are purchasing more powerful bikes over 1000cc (OECD undated).

<table>
<thead>
<tr>
<th>Country</th>
<th>Fatalities by age group (%) changes between 1990-2000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15-20 years</td>
</tr>
<tr>
<td>France</td>
<td>23% to 8%</td>
</tr>
<tr>
<td>UK</td>
<td>31% to 10%</td>
</tr>
<tr>
<td>US</td>
<td>18% to 9%</td>
</tr>
</tbody>
</table>

Clarke et al (2004) in their examination of motorcycle accidents in Scotland have identified two clear peaks in casualty age – 21-25 and 31-35. In addition, they state that, based on limited exposure data, males are over-represented.
Based on UK data drawn mainly from 1990s and early 2000s, the characteristics of fatally injured motorcyclists include:
- Riders (only 5.2% were passengers)
- Male (96.8% of riders)
- Peak age group of 30-34 years
- Main increase in fatalities occurred for the 30-49 year group (Broughton 2005)

Wick et al (1998) report on a sample of 86 motorcyclists injured in road traffic accidents in Germany during 1992 which warranted admission to a trauma centre. They found that 90.7% of the sample were male and most of them (30%) were aged 25-30 years, with an average age of 28.8 years.

A survey of 800 PTW riders at motorcycle shows in Germany (Schultz and Koch 1991) found that 89.2% were male with an average age of 27.7 years. They also noted that younger riders were more likely to be accident involved than older riders.

Zambon & Hasselberg (2006) looked at a range of factors which may affect the severity of motorcycle injuries in Sweden using police accident data and data from the population and housing census. They found that there was no effect of age or gender on the injury severity of motorcycle riders when factors related to the individual, the environment, the vehicle, and the crash were considered as exposure measures.

A study by Lateef (2002) collected data on 1,809 motorcyclists admitted in an Emergency Department in a hospital in Singapore in 2000-01. The mean age was 26.4±7.2 years and 95.9% were male.

6.3.2 Age only

The findings with respect to PTW rider age and accident involvement from the MAIDS study are summarised below. The study also found that riders less than 21 were the primary contributing factor 42% of the time, for riders over 21 this was less than 37% (ACEM 2004)

<table>
<thead>
<tr>
<th>Age group</th>
<th>Finding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 15</td>
<td>Neither under or over represented</td>
</tr>
<tr>
<td>16-17</td>
<td>Neither under or over represented</td>
</tr>
<tr>
<td>18-21</td>
<td>Over represented</td>
</tr>
<tr>
<td>22-25</td>
<td>Over represented</td>
</tr>
<tr>
<td>26-40</td>
<td>No interpretation provided</td>
</tr>
<tr>
<td>41-55</td>
<td>Under represented</td>
</tr>
<tr>
<td>&gt;56</td>
<td>No interpretation provided</td>
</tr>
</tbody>
</table>

Within Europe, moped riders tend to be younger (<25 years), whilst motorcycle riders tend to be older (25-35 years) although this is increasing in Germany to 35-45 years. The difference in the riding age between the two PTW types is also reflected in the casualty statistics (illustrated by Spain). In the Netherlands, 50% of urban moped victims are 14-18 and do not use helmet (APROSYS 2004)

58.7% of moped/mofa operators were under 21 years, while 88.1% of motorcycle operators were over 21 years (ACEM 2004)
• It is a common assertion in European countries that young people are prone to motorcycle and moped fatal accidents. This is borne out in data for 2002 in which more than 32% of motorcycle/moped occupant fatalities were those aged 25 years or less compared to 28% for car/taxi occupants (SafetyNet 2004)

• A study by Clarke et al (2004) examined 1,790 police accident files where a motorcyclist was involved. They conclude that there are two main groups of riders that interventions should be focussed on:
  - Young and inexperienced riders of smaller capacity machines such as scooters.
  - Older and more experienced riders of higher capacity machines.

• In their review of research into motorcycle accidents covering several countries over a long period of time, Huang and Preston (2004) note that there has been an increase in the age of rider casualties. Between 1982 and 2002, those aged 20 or under fell from 49% to 12% of casualties whilst for those aged 30-39 the casualty numbers had risen from 8% to 33% between these dates. Huang and Preston (2004) acknowledge that there is some statistical support for anecdotal evidence that the born again motorcycle rider is becoming a casualty feature although further work is needed to verify its extent and nature.

• From the CARE-Database, Stefan et al (2003) found differences between countries of the age of riders involved in accidents:
  - In Austria from 1992-1994 most injured riders were aged 18-21 years. After 1995 this shifted to those aged 23-28.
  - In Belgium the situation was similar to Austria with age groups up to 50 showing an increased involvement in PTW accidents.
  - In Denmark, there were high accident figures in the 18-23 age group in the early nineties with the risk becoming more evenly spread across age groups in recent years.
  - In Finland more than 40% of motorcycle riders suffering injuries are aged 16-18 years. This is due to those in Finland aged 16 being able to ride PTWs with an engine capacity of up to 125cc whereas in most other member states these types of PTW have stricter riding regulations.
  - The distribution in France shows a significant shift in injured PTW riders towards the older age groups. In 1991 the highest risk group was those aged 18-28 years but in 2001 it was those aged 23-31.
  - In Greece the probability of young people being involved in a PTW accident has risen dramatically in recent years (after 1995) with those aged up to 50 also showing a rising accident involvement.
  - In Italy there were high numbers of injured PTW riders aged 18-24 in the early nineties. This then shifted to those aged 17-20 years and then dissolved after 1996, with an even spread of injury risk.
  - There is no discernable spread of injury risk by age in Luxembourg due to small accident numbers.
  - In the Netherlands, the highest risk was for those aged 20-30 years up to 1999 (there was no data for 2000 and 2001).
  - The probability for those aged 17-28 of being involved in an accident in Spain decreased significantly since 1994. The risk was replaced by a uniform spread across ages by 2001.
  - In Sweden prior to 1993 those aged 16-25 were at a greater risk of injury but by 2001 there was no specific age group at risk.
  - In the UK after 1992 and until 2001 the accident risk became spread across all ages.
Across Europe the age of accident involved riders is increasing – for some countries those <30 years still dominate, for other the spread is uniform across age groups (Stefan et al 2003)

Based on survey responses from 11,360 UK motorcyclists, it was found that:
- Younger riders were found to be at much higher risk of accidents than older riders
- Increasing age (distinct from experience) significantly influences a rider’s accident liability which falls by 70% between the ages of 17 and 60
- There was no evidence of those returning to riding after a long break being at greater accident risk (Sexton et al 2004)

A study by Clarke et al (2004) examined 1,790 police accident files where a motorcyclist was involved. They found that accidents could be classified into three types where the motorcyclist was fully or partly to blame and these were analysed with respect to age:
- Right of way violations – Young riders (16-20) were more likely to be at fault.
- Bends – Those aged 26-30 had an increased propensity to loose control at bends.
- Overtaking/filtering – Those aged 51-55 were underrepresented whilst those aged 56-60 were over-represented but these results may have been influenced by small sample sizes.

Based on UK statistics, in 1980 more than 50% of motorcycle casualties were aged 20 years or less compared to less than 20% being 30 years or more. By 1997, this trend had reversed with 20% of motorcycle casualties aged 20 years or less and 50% aged 30 years or more. More mature riders of larger motorcycles are a major feature in the casualty statistics – Fatalities for those aged 30-39 and 40-49 rose by nearly 2.5 times and 1.7 times respectively between 1980 and 1997 and it may be that a large proportion are those returning to riding (Elliott et al 2003)

In Greece, a study was undertaken to investigate PTW use and accidents in 1995. It was found that there was no relationship between age and accident severity until riders were aged over 50, rising sharply for those aged over 70. (Frantzeskakis 1998)

Rider fatalities are greatest in the 20-29 age group. Rider fatalities in the 40+ age group are increasing with 40-49 approaching that of 20-29 (Shankar and Varghese 2006 - US) Gender only

Within the MAIDS study, when accident involved riders were compared against the exposure group, neither male nor female riders were under or over-represented (ACEM 2004)

6.4 Rider characteristics

6.4.1 Behaviour

General findings

Aspects pertaining to the MAIDS study which arose relating to rider behaviour were:
- 71.2% of PTW riders attempted to avoid the collision immediately prior to impact and of these 31% experienced a loss of control.
- Traffic control violations were involved in 8% of PTW cases and 18% of other vehicle driver cases (ACEM 2004)

A study by Clarke et al (2004) examined 1,790 police accident files where a motorcyclist was involved. Within this study, the researchers considered any simple behavioural countermeasures which could have made a substantial difference to the outcome of each accident. Table 6 shows the percentage of cases where each of the
19 countermeasures could have made a difference to the accident outcome, considered both from the point of view of the PTW rider and the other drivers or riders involved in the accident.

Table 6: Effective countermeasures for accident-involved motorcyclists (Clarke et al, 2004)

<table>
<thead>
<tr>
<th>Countermeasure</th>
<th>All motorcyclists</th>
<th>All other drivers/riders</th>
<th>Riders &lt; 25 years</th>
<th>Riders &gt; 25 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>2.2</td>
<td>25.4</td>
<td>3.42</td>
<td>1.3</td>
</tr>
<tr>
<td>Stop at junction</td>
<td>1.3</td>
<td>4.9</td>
<td>1.28</td>
<td>1.3</td>
</tr>
<tr>
<td>Right re-check</td>
<td>-</td>
<td>4.8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Approaching traffic speed check</td>
<td>0.7</td>
<td>3.0</td>
<td>0.85</td>
<td>0.3</td>
</tr>
<tr>
<td>Speed check/junction</td>
<td>9.9</td>
<td>0.2</td>
<td>11.1</td>
<td>8.6</td>
</tr>
<tr>
<td>M/C position</td>
<td>5.8</td>
<td>-</td>
<td>5.13</td>
<td>6.0</td>
</tr>
<tr>
<td>Safe distance</td>
<td>7.3</td>
<td>2.3</td>
<td>11.5</td>
<td>5.6</td>
</tr>
<tr>
<td>Distraction</td>
<td>7.3</td>
<td>2.3</td>
<td>9.4</td>
<td>5.6</td>
</tr>
<tr>
<td>Look ahead</td>
<td>0.9</td>
<td>0.2</td>
<td>0.43</td>
<td>1.3</td>
</tr>
<tr>
<td>Speed for conditions</td>
<td>19.0</td>
<td>0.5</td>
<td>20.5</td>
<td>17.9</td>
</tr>
<tr>
<td>Speed for bend</td>
<td>14.7</td>
<td>0.9</td>
<td>11.54</td>
<td>16.3</td>
</tr>
<tr>
<td>Position on bend</td>
<td>3.2</td>
<td>0.2</td>
<td>2.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Brake on bend</td>
<td>0.7</td>
<td>-</td>
<td>-</td>
<td>1.3</td>
</tr>
<tr>
<td>Mirrors &amp; blind spot</td>
<td>0.6</td>
<td>21.0</td>
<td>0.85</td>
<td>0.3</td>
</tr>
<tr>
<td>Indication</td>
<td>0.6</td>
<td>4.0</td>
<td>0.43</td>
<td>0.7</td>
</tr>
<tr>
<td>Overtake at junction</td>
<td>16.4</td>
<td>1.1</td>
<td>12.0</td>
<td>19.9</td>
</tr>
<tr>
<td>White line cross</td>
<td>0.6</td>
<td>0.4</td>
<td>0.43</td>
<td>0.7</td>
</tr>
<tr>
<td>Filtering caution</td>
<td>7.3</td>
<td>0.2</td>
<td>6.8</td>
<td>7.6</td>
</tr>
<tr>
<td>Speed-overtakes</td>
<td>1.3</td>
<td>0.5</td>
<td>1.3</td>
<td>1.3</td>
</tr>
</tbody>
</table>

- The authors conclude that:
  - The top three actions that could be taken by motorcyclists to reduce accident rates and/or severity are travelling at an appropriate speed for the conditions, not overtaking near a junction or entrance or travelling slower around a bend.
  - For younger riders, who tend to ride smaller PTW’s, there appears to be a problem with them either following too close to the vehicle in front or their machines having less effective brakes than larger PTW’s.
- For the other driver/rider involved, the top three actions would be to ensure foreground to distance is properly checked (vision), check blind spots and mirrors immediately before manoeuvring and to come to a stop at junctions, especially if the view is in doubt.

- Horswill and Helman (2001a) analysed the behaviour of the motorcyclists in a laboratory environment. They found that motorcyclists chose faster speeds than the car drivers, overtook more, and pulled into smaller gaps in traffic, though they did not travel any closer to the vehicle in front. The speed and following distance findings were reproduced by two further studies where cars and motorcycles were unobtrusively measured from the roadside (Huang and Preston 2004).

- In a UK study of 11,360 motorcyclists, it was found that:
  - The reported frequency of errors was the most important contributor to accident involvement
  - Traffic errors associated with failures of hazard perception or poor observational skills were the most consistent predictors of accident liability.
  - Riding style, getting pleasure from motorcycling, and liking for speed predict behavioural errors that predict accidents
  - Control errors concerning difficulties with control at high speed or errors in speed selection and stunt.Speeding (violation) behaviours were also important liability predictors in some analyses (not specified) (Sexton et al 2004)

**Age/gender**

- A study undertaken in Melbourne, Australia, investigated 222 motorcycle crashes occurring on public roads (Late November 1995 to End of January 1997) where rider or passenger was taken to a participating hospital or died (Haworth et al 1997). To account for exposure, 1195 motorcyclist trips which had passed the crash site at the same time of day and day of week that the crash occurred were used as controls. A questionnaire was applied to collect data on the accident, the motorcycle and the rider (experience, riding strategies, use of alcohol/medication, etc). Since this data was self-reported and could not be verified, only information provided by the controls was used to investigate riding strategies since there had previously been found to be evidence of socially desirable responding by accident-involved riders. Although riding strategies employed were similar across rider age groups, experience, licence status and training history, differences were noted as summarised below:
Table 7: Age and rider behaviour patterns

<table>
<thead>
<tr>
<th>Observational skills</th>
<th>Frequency of looking behind over one shoulder:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- decreased with age group</td>
</tr>
<tr>
<td></td>
<td>- was more common with training</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Approaching intersection</th>
<th>Inexperienced riders were more likely to decrease speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trained riders were more likely to change position to improve visibility</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Position on roadway</th>
<th>Younger riders and riders with training less likely to travel in the left-hand and more likely to travel in the right-hand wheel track (safer)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Following distance</th>
<th>Longer gaps left for inexperienced riders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shorter gaps for 25-34 year old riders</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Response to tail-gating</th>
<th>Learner and probationary riders and riders with training less likely to speed up</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Using the horn</th>
<th>More by experienced riders</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Dealing with emergency situations</th>
<th>More near misses usually experienced per month by experienced riders (who rode more)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Youngest age group report most usual number of near misses per month</td>
</tr>
<tr>
<td></td>
<td>Inexperienced and trained riders more likely to have practised emergency braking and/or counter-steering in the last 6 months</td>
</tr>
<tr>
<td></td>
<td>Riders with probationary licences were the most confident about performing sudden swerves in emergency situation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Usefulness of training</th>
<th>Riders aged 35 and over were likely to use cornering skill learnt in training ‘always’</th>
</tr>
</thead>
</table>

- In 2001, 1,451 motorcycle owners were surveyed to investigate age, gender and riding behaviour and their relationship to accident involvement. It was found that young and male riders were more likely to disobey traffic regulations whilst young riders generally were negligent of potential risk and motorcycle safety checks. In addition poor skills and reduced experience increase the risk, especially for young, female riders. Since most riders are self-taught, the provision of an appropriate training system and a low risk environment for novice riders is recommended (Chang and Yeh 2007).

- **Alcohol**

- Alcohol involved riders were over-represented in the MAIDS accident population and the unadjusted odds of being involved in an accident when the rider is under the influence of alcohol is 2.7 times greater than when they are not. (ACEM 2004).

- A study by Clarke et al (2004) examined 1,790 police accident files where a motorcyclist was involved. They found that:
  - Alcohol impairment is a greater factor for at-fault motorcyclists (3.4% of accidents in the sample) compared to at-fault drivers (1.3%).
  - Impaired riders are significantly more likely to be younger than other ‘at-fault’ riders.
- Riding over the speed limit, loss of control and riding without a safety helmet are all more prevalent with impaired riders.

- Huang and Preston (2004) state that various studies in several countries covering a long period of time show that for fatal accidents, motorcycle running off the road is the most common type, accounting for 41% of the total. These are often late night, weekend crashes involving a drunken motorcyclist (Preusser et al., 1995). As solo accidents without collision with another vehicle only account for a small proportion of total accidents, it appears that impairment has a much more deadly effect on motorcyclists.

- Based on data from the Fatality Analysis Reporting System (FARS), the National Highway Traffic Safety Administration found that between 1995-2004, alcohol related rider fatalities are declining (42% in 1995 to 34% in 2004). However whilst the National Highway Traffic Safety Administration defines a fatal traffic accident as alcohol-related if a driver/rider/pedestrian has a blood concentration (BAC) of 0.01 grams per decilitre (g/dL), in 2004 81% motorcycle operator fatalities had BAC levels of 0.08+g/dL suggesting that even though alcohol-related accidents are declining, there is still a strong underlying problem (Shankar and Varghese 2006).

- Based on data from the National Highway Traffic Safety Administration, Huang and Preston (2004) further state that alcohol impairment is more likely to result in speeding by the motorcyclist and non-use of their crash helmet.

- Zambon & Hasselberg (2006) looked at a range of factors which may affect the severity of motorcycle injuries in Sweden using police accident data and data from the population and housing census. The factor with the strongest relationship to injury severity was positive suspicion of alcohol consumption. It is discussed that alcohol consumption may lead to other risky behaviours such as non-helmet use and high speed. One study in Sweden found that among riders not wearing a helmet at the time of a fatal crash, 9 out of 10 were under the influence of alcohol.

- Based on an analysis of 717 UK fatal accidents involving motorcycles occurring between 1986 and 1995, alcohol was found to have a prominent role in fatal and serious accidents for which riders were responsible (Lynam et al 2001).

6.4.2 Motivations and attitudes

- In a study by Elliott et al (2003), a survey of 376 motorcyclists’ motivations to ride by Schulz et al (1991) is reported. Analysis of the survey results found that three distinct categories of rider could be defined according combinations of the twelve motivational aspects as shown in Table 8 below.
**Table 8: Rider categories defined by motivational factors**

<table>
<thead>
<tr>
<th>Rider categories defined by motivational factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Biking for pleasure</strong></td>
</tr>
<tr>
<td>This is related to:</td>
</tr>
<tr>
<td>- Escapism (Escape from everyday reality including aspects such as self-discovery, putting oneself in a good mood, forgetting everyday worries and 'letting off steam').</td>
</tr>
<tr>
<td>- Hedonism (The desire for pleasurable experiences from motorcycling covering positive emotions such as joy, fun and pleasure).</td>
</tr>
<tr>
<td>- Flow (Attention is narrowed down to a limited field, the self loses meaning, feel like part of the machine).</td>
</tr>
<tr>
<td>- Identification with the bike (The bike is an intrinsic part of the rider’s life whose experiences grow with it).</td>
</tr>
<tr>
<td>- Social aspects (Involvement in group activities).</td>
</tr>
<tr>
<td><strong>2. Biking as a fast competitive sport</strong></td>
</tr>
<tr>
<td>This is related to:</td>
</tr>
<tr>
<td>- Dynamic aspects (This relates to the physics of the motorcycle covering the experience of acceleration, speed, power, mobility and cornering).</td>
</tr>
<tr>
<td>- Performance aspects (This relates to the sporting side of riding, mastering the machine, coping with the demands of riding, testing bike and rider to limits)</td>
</tr>
<tr>
<td>- Exhibition riding ((Demonstrate/perform riding skills to other road users.)</td>
</tr>
<tr>
<td>- Thrill seeking (The need to engage in risky situations and activities to achieve physiological arousal).</td>
</tr>
<tr>
<td>- Rivalry (Competitive riding covering being faster and better than others).</td>
</tr>
<tr>
<td><strong>3. Control over the motorbike</strong></td>
</tr>
<tr>
<td>This is related to:</td>
</tr>
<tr>
<td>- Control beliefs (Related to those who believe that they can control themselves, the vehicle, other road users and the situation all of the time).</td>
</tr>
<tr>
<td>- Safety behaviour (Defensive riding and behaviour e.g. wearing protective equipment).</td>
</tr>
</tbody>
</table>

- Analysis by age revealed that:
  - Younger riders were more influenced by:
    - Riding pleasure (with the exception of social aspect where there were no significant differences).
    - Exhibition riding, rivalry and thrill seeking motives compared to older age groups. However no significant age effects of dynamic aspects or performance aspects.
  - Younger riders were less influenced by safety behaviour motives compared to these other motives and compared to older drivers.
  - Younger riders had weaker control beliefs than older age groups.
- A further study by Walters (1982) was also reported by Elliott et al (2003) in which 100 in-depth interviews of motorcyclists were conducted in Wales to investigate their motivations and attitudes towards riding. It was concluded that:
  - 48% were enthusiasts who rode for pleasure - This group was categorised by ‘younger riders, who used their motorcycles for work and also pleasure, and older riders, who had ridden a motorcycle for a long period of time and typically owned a car as an alternative mode of transport. Enthusiasts were found to accept the risk involved in riding, but unlike practical riders, tended to perceive it as a challenge rather than a deterrent. They were motivated by the excitement, exhilaration, and sense of freedom and control which they believed could not be obtained from driving a car. Riders in this category also claimed to be confident in their ability to handle the motorcycle correctly’. 

D3 Powered two wheeler Integrated Safety (PiSa): Review of PTW safety technologies and literature
- 35% were practical users – This group ‘perceived the main advantages to be economical to run and convenient to use and park. This group of riders was mostly female, and tended to ride smaller bikes for the purpose of short journeys and for travelling to and from work. In addition, such riders disliked the level of arousal generated in the course of riding, and tended to be cautious in their approach to riding in terms of their handling and their use of speed’.

- 10% were irresponsible users – This group ‘were found to have a lack of awareness of the risk in motorcycling, were overconfident, and perceived themselves as ‘invincible’. Gaining attention, excitement and independence were cited as motivations to behave in such a manner. Such riders were young, typically 17-18 years old’.

- 7% could not be classified by these categories.

- Brendicke (1991) carried out a study to investigate the attitudes of various age groups of motorcycle riders towards risk. The study was undertaken in Germany where, at that time, younger riders (aged 18-20) were over represented in the accident statistics. This study asked participants to rate a range of statements about their attitudes towards riding PTW’s. In brief, for many young people, their PTW was an essential part of their lives and an integrated part of their leisure activities. The sensation seeking aspect of PTW riding was dominant in the younger sector of riders. This sector of riders was also more keen on trying out their performance limits and want to show their skills to peers and other road users which often equates to risk taking behaviours. Older riders tend to participate in training schemes to improve their riding and such programs are often not attractive to younger riders.

- As part of their study in 1986, Hobbs et al assessed attitudes towards motorcycle accidents, specifically accident avoidance. One finding was that younger riders are more likely to believe that it should not be the sole responsibility of motorcyclists to avoid accidents and other road users should take into consideration motorcyclists’ vulnerability. This is supported by the findings of Schulz and Kerwien (1990) who noted that younger riders under-estimated the hazards associated with a variety of traffic situations whilst they over-estimated their own control abilities and tended to believe that the responsibility for a potential accident rests with other drivers and not themselves. (Elliott et al 2003).

- A study by Clarke et al (2004) examined 1,790 police accident files where a motorcyclist was involved and conducted a questionnaire survey to which there were 147 respondents. With respect to attitude they found:
  - Speeding – 58% percent of respondents admitted to always or frequently breaking the speed limit. Riders made a clear distinction between ‘breaking the speed limit’ (79.6% considered ‘observing the speed limit’ as one of the least important safety measures a motorcyclist can take) and riding too fast for the conditions (but not necessarily breaking the speed limit) which 25.5% of riders considered a major cause of motorcycle accidents.
  - Risk-taking – The next most cited cause of motorcycle accidents was taking unnecessary risks. Whilst the questionnaire respondents mentioned no specific risks, the database indicated activities which might be covered by the category including: deliberate close following, risky overtaking manoeuvres, ignoring road signals/signs and riding under the influence of alcohol or when tired. The study reports from the literature that age is the most important factor in risk taking stating that young riders are far more likely to be accident involved.
6.4.3 Experience

- The MAIDS study found that riders with less than six months experience had the greatest risk of PTW accident involvement and that typically more experienced riders are less likely to be the primary contributory factor of an accident. 29% of riders with less than 6 months experience had a skills deficiency compared to 6.4% of riders with 98+ months of experience (ACEM 2004)
- Based on a UK survey of 11,360 motorcyclists, riding experience is negatively related to accident liability; the effect of experience alone reduces accident liability by 52% between 1 and 44 years of experience (Sexton et al 2004)
- A survey of 800 PTW riders at motorcycle shows in Germany, Schultz and Koch (1991), found that the average length of riding experience was 6 years.

6.5 Use of braking systems

6.5.1 The role of braking in accidents

- From the MAIDS study, it was found that in multiple vehicle collisions 49.3% of PTW riders applied their brakes as a collision avoidance measure (ACEM 2004)
- The APROSYS in-depth analysis of motorcycle accidents found that accident avoidance by the PTW rider is rarely successful. When an attempt is made to avoid the accident, braking is most often encountered.
- Thom et al (1985) cite an investigation of 900 accidents in the US by Hurt et al in 1981 which showed that most accident involved motorcycle riders do not use the available braking force of the bike. When faced with violation of right of way and imminent collision, 31.4% of studied riders did nothing to avoid the collision, 18.2% took the less effective measure of using rear brake alone.

6.5.2 Problems in brake use

- Eberspächer (1991) suggests that in many accident cases involving motorcycles inappropriate braking behaviour may be the primary factor. In a potential accident scenario, shock and panic results in poor co-ordination destabilising the braking control mechanisms employed by the rider and causing sub-optimal braking.
- With respect to motorcycle fatalities in the US, Mortimer (2002) state that some crashes may have been avoided or reduced in severity if the rider was able to reduce speed more effectively before the crash, provided there was sufficient time to take braking action.
- A survey was then conducted by Mortimer (2002) of 180 experienced motorcyclists and it was found that when braking hard on:
  - Dry roads, 75% of experienced riders and 65% of less experienced riders said they would use both brakes,
  - Wet roads, 60% of experienced riders and 40% of less experienced riders said they would use both brakes when braking hard.

The results also showed that those who did not use both brakes, tended to use the rear brake first and then follow with the front brake. In non emergency situations, most used only the rear brake thus illustrating that such riders are habituated to using the rear brake more than the front and that this behaviour may transfer to emergency situations.

- Huang & Preston (2004) discuss a study by Seppard et al, 1985 which showed that many motorcyclists braked incorrectly with only 19% only using the rear brake even in an emergency situation and 35% using only the front brake. The characteristics of a
PTW determine that incorrect braking will have more severe adverse effects on the riders with less experience.

- Thom et al (1985) discuss that from studies into motorcycle accidents, ineffective use of the hand control operating the front brake appears to be a contributory factor in many cases. The front brake normally provides 60 to 80% of the available braking force and this can increase to 100% in extreme cases where the rear wheel leaves the ground. This means that the effective use of the front brake can be critical in collision avoidance.

- One of the problems of conventional motorcycle brakes is the separation of controls for the front and rear brakes. In addition the right hand is also used to operate the twist grip throttle so that to activate the brake, the fingers must first be released from the throttle grip then extended to grip the brake lever and then contracted to operate the brake.

- To investigate this, Thom et al (1985) undertook an experiment to investigate the difference in response times between two rider hand positions for front brake use. The two conditions studied were:
  - The conventional position with the right hand holding the throttle grip with all fingers,
  - An alternative position where two fingers were extended out (covered) onto the brake lever in advance of any need for braking.

- The study used experienced and inexperienced riders to apply brakes to a static motorcycle and the response times were noted. The results showed that:
  - The experienced riders had significantly quicker response times than inexperienced riders,
  - For all riders, covering the lever brake resulted in significantly quicker response times,
  - Male riders had quicker response times than female riders in both conditions.

- Further factors that can effect the response time of brake activation include fatigue, ambient and hand temperature, control and hand size relationship, vigilance and distraction. (Thom et al 1985).

6.5.3 Need for training

- Hagstotz & Ludsteck (1995) carried out interviews and braking trials with a number of motorcyclists in southern Germany. They found from the interviews that particularly in the case of occasional riders, the riders had insufficient knowledge about correct braking procedures and overestimate their own braking abilities.

- Proper use of front and rear brake together produced the most effective stopping – such use requires proper riding techniques, training and experience (Fries et al 1989)

- Eberspächer (1991) suggests that high intensity training of riders including enforced brake behaviour in realistic conditions is essential along with the adaptation of brake technology to include brakes only operated by one control, automatic co-ordination between front and rear wheel braking and an appropriate anti-lock system.

- Although technologies may provide improved braking, rider training is essential to ensure that motorcyclists are able to make best use of the system(s) and the circumstances in which they should be applied (Huang & Preston, 2004)
6.6 Cognitive psychology theories

- In providing guidance for the appropriate HMI design within PISa, a summary of cognitive psychology theories which discuss ways in which information is processed efficiently is presented as a foundation for future developments.
- The introduction of displays within vehicles raises issues that are primarily related to the cognitive psychological topics of human attention and workload - poorly designed systems may significantly distract drivers from primary task activities, and may lead to situations of mental overload. Figure 53 below highlights the basic psychological concepts of relevance.

![Diagram of Psychological Theories](image)

**Figure 53: Psychological theories relevant to the design of in-vehicle displays**

6.6.1 Functions of Attention

- Eysenck (1993) distinguished three types of attention each of which have relevance to vehicle operators:
  - Focused attention refers to concentration on single tasks (failure in this is ‘distraction’) e.g. Monitoring traffic light status when in close proximity of a junction
  - Selective attention refers to the process of selecting which stimuli to attend to, whilst ignoring others e.g. General monitoring of the road scene for hazards
  - Divided attention refers to performing two or more tasks concurrently e.g. prior to overtaking, there will be monitoring of the opposite carriageway and the behaviour of the vehicle in front.
• Attention can also be viewed as a resource with limited capacity, such that the amount of resources required on given tasks amount to the rider’s mental workload. (Midtland, 1993; Verwey, 1990b). If a task, or combination of tasks, requires more resources than are available, then driver’s mental workload will be exceeded and their performance will deteriorate.

6.6.2 Controlled vs Automatic Processing

• The mental workload of the rider will be influenced by the way in which information is processed which can be by two distinct means as outlined in Table 9.

Table 9: Differences between controlled and automatic processing

<table>
<thead>
<tr>
<th></th>
<th>Controlled</th>
<th>Automatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relatively slow</td>
<td>Relatively fast</td>
<td></td>
</tr>
<tr>
<td>Information processed</td>
<td>Information can be processed in parallel</td>
<td></td>
</tr>
<tr>
<td>(see Section 5.4)</td>
<td>(see Section 5.4)</td>
<td></td>
</tr>
<tr>
<td>Effortful, requiring</td>
<td>Effortless, requiring few/no attentional</td>
<td></td>
</tr>
<tr>
<td>attentional resources</td>
<td>resources</td>
<td></td>
</tr>
<tr>
<td>Capacity limited</td>
<td>Capacity unlimited</td>
<td></td>
</tr>
<tr>
<td>Under an individual’s</td>
<td>Not easily altered by conscious control</td>
<td></td>
</tr>
<tr>
<td>control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Used to deal with novel, inconsistent information</td>
<td>Developed through extensive, consistent practice</td>
<td></td>
</tr>
<tr>
<td>Information processed</td>
<td>Information processed as symbols/signs</td>
<td></td>
</tr>
<tr>
<td>as symbols/signs</td>
<td>Information processed as signals/signs</td>
<td></td>
</tr>
</tbody>
</table>

• With respect to the use of telematics systems within vehicles, examples of tasks that are likely to require controlled processing include the reading of text sentences, using a map-based information display, and listening to a novel voice instruction. In contrast, given a consistent presentation (in terms of format and location and provided the items well known and understood), auditory tones, icons and single word text may be automatically processed.

• The development of automatic processing for a particular task will ensure fast processing, requiring few resources, thus enabling timesharing with other tasks. In addition, the presentation of automatic stimuli will provoke an involuntary shift of attention (Schneider & Shiffren, 1977). The resulting, so called ‘automatic attention response’ may be advantageous in time-critical, safety-related situations, e.g. reacting to a collision avoidance warning.

• However, the unavoidable nature of automatic processes may be undesirable in situations where an alternative, novel response is required. For instance in the case of an unintended acceleration in which a driver mistakenly places their foot on the accelerator instead of the brake in an automatic car. The driver’s surprise at the car’s response of accelerating instead of slowing is compounded when further attempts to activate the brake result in more acceleration. The engrained automatic processing equating the use of the brake to slowing the car means that it is difficult for the driver to respond in a more appropriate manner.
6.6.3 **Serial vs Parallel Processing**

- Serial processing occurs when tasks or task elements are attended to in sequence e.g. scanning the road ahead and then scanning a display. Efficient serial processing may arise if the information within multiple sources are predictable and do not overlap.

- Parallel processing occurs when two or more information sources/elements are processed simultaneously e.g. processing a vision enhancement image on a HUD whilst viewing the actual road scene. There are obvious advantages in aiming for parallel processing in the design of integrated displays, since increased efficiency will arise in terms of the number of bits of information processed per unit time. As a consequence, the time required for uptake of multiple information sources will be reduced.

  - Stokes et al (1990) describe four properties of information sources that will promote parallel processing:
    - Practice leading to automatic processing
    - Ensuring elements of a display are within the two degrees of foveal vision (Refer to Principles of Proximity in Section 6.6.5 below)
    - Integrating elements of a display within a single object (Refer to Principles of Proximity in Section 6.6.5 below)
    - Ensuring tasks do not compete for the same attentional resources (Refer to Compatibility Principles in Section 6.6.5 below).

6.6.4 **Basic Mechanisms of Timesharing**

- Wickens (1992) outlines several basic mechanisms that will influence how well two or more tasks can be timeshared:
  - Scheduling and prompt switching between activities - i.e. an efficient management of the available time to carry out the tasks (e.g. taking eyes off road to look at display for a brief period only).
  - Confusion of task elements (also called cross talk) - responses or relevant processes for one task get activated by stimuli for a different task (e.g. when the tone signalling a route guidance message is similar to that for a collision warning, it may lead to an automatic braking response).
  - Co-operation between task processes - similarity between tasks may enable a strategy to be developed in which activities are combined into a single behavioural unit, thus enhancing timesharing performance. A traditional driving task example is the combined, concurrent use of gears and clutch.
  - Competition for task resources - it has been postulated that humans possess several independent resource pools, such that the ability to divide attention between concurrent tasks is a function of the extent to which these tasks use separate, rather than common, resources e.g. if the rider is overloaded visually, auditory communication may increase the processing capacity. (Wickens, 1984; Allport et al, 1972).

6.6.5 **Practical Theories**

- Multiple Resource theory (Wickens, 1984) argues that time-sharing between tasks will be more efficient when there is a minimum of competition for common resources along each of the following four dimensions – Refer to Figure 54.
  - Cognitive stages - Early processes (i.e. perceptual and central processing) vs late processes (i.e. response selections and execution).
  - Input modalities - Auditory vs visual encoding.
- Output modalities:- Vocal (i.e. calling out response) vs manual response (i.e. use of limbs).
- Processing codes - Spatial (i.e. connected with appearance) vs verbal (i.e. connected with words, language, or logical operations).

![Figure 54: Multiple resources theory (Wickens, 1984)](image)

- As driving can be considered to predominantly involve spatial encoding within the visual modality (e.g. speed estimates of own car/other road users, judging road geometry), necessitating manual responses (steering, accelerator, brakes, gears etc.), this theory would predict that the ideal means of presenting secondary information would be auditory/verbal, requiring a vocal response.

- Compatibility Principles consider the mapping between display and task characteristics:
  - Stimulus-Response (SR) theory, originally proposed by Fitts and Seeger (1953), concerns the expectancies held as to how displayed information corresponds to a response (both in terms of location and movement). As an example, drivers will expect a perpendicular left arrow to correspond to a perpendicular left turn.
  - Stimulus/Central processing/Response (SCR) compatibility (Wickens 1992) extends to Stimulus-Response model to consider how information is processed. Four stimulus display formats are possible (speech, print, sound localisation and pitch, or analogue pictures) which can be allocated to either verbal or spatial working memory. Responses can be either manual or speech. This theory states, based on empirical foundations, that verbal tasks are best served by auditory input and speech output, whereas spatial tasks are best served by visual input and manual output.

- The Principle of proximity (Wickens and Andre, 1990) maintains that if two information sources must be integrated as part of a task, then there will be benefits in ensuring high display proximity with respect to:
  - The physical position of displays - i.e. ensuring different, but related, displays or information elements are separated by less than two degrees in space (i.e. both within foveal vision).
  - The integration of information elements within displays (termed objectness). An example is the representation of the two traffic conditions variables: average
traffic speed, and queue length, within a single rectangle object. With experience, the driver will learn to associate certain shapes with the severity of the traffic problems further along the route.

6.7 HMI

6.7.1 Guidelines/principles

**European Statement of Principles on the Design of Human Machine Interaction**

- One of the main sources of widely-agreed human-machine interface (HMI) guidelines is the ‘European Statement of Principles (ESoP) on the Design of Human Machine Interaction’. The most recent version was published in June 2005 by the European Commission. The scope of the principles is thus:

- “These principles apply to in-vehicle information and communication systems intended for use by the driver while the vehicle is in motion, for example, navigation systems, telephones and traffic information. They are not specifically intended to apply to systems providing vehicle stabilization (such as ABS and ESC) or to Advanced Driver Assistance Systems (ADAS) such as adaptive cruise control, collision mitigation systems, rear view camera and night-vision. ADAS are fundamentally different and require additional considerations in terms of Human Machine Interaction.”

- The ESoP has no mandatory status. The principles are advisory only and are not a substitute for regulations and standards. However they could be considered as best practice statements in product liability terms.

- Therefore whilst the ESoP does not directly apply to IS Systems, it does provide some basic principles which are of relevance to PIg.

- The ESoP documents principles under 6 main sections and each principle is followed by further text providing: Explanation; Examples; Applicability; Verification/Applicable Methods (with the exception of Section 1 ‘Design goals’ where the further text only covers ‘Explanation’). The principles are replicated below:

**Section 1: Design Goals**

- **Design Goal I:** The system supports the driver and does not give rise to potentially hazardous behaviour by the driver or other road users.

- **Design Goal II:** The allocation of driver attention to the system displays or controls remains compatible with the attentional demands of the driving situation.

- **Design Goal III:** The system does not distract or visually entertain the driver.

- **Design Goal IV:** The system does not present information to the driver which results in potentially hazardous behaviour by the driver or other road users.

- **Design Goal V:** Interfaces and interaction with systems intended to be used in combination by the driver while the vehicle is in motion are consistent and compatible.

**Section 2: Installation Principles**

- **Principle 2.1:** The system should be located and securely fitted in accordance with relevant regulations, standards and manufacturers instructions for installing the system in vehicles.

- **Principle 2.2:** No part of the system should obstruct the driver's view of the road scene.

- **Principle 2.3:** The system should not obstruct vehicle controls and displays required for the primary driving task.
• Principle 2.4: Visual displays should be positioned as close as practicable to the driver’s normal line of sight
• Principle 2.5: Visual displays should be designed and installed to avoid glare and reflections.

Section 3: Information Presentation Principles

• Principle 3.1: Visually displayed information presented at any one time by the system should be designed such that the driver is able to assimilate the relevant information with a few glances which are brief enough not to adversely affect driving.
• Principle 3.2: Internationally and/or nationally agreed standards relating to legibility, audibility, icons, symbols, words, acronyms and/or abbreviations should be used.
• Principle 3.3: Information relevant to the driving task should be accurate and provided in a timely manner.
• Principle 3.4: Information which has the highest safety relevance should be given priority.
• Principle 3.5: System generated sounds, with sound levels that cannot be controlled by the driver, should not mask audible warnings from within the vehicle or the outside.

Section 4: Principles on Interaction with Displays & Controls

• Principle 4.1: The driver should always be able to keep at least one hand on the steering wheel while interacting with the system.
• Principle 4.2: The system should not require long and uninterruptible sequences of manual-visual interactions. If the sequence is short, it may be uninterruptible.
• Principle 4.3: System controls should be designed such that they can be operated without adverse impact on the primary driving controls.
• Principle 4.4: The driver should be able to control the pace of interaction with the system. In particular the system should not require the driver to make time-critical responses when providing inputs to the system.
• Principle 4.5: The driver should be able to resume an interrupted sequence of interactions with the system at the point of interruption or at another logical point.
• Principle 4.6: The driver should have control of the loudness of auditory information where there is likelihood of distraction.
• Principle 4.7: The systems response (e.g. feedback, confirmation) following driver input should be timely and clearly perceptible.
• Principle 4.8: Systems providing non-safety related dynamic visual information should be capable of being switched into a mode where that information is not provided to the driver.

Section 5: System Behaviour Principles

• Principle 5.1: While the vehicle is in motion, visual information not related to driving that is likely to distract the driver significantly should be automatically disabled, or presented in such a way that the driver cannot see it.
• Principle 5.2: The behaviour of the system should not adversely interfere with displays or controls required for the primary driving task and for road safety.
• Principle 5.3: System functions not intended to be used by the driver while driving should be made impossible to interact with while the vehicle is in motion, or, as a less preferred option, clear warnings should be provided against the unintended use.

• Principle 5.4: Information should be presented to the driver about current status, and any malfunction within the system that is likely to have an impact on safety.

• Principle 5.5: In the event of a partial or total failure of the system, the vehicle should remain controllable, or at least should be capable of being brought to a halt in a safe manner.

Section 6: Principles on Information about the System

• Principle 6.1: The system should have adequate instructions for the driver covering use and relevant aspects of installation and maintenance.

• Principle 6.2: System instructions should be correct and simple.

• Principle 6.3: System instructions should be in languages or forms designed to be understood by the intended group of drivers.

• Principle 6.4: The instructions should clearly state which aspects of the system are intended to be used by the driver while driving and those aspects (e.g. specific functions, menus etc.) which are not intended to be used by the driver while driving.

• Principle 6.5: All product information should be designed to accurately convey the system functionality.

• Principle 6.6: Product information should make it clear if special skills are required to use the system as intended by the manufacturer or if the product is unsuitable for particular users.

• Principle 6.7: Representations of system use (e.g. descriptions, photographs and sketches) should neither create unrealistic expectations on the part of potential users nor encourage unsafe use.

• A supplement to the ESoP is ‘Recommendations on Safe Use (RSU) 2005’ The supplement summarises essential safety aspects concerning use of, and influencing use of, in-vehicle information and communication systems. Following a discussion of the context of use, principles are presented relevant for employers, point-of-sale, vehicle hire companies and drivers themselves. These supplementary principles are presented under 2 main headings and are accompanied by further text as above (i.e. Explanation; Examples; Applicability; Verification/Applicable Methods).

Principles on Influencing Use

• Principle 1.1: Employers should ensure that all in-vehicle information systems are maintained in accordance with the manufacturer’s instructions.

• Principle 1.2: Employer’s procedures and incentive schemes should not cause or encourage system misuse. There should be a clear distinction between systems or functions that are intended (by the employer) to be used while driving and those that are not.

• Principle 1.3: Adequate training should be given on all in-vehicle systems that drivers are required to use by employers while driving. Employers should ensure that employees can use the systems without endangering themselves or other road users.

• Principle 1.4: Employers should ensure that a copy of the manufacturer’s instructions for use is available in every equipped vehicle.
• Principle 1.5: Point of sale promotion (e.g. advertising) should not encourage unsafe use.

• Principle 1.6: Point of sale information should inform vehicle purchasers of the safety issues associated with in-vehicle information systems.

• Principle 1.7: Vehicle hire companies should ensure that all information and communication systems are maintained in accordance with the manufacturer’s instructions.

• Principle 1.8: Vehicle hire companies should ensure that a copy of the manufacturer’s instructions for use is available in every equipped vehicle.

• Principle 1.9: Vehicle hire personnel should have adequate knowledge concerning in-vehicle information systems within the vehicles they make available and should offer instructions in their safe use.

Principles for Drivers

• Principle 2.1: Drivers should ensure that nomadic systems and after-market systems are installed in accordance with the manufacturer’s instructions.

• Principle 2.2: Drivers should ensure that all in-vehicle systems are maintained in accordance with the manufacturer’s instructions.

• Principle 2.3: Drivers are responsible for modifications to any system. These need to be in accordance with technical descriptions and should not contradict the information provided by the manufacturer.

• Principle 2.4: Drivers should only use in-vehicle equipment as recommended by the manufacturer. This may require a period of familiarisation or training.

• Principle 2.5: Drivers should only use information and communication systems while driving if it is safe to do so.

• Principle 2.6: Nomadic systems should not be used hand-held or unsecured within the vehicle while driving.

• Principle 2.7: All instructions associated with in-vehicle equipment should be retained with the vehicle and passed to the next vehicle owner or user.

• Equivalents to the ESoP exist in the U.S. and Japan:

Crash Warning System interfaces (NHSTA)

• A further set of guidelines is that provided by NHSTA concerning Crash Warning System interfaces; Human Factors insights and lessons learnt (Campbell et al 2007). The aim of the report was to develop human factors guidelines for crash warning devices that emphasise driver performance and safety. The guidelines reflect the best-available human factors information and are intended for use by those with roles of conceptualisation, development, design, testing and evaluation of in-vehicle crash avoidance systems.
• The report is structured in an easy-to-use format. Each double-page spread is identically laid out and includes:

<table>
<thead>
<tr>
<th>Left-hand page</th>
<th>Right-hand page</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Title of the guideline.</td>
<td>• Discussion outlining the logic, premises, assumptions and train-of-thought.</td>
</tr>
<tr>
<td>• Introduction providing basic information about the design parameter.</td>
<td>• Design issues highlighting any special design considerations.</td>
</tr>
<tr>
<td>• Design guidance associated with the parameter is presented and is usually quantitative.</td>
<td>• Cross-references to related guidelines.</td>
</tr>
<tr>
<td>• Bar scale rating indicating the extent to which the guidance is based on expert judgment, experimental data or both.</td>
<td>• References.</td>
</tr>
<tr>
<td>• Figure, table or graphic to illustrate the design guidance.</td>
<td></td>
</tr>
</tbody>
</table>

• The guidelines covered in the report are:

**General guidelines for CWS design**

• How to Select the Number of Warning Stages
• How to Prioritize Multiple Warnings
• How to Integrate Warning Systems
• How to Make Warnings Compatible with Driver Responses
• How to Prevent False or Nuisance Warnings
• Warning Timing

**Chapter 3: Auditory warnings**

• When to Use Auditory Warnings
• Determining the Appropriate Auditory Signal
• Desired Characteristics of Auditory ICWs
• Desired Characteristics of Auditory CCWs
• Desired Characteristics of Speech-Based Warnings
• Perceived Urgency and Annoyance of Auditory Warnings

**Chapter 4: Visual warnings**

• When to Use Visual Warnings
• Determining the Appropriate Type of Visual Display
• Desired Characteristics of Visual ICWs
• Desired Characteristics of Visual CCWs
• General Characteristics of Visual ICWs and CCWs

**Chapter 5: Haptic warnings**

• When to Use Haptic Warnings
• Determining the Appropriate Display Type for Haptic ICWs
• Desired Characteristics of Haptic ICWs

**Chapter 6: Controls used in CWS devices**

• Selection of Control Type
• Control Movement Compatibility
• Control Coding
• Labels for Controls
• Specific Guidelines for Design of CWS Controls

Chapter 7: Forward collision warning systems
• Design of ICWs for FCW Systems
• Design of CCWs for FCW Systems
• Design of Visual, Auditory, and Haptic Warnings for ICWs

Chapter 8: Lane change warning systems
• Design of ICWs for LCW Systems
• Design of CCWs for LCW Systems
• Design of Visual, Auditory, and Haptic Warnings for LCW systems

Chapter 9: Road departure warning systems
• Design of Lane Drift Warning ICWs for RDCW Systems
• Design of Lane Drift Warning CCWs for RDCW Systems
• Design of Curve Speed Warning ICWs for RDCW Systems
• Design of Curve Speed Warning CCWs for RDCW Systems

Chapter 10: Application to heavy trucks and buses
• Large Vehicle CWS Display and Enunciator Location
• Large Vehicle CWS Warning Modality
• Large Vehicle CWS Signal Design
• Large Vehicle CWS Driver Controls

6.7.2 Standards
• The International Standards Organisation (ISO) has two working groups (WGs) responsible for developing standards for advanced driver technologies. The WGs and associated standards are listed below:

Working Group Full title: ISO TC22 (Road Vehicles) SC13 (Ergonomics applicable to road vehicles) WG8 (Transport information and control systems, on-board Man-machine interface)
## Published standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 15005:2002</td>
<td>Road vehicles -- Ergonomic aspects of transport information and control systems -- Dialogue management principles and compliance procedures</td>
</tr>
<tr>
<td>ISO 15006:2004</td>
<td>Road vehicles -- Ergonomic aspects of transport information and control systems -- Specifications and compliance procedures for in-vehicle auditory presentation</td>
</tr>
<tr>
<td>ISO 15007-1:2002</td>
<td>Road vehicles -- Measurement of driver visual behaviour with respect to transport information and control systems -- Part 1: Definitions and parameters</td>
</tr>
<tr>
<td>ISO/TS 15007-2:2001</td>
<td>Road vehicles -- Measurement of driver visual behaviour with respect to transport information and control systems -- Part 2: Equipment and procedures</td>
</tr>
<tr>
<td>ISO 15008:2003</td>
<td>Road vehicles -- Ergonomic aspects of transport information and control systems -- Specifications and compliance procedures for in-vehicle visual presentation</td>
</tr>
<tr>
<td>ISO/TR 16352:2005</td>
<td>Road vehicles -- Ergonomic aspects of in-vehicle presentation for transport information and control systems -- Warning systems</td>
</tr>
<tr>
<td>ISO/TS 16951:2004</td>
<td>Road vehicles -- Ergonomic aspects of transport information and control systems (TICS) -- Procedures for determining priority of on-board messages presented to drivers</td>
</tr>
<tr>
<td>ISO 17287:2003</td>
<td>Road vehicles -- Ergonomic aspects of transport information and control systems -- Procedure for assessing suitability for use while driving</td>
</tr>
</tbody>
</table>

## Standards under development

<table>
<thead>
<tr>
<th>Standard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISO 16673</td>
<td>Road vehicles -- Ergonomic aspects of transport information and control systems -- Occlusion method to assess visual demand due to the use of in-vehicle systems</td>
</tr>
<tr>
<td>ISO/CD 26022</td>
<td>Road vehicles -- Ergonomic aspects of transport information and control systems -- Simulated lane change test to assess driver distraction</td>
</tr>
</tbody>
</table>
Published standards

| ISO 15622:2002 | Transport information and control systems -- Adaptive Cruise Control Systems -- Performance requirements and test procedures |
| ISO 15623:2002 | Transport information and control systems -- Forward vehicle collision warning systems -- Performance requirements and test procedures |
| ISO 17361:2007 | Intelligent transport systems -- Lane departure warning systems -- Performance requirements and test procedures |
| ISO 17386:2004 | Transport information and control systems -- Manoeuvring Aids for Low Speed Operation (MALSO) -- Performance requirements and test procedures |

Standards under development

| ISO/DIS 17387  | Intelligent Transportation Systems -- Lane Change Decision Aid Systems -- Performance requirements and test procedures |
| ISO/NP 22178   | Low speed following (LSF) systems |
| ISO/CD 22179   | Full speed range adaptive cruise control (FSRA) systems |
| ISO/AWI 22840  | Extended Reversing and Backing Aid (ERBA) |

6.7.3 Evaluation methods/measures

- The most current reviews of methodological approaches are provided by two 6th Framework IST Programme projects:
  - HUMANIST (http://www.noehumanist.org/start.htm)
  - AIDE (http://www.aide-eu.org/index.html)

**HUMANIST deliverable D.2/E.2 (2004), Impact of IVIS on driver workload and distraction: review of assessment methods and recent findings**

- Based on a review of previous studies and the expertise of the consortium, Annex 16 to this document provides a review of over 70 metrics that have been employed to measure driver workload and/or distraction. Each metric is described/assessed in terms of the following:
  - Technique
  - Tool
  - Environment
  - Aspect of the system/human investigated
  - Type of adapt obtained
  - Effectiveness
  - Practical issues
- Useful references

- The outcome is a list of metrics highlighted as the most frequently employed/most useful (by the HUMANIST Consortium). These are:
  - **Lane standard deviation**: The deviation in horizontal distance between the vehicle centre and the road centre line. A useful measure of distraction particularly for systems that require a large amount of visual interaction.
  - **Time to line crossing (TLC)**: Continuous measure that represents the time required for the vehicle to reach either the centre or edge line of the driving lane. A valuable method of assessing visual distraction.
  - **Time headway**: Following distance divided by the rate of change of the following distance. Effective method of indicating a lack of driver alertness and can be associated with the interference of in-vehicle systems.
  - **Minimum following distance**: Effective method of indicating a lack of driver alertness and can be associated with the interference of in-vehicle systems.
  - **Brake response time**: As triggered by events such as sudden appearance of vehicle/pedestrian. Indication of attention to road scene.
  - **Glance duration**: The amount of time it takes the driver to extract information from a (defined) part of the visual scene. Used as a measure of the visual demand imposed by a display or changes in patterns of visual scanning of the road scene.
  - **Glance frequency**: The number of times a (defined) part of the visual scene is viewed. Used as a measure of the visual demand imposed by a display or changes in patterns of visual scanning of the road scene.
  - **Visual occlusion**: A non-driving method by which to determine the visual demand of a system using a ‘shutter’ system to mimic short glances to a display.

**AIDE deliverable 2.2.5 (2004), Driving performance assessment – methods & metrics**

- Further, in-depth, discussion of a range of assessment methods is provided within this deliverable. This focuses mostly on vehicle control measures under the headings of: speed, lateral position, time to line crossing, headway, brake, steering grip and steering wheel movements (mirroring many of the metrics identified in the HUMANIST deliverable above). In addition, there is an in-depth section on the Lane Change Test which has been proposed as a method of determining whether the additional workload produced by a secondary task is caused by visual or cognitive distraction (see the section on standards for a reference to ISO/CD 26022 which is a standard under development to specify the Lane Change Test method).

**AIDE deliverable 2.1.1 (2004), Driving performance assessment – methods & metrics**

- A second AIDE deliverable provides a high level summary of user-centred design approaches appropriate to driver-vehicle systems development using the definitions of the usability engineering field. Specific chapters cover methodological issues relating to: User mental model and requirements, Usability and acceptance, Workload, Situation awareness. One aspect that is worth detailing here is the aspect of appropriate test environments. Figure 55 below provides an overview of likely test environments for assessing vehicle technologies (not from the AIDE deliverable), showing how use of the different environments affects realism and experimental control.
• Laboratory testing (e.g. PC simulation)
• Driving simulator
  – Low-cost driving simulator
  – Advanced graphics, fixed base simulation
  – Advanced graphics, dynamic simulation
• Test track trials
• Road trials
• Naturalistic driving

Reducing control

Increasing realism

**Figure 55: Assessment environments for driver technologies**

An extracted table (below) from the AIDE deliverable highlights the pros and cons of the different environments (text in *italics* indicates modifications of the original table)

<table>
<thead>
<tr>
<th>Environment</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory (including simulators)</td>
<td>Critical and dangerous situations can be tested</td>
<td>Due to lack of danger, Subject might perform in a different way than a “real” in-traffic performance Realism might be missing, due to low resolution of devices (Screens, audio…)</td>
</tr>
<tr>
<td></td>
<td>Repetitive testing is less time-consuming</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No danger for Subjects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reliable data is collected</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Specific Scenarios can be forced to happen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>The very same initial conditions can be repeated</td>
<td></td>
</tr>
<tr>
<td>Test Track</td>
<td>High control of variables</td>
<td>Lack of danger of real traffic might result in low level of Task Demand</td>
</tr>
<tr>
<td></td>
<td>Subjects are in a car, so IVIS / ADAS can be tested along with driving task</td>
<td></td>
</tr>
<tr>
<td>Real Traffic (including road trials and naturalistic driving)</td>
<td>Highest level of realism</td>
<td>Dangerous situations cannot be tested (e.g. CW, ADAS malfunction and failure)</td>
</tr>
<tr>
<td></td>
<td>Accurate data can be gathered</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Best way to test visual aspects of ADAS</td>
<td></td>
</tr>
</tbody>
</table>

**Table 10: Pros and cons of different test environments** (from AIDE deliverable 2.1.1 (2004), Review of existing tools and methods)

6.8 Driver issues - ‘Looked but failed to see’

- So far within this section, it is issues relating to the motorcyclist which have been discussed. However there is also merit in looking more closely at the actions of other vehicle drivers especially with respect to the ‘Looked-but-failed-to-see’ (sometimes referred to as ‘SMIDSY’ – ‘Sorry Mate I Didn’t See You) in order to determine what factors might be applied to motorcycles to assist other drivers in such circumstances.
6.8.1 Cognitive processing

- The model below shows that in order to see and respond to a visual stimulus, the driver/rider undertakes a series of cognitive processing tasks:
  - **Detection** – Firstly the target must be seen (detected) i.e. the driver/rider has been aware that there is an object in the visual field which may need attending to.
  - **Identification** – The driver/rider must then interpret what they have detected by obtaining as much relevant information concerning the object that they can and comparing it with records of similar encounters held in their memory.
  - **Decision** – The driver/rider needs to assess the circumstances of the encounter and based on previous interactions, determine an appropriate course of response.
  - **Reaction** – The driver/rider then enacts the physical actions required to carry out the response identified within the previous processing stage.

![Diagram of Cognitive Processing](image)

**Figure 56: Processing of visual information (based on Allen et al 1996)**

- Failure in any one of these stages can lead to an inappropriate response to the situation being enacted by the driver/rider e.g. engaging in an incorrect manoeuvre, and so may increase the risk of accident occurrence.
- ‘Looked-but-failed-to-see’ errors are associated with the first two stages i.e. not seeing the motorcyclist or seeing the motorcyclists and misinterpreting what is being seen.
- The first of these stages – Detection, is associated with conspicuity on the premise that the more conspicuous an object is the more likely a road user is to detect it.

6.8.2 Definitions of conspicuity

- Visual conspicuity as it is usually understood refers to the ability of an object to attract attention and to be easily located, due to its physical properties (e.g., Engel, 1976 in Wulf et al 1989).
- Conspicuity is characterised by identification, spatial and temporal uncertainty i.e. the observer is not aware of what the object of interest is (another vehicle, a child pedestrian, etc), where it will appear in the visual field nor when it will appear. Hughes and Cole (1984) in Wulf et al (1989) use the term ‘attention conspicuity’ to describe the potential of an object to attract attention when the observer’s attention is not specifically directed to its possible occurrence. Whilst ‘search’ conspicuity occurs when the observer is cued on some aspect to search for.
  - **Sensory conspicuity** relates to the physical properties of the object and are discussed in Deliverable 2 in terms of aspects which potential solutions should seek to embrace.
Cognitive conspicuity refers to the interests and experience of the observer. For instance, Huang and Preston (2004) state that car drivers who ride a motorcycle themselves or who have a relation to motorcycle riders are less likely to collide with motorcyclists (TRACE 2007) whilst the MAIDS study found that other vehicle drivers who also held a PTW licence committed less perception errors than those who didn’t (26.4% compared to 50.9%) (ACEM 2004)

6.8.3 Factors affecting detection

- The Expectancy phenomenon Australian Motorcycle Council, 1984; Fulton et al, 1980; Nagayama et al, 1975) theorises that road users may be conditioned to respond to large stimuli (automobiles), which they encounter more often; thus, they may find it more difficult to notice motorcycles which average about 1 per 175 vehicles in traffic. (Wulf et al 1989)
- The cost of detection failures to the driver may be a possible factor in poor detection of motorcycles. Wulf et al (1989) suggest that some drivers rank order hazards to them in the environment in their decision-making. Since failing to detect a vehicle larger than themselves has greater potential to result in injury to them than one which is smaller, motorcycles can become overlooked.
- Tunnel vision, as termed by Mackworth (1965) in Wulf et al (1989) occurs in visually complex scenarios e.g. driving in urban traffic, in which greater effort is required to process information causing the average eye-fixation time to increase. This reduces the number of fixations which can be made in a given time interval and so targets (motorcycles) may be overlooked. In addition, there is a reduction in the effectiveness of peripheral vision which decreases the functional visual field (tunnelling). A review by Huang and Preston (2004) supports the circumstances of tunnelling since for ‘Did not see at all’ or ‘Did not see in time’ accidents’ were associated with heavy traffic and complex visual scenes.
- Relative size of motorcycles – When viewed head-on PTW’s present only 30-40% of the area presented by cars which makes them more difficult to detect. (Huang & Preston 2004)
- Other factors include - physiology of the human eye in various light and manoeuvre scenarios; blind spots, glare, fog, rain and obstructions (Huang & Preston, 2004)

6.8.4 Factors affecting identification

- Having detected the motorcycle, the driver must then determine what it is they have detected and its characteristics in order to make an appropriate response. Generally research suggests that there is inappropriate driver behaviour after detection which suggests that it is not just perception in question but decision making (Brooks 1988).
- An example of an identification error is shown in Figure 57 below. If the oncoming lights at night are associated with a car rather than a car with a motorcyclist in front, the driver may undertake an inappropriate manoeuvre.
Even if the driver does identify the motorcyclist correctly, they may make incorrect judgements about its rate of approach which may again lead to an unsafe manoeuvre being undertaken.

Figure 57: Example of an Identification error (Adapted from FEMA website)
7 Gender issues

7.1 Summary

7.1.1 Introduction
There has been very little research into gender differences when analysing accidents, driving behaviour etc, in respect of motorcyclists.

7.1.2 Rider gender
The data in this section along with that in section 6.3.1 indicates that PTW use is dominated by male riders.

7.1.3 PTW type
Whilst males are more likely than females to use mopeds/mofas and motorcycles, females are more likely to operate mopeds/mofas than motorcycles (22.4% versus 6.5%). (MAIDS study – ACEM 2004).

A Motorcycle Industry Association survey found that females ride a range of bikes:

- Supersports 20%
- Sport/Tourer 18%
- Custom 14%
- Touring 7%
- Off-road 11% (MCIA 2005)

The survey also found that 28% of females used a motorcycle as their main form of transport and 27% used a moped (MCIA 2005).

7.1.4 Usage
- More males than females are likely to use a motorcycle to make a trip (Huang and Preston 2004)
- Those females who use motorcycles make about the same number of trips as males (Huang and Preston 2004)
- Females make shorter trips than males (Huang and Preston 2004)
- More females used their bike everyday compared to males (MCIA 2005).
- More females than males used their bike for general transport than males but less for pleasure (MCIA 2005).
- 63% of female respondents said they were all year riders and 37% said not generally in winter (MCIA 2005).

7.1.5 Accident involvement
Whilst section 6.1.2 states that there are more male motorcyclists casualties it must be remembered that this may be due to their greater prevalence. When controlling for exposure, the MAIDS study found that male and female riders were neither under or over-represented in the accident population (ACEM 2004).
Stefan et al (2003) stated that, as female drivers as a percentage of the total number of motorcyclists injured, The Netherlands feature the highest share of injured female drivers among all Member States, followed by Austria and Spain (both 7.7%). Belgium, on the other hand, has the lowest mean fraction of injured females (4.1%).

7.1.6 Injury severity
De Lapparent M (2006) developed a model which can estimate the probabilities of the severity of motorcycle accidents in large and dense French urban areas in 2003. The model shows that:

- Male motorcyclists have lower probabilities to be slightly injured or severely injured and greater probabilities to be fatally injured although only the decrease in the probabilities to be slightly injured is significant.
- Gender comparisons by age and motorcycle type found that 4 of the 6 female motorcyclists’ categorisations were ranked in the top five groups which are the most exposed to risk of injury.

A study, based on Northern Italian data, by Valent et al (2002) found that amongst moped riders, women represented 21% of all riders and were at a lower risk of death than male riders.

7.1.7 Trends and forecasts
The following data has been found in this area:

- The Government’s Motorcycling Strategy (UK) (2005) states that more women are taking up motorcycling (no further information is provided).
- Stefan et al (2003) note variations in PTW use by gender across Europe with some countries showing an increase and some a decrease.

However due to the lack of trend and forecast data, it is not possible to state if, and to what extent, current ratios may change in the future.

7.2 Introduction
- Males make up by far the greater proportion of riders of scooters and motorcycles in the UK and Northern Europe. There is however very little research into gender differences when analysing accidents, driving behaviour etc, in respect of motorcyclists. Research in such areas has been carried out in respect of car drivers, and some of this information may be relevant to powered two wheelers (PTWs). Below are brief notes of some of the data available regarding gender in respect of motorcyclists.

7.3 National UK Data 2004

Table 11: PTW Riders by gender and number injured (RCGB, 2004)

<table>
<thead>
<tr>
<th>PTW Type</th>
<th>Male Involved</th>
<th>Of which casualties (%)</th>
<th>Female Involved</th>
<th>Of which casualties (%)</th>
<th>All Involved</th>
<th>Of which casualties (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moped</td>
<td>4,364</td>
<td>3,954 (90.6%)</td>
<td>783</td>
<td>738 (94.3%)</td>
<td>5,238</td>
<td>4,695 (89.6%)</td>
</tr>
<tr>
<td>Motorcycle</td>
<td>20,007</td>
<td>18,261 (91.3%)</td>
<td>1,325</td>
<td>1,240 (93.6%)</td>
<td>21,619</td>
<td>19,506 (90.2%)</td>
</tr>
</tbody>
</table>
• Of moped rider casualties, 83.3% were male riders, 14.9% were female riders and 1.8% where the gender was unknown.
• Of motorcycle rider casualties, 92.5% were male riders, 6.1% were female riders and 1.4% where the gender was unknown.

7.4 The Governments Motorcycling Strategy 2005 (UK)
• More women are taking up motorcycling, but the vast majority of motorcyclists are male. This is reflected in the casualty statistics. In 2003 about 11% of casualties were female.

7.5 Huang & Preston (2004)
• The UK National Travel Survey data is based on a relatively small sample of PTW riders and the data has to be aggregated over time, which masks changes over time. Huang & Preston (2004) used data from the National Travel Survey from 1992 to 1999 and found that men were 6 times more likely to register a trip as a motorcycle driver than women. Overall 1 per cent of the sample registered a motorcycle trip. This was more than doubled for men less than 60 years old. Although women were less likely to be motorcycle drivers than men, those who used motorcycles made about the same number of trips as men (9.6 trips in the travel week compared with 9.2 for men). However, the overall distance travelled by women was 42 per cent less than that travelled by men.
• Women tended to make much shorter trips on average than men, travelling 4.6 miles compared to 8.3 miles. This resulted in males drivers travelling nearly 76 miles in the travel week compared with 44 miles for women. Men aged 16–29 were the heaviest users of motorcycles in terms of distance ridden averaging 85 miles in the travel week for this age group.
• The risk taking behaviour of motorcyclists is also influenced by demographic factors. For example, Chesham et al., (1993) found that young male motorcyclists are at a higher risk of accident involvement than other motorcyclists.

7.6 MAIDS study
• Table 2 provides information on the distribution of rider gender within the MAIDS accident data and within the exposure data. There were 798 male riders who participated in the MAIDS study (86.6%) and 791 male riders who agreed to participate in the petrol station exposure data collection (85.7%). There were 123 females in the accident data and 132 females in the exposure populations. No significant differences were noted in either population, indicating that neither males nor females were under or over-represented in the accident population.

<table>
<thead>
<tr>
<th></th>
<th>Accident data</th>
<th>Exposure data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent</td>
</tr>
<tr>
<td>Male</td>
<td>798</td>
<td>86.6</td>
</tr>
<tr>
<td>Female</td>
<td>123</td>
<td>13.4</td>
</tr>
<tr>
<td>Total</td>
<td>921</td>
<td>100.0</td>
</tr>
</tbody>
</table>
When the PTW rider gender is distributed according to PTW legal category (see Table 13) the data shows that more females operate L1 vehicles when compared to L3 vehicles (i.e., 22.4% versus 6.5%). Similarly the data shows that a lower percentage of males ride L1 vehicles when compared with L3 vehicles (i.e., 77.6% versus 86.6%).

<table>
<thead>
<tr>
<th></th>
<th>L1 vehicles</th>
<th></th>
<th>L3 vehicles</th>
<th></th>
<th>Total</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent of L1</td>
<td>Frequency</td>
<td>Percent of L3</td>
<td>Frequency</td>
<td>Percent</td>
</tr>
<tr>
<td>Male</td>
<td>309</td>
<td>77.6</td>
<td>489</td>
<td>93.5</td>
<td>798</td>
<td>86.6</td>
</tr>
<tr>
<td>Female</td>
<td>89</td>
<td>22.4</td>
<td>34</td>
<td>6.5</td>
<td>123</td>
<td>13.4</td>
</tr>
<tr>
<td>Total</td>
<td>398</td>
<td>100.0</td>
<td>523</td>
<td>100.0</td>
<td>921</td>
<td>100.0</td>
</tr>
</tbody>
</table>

7.7 De Lapparent M (2006)

- This study developed a model which can be used to estimate the probabilities of the severity of motorcycle accidents in large and dense French urban areas in 2003.
- "The model shows that male motorcyclists have lower probabilities to be slightly injured or severely injured and greater probabilities to be fatally injured. In addition to different physical and physiological capacities, the differences in male and female probabilities might have to do with their socioeconomic and demographic characteristics, manners, routes, or times of day as some routes are more risky than others at different times of the day (Mullin, 1997). Only the decrease in the probabilities to be slightly injured is significant. The result is along intuition if we assume that males are generally more resistant to physical injuries."
- "Women motorcyclists between 30 and 50 years old driving powerful motorcycles are the most exposed to risk of injury. Women motorcyclists over 50 years old driving powerful motorcycles are the second group of motorcyclists which is the most exposed to the risk of injury. The fourth and the fifth groups which are the most exposed to risk of severe accidents involve women motorcyclists less than 30 years old driving respectively light motorcycles and powerful motorcycles. Even though there are 4 different groups of women motorcyclists among 6 which are ranked in the top five groups which are the most exposed to risk of injury, women motorcyclists over 50 years old driving light motorcycles are the less exposed to the risk of injury among the 12 groups we consider".
- The first group of male motorcyclists which is the most exposed to risk of severe accident involves male motorcyclists between 30 and 50 years old driving powerful motorcycles. This group is ranked at the third position among the 12 groups of motorcyclists. The group of male motorcyclists which is the least exposed to severe accidents involves male motorcyclists less than 30 years old and driving light motorcycles. This group is ranked at position 11 among the 12 groups of motorcyclists.

7.8 Motorcycle Industry Fact Sheet 2005

- There are approx 3.5 million motorcycle licence holders in the UK and around 15% are women, which totals approx 525,000 women riders. There are approx 1.5 million active riders of which 10-15% are women. An MCI survey found that women ride a range of bikes:
  - Supersports 20%
- Sport/Tourer  18%
- Custom       14%
- Touring      7%
- Off-road     11%

• A survey by MCI in 2000 found that women aged 35 -44 are most likely to have a licence and women under 25 are least likely to ride. Regarding experience:
  - 75% had a full licence to ride
  - 18% have 2-5 years experience
  - 13% have 5-10 years experience
  - 35% have 10-20 years experience
  - 25% have 20 years or more

• 28% of women used a motorcycle as their main form of transport, 27% used a moped. 40% used their bike every day compared to men (33%). 63% said they were all year riders, 37% said not generally in winter. 42% used a bike mainly for pleasure (men said 51%).

• Mopeds were ridden by 33% of women as their main bike and women accounted for 25% of all moped riders in the survey.

7.9 Valent et al 2002

• This study looked at accident data in a northern Italian province between 1991 and 1996, where mortality rates from road accidents were higher than the national average. They found that amongst moped riders, women represented 21% of all riders and were at a lower risk of death than male riders.

7.10 Stefan et al 2003

• "There is little information available about the relationship between gender and motorcycling. Besides the general statement that young women are holding more motorcycle driving licences in the northern parts of Europe, only few details can be found.

• In 1990, the fraction of French women riding motorcycles was a mere 4%. This figure dropped to 3% in 1993. In comparison to France, the development in Germany is contrary, with the share of female motorcyclists increasing continuously from 11% in 1990 to 14% eight years later. Apart from this, motorcycling is still dominated by males in most European countries.

• Figure 58 below shows the fraction of female drivers per total number of injured motorcyclists in percent. With an average fraction of female motorcyclists of 9.0%, The Netherlands feature the highest share of injured female drivers among all Member States, followed by Austria and Spain (both 7.7%). Belgium, on the other hand, has the lowest mean fraction of injured females (4.1%).
Another fact worth mentioning is that in France (1993), 4.7% of injured motorcyclists were female. Yet, traffic evaluations during that year showed that their overall share as road users (motorcyclists) was only 3%. Still, without more detailed information on this subject, any further assumptions would be merely speculative. Data for Portugal, again, show an inexplicable rise after 1997, which probably does not correctly reflect national figures.

Figure 58: Percentage of female drivers per total number of injured motorcyclists in different European countries 1999 - 2001

- Another fact worth mentioning is that in France (1993), 4.7% of injured motorcyclists were female. Yet, traffic evaluations during that year showed that their overall share as road users (motorcyclists) was only 3%. Still, without more detailed information on this subject, any further assumptions would be merely speculative. Data for Portugal, again, show an inexplicable rise after 1997, which probably does not correctly reflect national figures.
8 Conclusions

8.1 Technologies
The aim of this review is to identify technologies which may have a role to play in an integrated safety system for motorcyclists in the future.

8.1.1 What safety devices are currently implemented on PTW’s and how do they perform?
The review first discusses motorcycle-focused safety systems which are either currently employed, realised on concept vehicles or the subject of research and which have the potential to be used within an integrated safety system.

Existing technologies
Existing technologies are reviewed in order to understand how they could be extended to contribute to a future integrated safety system or how their deficiencies could be used as the basis for other devices to address. These aspects which future systems should consider addressing are summarised below:

<table>
<thead>
<tr>
<th>Crash helmets (page 16)</th>
<th>Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Many severe and fatal injuries are to the head (AIS2+) (ACEM 2004)</td>
</tr>
<tr>
<td></td>
<td>Approximately 10% of crash helmets came off during the accident due to improper fastening or damage during accident (MAIDS 2004)</td>
</tr>
<tr>
<td></td>
<td>Past a critical impact speed to the helmet (13 mph), which is likely to occur in real life accident situations, helmet use reduces the severity of head injuries at the expense of increasing the severity of neck injuries (Huang and Preston 2004)</td>
</tr>
<tr>
<td></td>
<td>International studies show that crash helmet use compliance is lowest in southern (European) countries (Stefan et al 2003)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Advanced technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head-up display (Gotoh et al) and rear-view cameras (Reevu) – Passive devices only.</td>
</tr>
</tbody>
</table>

| Cervical spine brace (page 20) | Reduces injury risk to neck, cervical spine, spinal cord and collar bone resulting from hyperflexion, hyperextension and lateral hyperflexion (overflexion of the head when forced forwards, rearwards and sideways) and also compression of the spinal column. |

<table>
<thead>
<tr>
<th>Rider clothing (page 21)</th>
<th>Protective clothing is less effective in reducing injuries associated with:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Severe bending, crushing and torsional forces to the lower limbs,</td>
</tr>
<tr>
<td></td>
<td>- Massive penetrating injuries to any part of the body,</td>
</tr>
<tr>
<td></td>
<td>- High energy impacts to chest and abdomen causing injuries through shock waves and severe bending forces (de Rome and Stanford undated)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leg protectors (including crash bars and fairings) (page 27)</th>
<th>Design recommendations for leg protection include:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Mitigation against the direction of force against the rider’s leg and the loading of that force (Elliot et al 2003)</td>
</tr>
<tr>
<td></td>
<td>- Coverage of the foot to the front and side (Otte 1994 in Elliott et al 2003)</td>
</tr>
<tr>
<td></td>
<td>- Elimination of compression effects (Otte 1994 in Elliott et al 2003)</td>
</tr>
</tbody>
</table>
- Frontal protection to the tibia by an energy absorbing element which should not retain the rider to the machine (Otte 1994 in Elliott et al 2003)

**Enclosed PTW – BMW C1 (page 28)**

Integral safety frame, seat-belts and a crumple zone have the potential to offer improved safety benefits.

**Braking systems (Linked, Combined and Anti-braking systems) (page 30)**

The following recommendations have been made regarding the design of braking systems:
- Brakes only operated by one control
- Automatic co-ordination between front and rear wheel braking and combine with
- An appropriate anti-lock system (Eberspächer 1991, Hagstotz & Ludsteck 1995)
- Automatic Stability Control and Brake Assist can further enhance braking performance.

**Roll stability (page 33)**

A function within the Xtreme Beam system is to advise riders when a pre-determined lean angle during cornering has been reached thereby reducing the potential occurrence of roll-over – Advisory function only, not assistive.

**Conspicuity enhancements (page 33)**

Recommendations for improved conspicuity are:
- Increase luminance contrast
- Increase colour contrast
- Maximisation of the motorcycle’s size (or apparent size)
- Strengthening the shape or pattern recognition
- Employing changes of state

Estimations of speed and distance can be improved by maximising the distance between two or more parts of the motorcycle to assist triangulation.

**Emergency lighting (page 39)**

The Xtreme Beam lighting system automatically activates a safety strobe when the motorcycle’s tyres loose contact with the road.

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**Integrated Safety devices**

Integrated Safety devices which have more recently been integrated into motorcycles include:

<table>
<thead>
<tr>
<th>Rider airbags (page 22)</th>
<th>Wireless activation if pre-collision parameters met.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorcycle airbags (page 24)</td>
<td>Need to extend deployment scenarios.</td>
</tr>
<tr>
<td>Intelligent speed adaptation (page 37)</td>
<td>Concept proven in field trials.</td>
</tr>
<tr>
<td>Braking control systems <em>(page 32)</em></td>
<td>Automatic Stability Control and Brake Assist can further enhance braking performance.</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Adaptive/active lighting <em>(page 38)</em></td>
<td>Operational systems developed by Suzuki and Yamaha.</td>
</tr>
</tbody>
</table>
| Vision enhancement *(page 39)* | Front view: Display showing heading of vehicle, objects, stop signs, road markings.  
Rear view: Display showing vehicle presence to the rear.  
Representations may be real (camera) or symbolic. (Honda)  
Passive systems only. |
| Inter-vehicle communications *(page 40)* | The Advanced Safety Vehicle ASV-3 developed by Honda offers promise to PISa since when the vehicle comes to a stop at an intersection, the Inter-Vehicle Communication System detects the position of any approaching vehicles and assists the driver in determining whether it is safe to proceed. |
| Pedestrian detection systems *(page 42)* | These systems aim to detect and warn the PTW rider of potential conflicts with pedestrians. Advisory only. |
| Curve speed warning *(page 42)* | These systems warn the rider of the presence and nature of upcoming curves and bends. Advisory only. |
| Impact sensing cut-off *(page 42)* | These systems automatically disable fuel and electrical systems in the event of an accident. |
| Vehicle diagnostics *(page 42)* | The vehicle diagnostic system discussed monitors and advises the rider of the status of the tyres. |
| Alcohol interlock *(page 42)* | The aim of the system is to prevent riding above the legally prescribed limit. (Alcohol involved riders were over-represented in the MAIDS accident population and the unadjusted odds of being involved in an accident when the rider is under the influence of alcohol is 2.7 times greater than when they are not (ACEM 2004)). |
8.1.2 What IS devices are currently implemented in other transport forms and how do they relate to PISa?

Following the review of motorcycle-focussed systems, IS devices which are currently found on other forms of transport are then discussed. Those of interest to PISa include:

<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic Stability Control</td>
<td>The concept of ESC holds great promise for motorcycle application. (Based on UK data drawn from 1990s and early 2000s, the predominant failure leading to a motorcyclist fatality was loss of control by the rider due to excessive speed (37% of accidents) Broughton 2005) However due to the very different natures of four and two-wheeler, simple transference of the system is unlikely to be possible. When combined with navigation information and other advanced systems, performance could be enhanced through appropriate speed selection and course maintenance.</td>
</tr>
<tr>
<td>Brake assistance</td>
<td>Brake assistance similarly holds great promise for motorcyclists conceptually (In multiple-vehicle collisions, 71.2% of PTW operators attempted some form of collision avoidance (49.3% by braking) although in 32.2% of these collisions, there was no time for the PTW operator to complete their action (ACEM 2004)), but transference of the system may require significant re-design.</td>
</tr>
<tr>
<td>Adaptive cruise control</td>
<td>Acceleration and braking is automatically employed to maintain the vehicle at a set distance from the vehicle in front. When this distance is achieved or exceeded, a pre-set, driver selected cruising speed is maintained.</td>
</tr>
<tr>
<td>Safe following system</td>
<td>Some form of safe following system may be a useful support device for motorcyclists.</td>
</tr>
<tr>
<td>Automatic steering</td>
<td>Experimental electronic steering system which automatically maintained the vehicle on the road using vehicle dynamic data, digital map and GPS.</td>
</tr>
<tr>
<td>Lane change assistant</td>
<td>Whilst the lane change assistant holds great potential for motorcyclists by being implemented on other vehicles i.e. car drivers have warning of a motorcycle approaching from behind prior to changing lane, an adapted version for motorcyclists may be beneficial in detecting and then advising motorcyclists of another vehicle turning into their path. Such a system would support the accident scenario identified within APROPSYS of a PTW overtaking a car which is turning left.</td>
</tr>
<tr>
<td>Intelligent speed adaptation</td>
<td>ISA is likely to be an area of interest to PISa since speeding of the rider is often an important causation factor in all types of accidents (APROPSYS literature review 2004). As well as the absolute speed of the motorcyclist being of relevance, a system to monitor and act on the relative speed of the motorcyclist to other traffic is of potential benefit since the MAIDS report also states that in 18% of all cases, PTW travelling speeds were greater or less than the surrounding traffic and were considered to be a contributory factor.</td>
</tr>
</tbody>
</table>
**Adaptive lighting (page 53)**
Various forms of automatic curve illumination are available and also a rear lighting system which enlarges the brake area when the brakes are forcefully applied.

**Automated crash notification (page 54)**
Due to the vulnerability of motorcyclists in an accident, automatic crash notification is likely to offer benefit.

**Lane departing avoidance system (page 57)**
Warning systems advise driver of imminent deviation outside of their lane. Autonomous lane keeping systems use visual images to determine the vehicles road position and drive actuators to adjust this if required.

**Collision avoidance system (page 58)**
Due to the vulnerability of motorcyclists, collision avoidance systems are a key focus for PISa.

**Road surface condition monitoring systems (page 59)**
The susceptibility of PTWs to adverse interaction with poor road surface conditions, as noted in D02, suggests that systems to identify, advise and possibly assist the rider in negotiating road surface hazards are likely to be of benefit.

**Driver vigilance systems (page 60)**
Systems to monitor rider vigilance i.e. detect rider states which may be indicative of increased accident risk, may be a useful support system for motorcyclists.

**Pedestrian protection (page 60)**
Whilst pedestrian protection may not be a particular concern of PISa, the concept of outward deflecting devices may be worthy of consideration to provide additional protection to the motorcyclist.

### 8.2 Rider and driver issues
The section of the report pertaining to rider/driver issues provides supporting information which may be of relevance in the development of systems within PISa. Specific points of interest are discussed below.

#### 8.2.1 What are the aspects of PTW use which PISa may need to support?
Across Europe there is a mixture of use of PTW between leisure and work use, so accident factors which PISa may want to mitigate against will be quite varied. However guidance to this is provided in Deliverable D2.

Studies reported by Robertson (2002) and Huang and Preston (2004) identify some of the unique aspects pertaining to PTW manoeuvres which Clarke et al (2004) state may increase accident risk due to lack of appreciation of these factors by four-wheeled road users. Whilst measures could be introduced in the future to eliminate such manoeuvres possibly by traffic regulations and/or technological systems, such an approach would be very contentious due to the restrictions it would impose. A further measure would be to rely on training of both the other vehicle driver and the motorcyclist to increase awareness of these manoeuvres and educate as to appropriate situations of use, respectively; however such an approach may only be of limited effectiveness on its own. The role for PISa would be to consider these types of manoeuvres and investigate how rider safety can be supported. Some of these aspects are already discussed within the technologies section.
8.2.2 What age and gender of rider need to be accommodated by IS systems?

In terms of the gender and age of riders that are of relevance to PISa, most research confirms a high accident involvement of male riders (OECD undated, Broughton 2005, Wick et al 1998 and Schultz and Koch 1991), although within the MAIDS study, when accident involved riders were compared against the exposure group, neither male nor female riders were under or over-represented (ACEM 2004). Whilst the data suggests a dominance of male riders, good inclusive design practice would recommend that solutions designed by PISa consider the range of abilities of both genders.

With respect to age, Stefan et al (2003), using the CARE-Database found that across Europe the age of accident involved riders is increasing – for some countries riders less than 30 years still dominate, whilst for other countries the spread is uniform across age groups. There are mixed findings with respect to the additional accident risk of older riders returning to biking (Huang and Preston 2004, Elliott et al 2003 and Sexton et al 2004), although within D2 it was found that riders of large machines were identified as a specific class of concern (Sexton et al 2004) and that there is a relationship between engine size and injury severity which is also associated with rider age (Broughton 2005). It may be prudent therefore for PISa to consider the suitability of any proposed motorcycle systems to older riders which would be in line with good inclusive design practice.

8.2.3 What aspects of rider behaviour may be pertinent to PISa?

The literature suggests associations between types of rider behaviour and other factors including:

- Alcohol use – The over-representation of alcohol involved riders in accidents (ACEM 2004) and its association with speeding and lack of crash helmet use suggests that this may be a factor for consideration within PISa. It is important that any IS systems introduced to support normal riding are not abused by alcohol impaired riders to compensate for their reduced riding abilities. PISa needs to clearly state that its systems are not designed to support overtly risky riding behaviours and if possible apply other devices to prevent this happening e.g. alcohol interlocks.

- Motivations and attitudes – Different studies have investigated rider attitudes and the motivations for them (Schulz et al 1991 and Walters 1982 as reported in Elliott et al 2003). Whilst there have been different resultant categorisations of riders, the challenges to the PISa team will be in accommodating those who, either intentionally or unintentionally, will push IS systems to the limits. For example, if a rider adopts a riding style which has such constant heavy reliance on emergency systems such that their use becomes part of everyday riding, then a system to monitor usage levels and implement a change in the performance characteristics of the bike to reduce future occurrences may be a solution. However developments such as these would probably be of lower priority within PISa whose resources are prioritised on developing systems to support normal, opposed to extreme, riding behaviour.

- Experience – Research indicates that a negative relationship between experience and accident involvement. Whilst IS systems will help to protect the less experienced riders from their own mistakes, they should not encourage dependence and prevent riders from learning safe riding strategies. Whilst this is an important consideration, it is secondary to the primary aim of PISa to develop IS systems to improve rider safety.

8.2.4 What can be learnt from the usability of braking systems?

Evidence from MAIDS, APROSYS and Thom et al (1985) suggests that braking is often employed as a collision avoidance measure but is not always effective. Further studies have indicated that both cognitive and physical factors may contribute to this i.e. riders are not
sure how to use the system to maximum effectiveness (Hagstotz & Ludsteck 1995 and Fries et al 1989) or are physically restricted in doing so (Thom et al 1985). The key lesson to learn from this analysis for PISa is that whatever systems are implemented, they need to be appropriately designed and full consideration should be given to the content and form of training.

8.2.5 What guidance is there to assist in IS system design?

Theories of cognitive psychology

Since rider attention is a limited capacity resource, the interface design should seek to minimise the attentional demands placed on the rider. Designs which support automatic processing (require minimal conscious effort) and parallel processing (where two or more information sources/elements are processed simultaneously e.g. processing a vision enhancement image on a HUD whilst viewing the actual road scene.) will achieve faster processing times. Improvements in time-sharing performance can be achieved through:

- Reducing the competition for common processing resources (‘Multiple Resource theory’ Wickens, 1984) - As driving can be considered to predominantly involve spatial encoding within the visual modality (e.g. speed estimates of own car/other road users, judging road geometry), necessitating manual responses (steering, accelerator, brakes, gears etc.), this theory would predict that the ideal means of presenting secondary information would be auditory/verbal, requiring a vocal response. Given the similarity of the driving and riding function in terms of the description above, the recommendation may equally apply to riders.

- Achieving the optimum match between the form of stimulus input, its method of processing the form of response required (Stimulus/Central processing/Response (SCR) compatibility theory Wickens 1992) - This theory states, based on empirical foundations, that verbal tasks are best served by auditory input and speech output, whereas spatial tasks are best served by visual input and manual output.

- Ensuring high display proximity between two or more information sources to be processed together (‘The Principle of Proximity’ Wickens and Andre 1990) – This states that different, but related, displays or information elements should be separated by less than two degrees in space (i.e. both within foveal vision) and that where two or more pieces of information are used together in one display they should be integrated.

HMI Guidelines/principles

The ‘European Statement of Principles (ESoP) on the Design of Human Machine Interaction’ covers in-vehicle information and communication systems intended for use by the driver while the vehicle is in motion. They are directed to navigation systems, traffic information, etc and not ABS, ESP or ADAS since these are fundamentally different and require additional considerations in terms of Human Machine Interaction. However whilst the ESoP does not directly apply to IS Systems, it does provide some basic principles which are of relevance to PISa including:

- Section 3: Information Presentation Principles
- Section 4: Principles on Interaction with Displays & Controls
- Section 5: System Behaviour Principles
- Section 6: Principles on Information about the System
- Recommendations on Safe Use (RSU) 2005 providing guidance for employers, point-of-sale, vehicle hire companies and drivers themselves.

Equivalents to the ESoP exist in the U.S. and Japan.
In addition, NHSTA in the US have produced guidelines for Crash Warning Systems Interfaces (Campbell et al 2007) which cover:

- Chapter 2: General guidelines for CWS design
- Chapter 3: Auditory warnings
- Chapter 4: Visual warnings
- Chapter 5: Haptic warnings
- Chapter 6: Controls used in CWS devices
- Chapter 7: Forward collision warning systems
- Chapter 8: Lane change warning systems
- Chapter 9: Road departure warning systems

**Standards**

The International Standards Organisation (ISO) has two working groups (WGs) responsible for developing standards for advanced driver technologies. Published Standards and Standards under development are provided for:

- ISO TC22 (Road Vehicles) SC13 (Ergonomics applicable to road vehicles) WG8 (Transport information and control systems, on-board Man-machine interface)
- Working Group Full title: ISO TC 204 (Intelligent transport systems) WG 14 (Vehicle/roadway warning and control systems)

**Evaluation methods/measures**

The most current reviews of methodological approaches are provided by two 6th Framework IST Programme projects:

- HUMANIST (http://www.noehumanist.org/start.htm)
- AIDE (http://www.aide-eu.org/index.html)

The deliverables of relevance to PISa are:

- HUMANIST deliverable D.2/E.2 (2004), Impact of IVIS on driver workload and distraction: review of assessment methods and recent findings. (Metrics of relevance cover: Lane standard deviation, Time to line crossing (TLC), Time headway, Minimum following distance, Brake response time, Glance duration, Glance frequency and Visual occlusion).
- AIDE deliverable 2.2.5 (2004), Driving performance assessment – methods & metrics. (This covers: speed, lateral position, time to line crossing, headway, brake, steering grip and steering wheel movements as well as an in-depth section on the Lane Change Test).
- AIDE deliverable 2.1.1 (2004), Driving performance assessment – methods & metrics. (This covers methodological issues relating to user-centred design approaches and includes: User mental model and requirements, Usability and acceptance, Workload, Situation awareness. It also assesses environments varying from Laboratory testing to naturalistic driving).

**8.2.6 Driver issues – ‘Looked-but-failed-to-see’**

The model of cognitive processing developed from Allen et al (1996) relates ‘Looked-but-failed-to-see’ accidents to errors of detection (the driver does not see a motorcyclist) or identification (the driver misinterprets the motorcyclist) either of which can result in an inappropriate manoeuvre by the driver. Factors which can be used to address detection and identification errors are outlined in the earlier discussion of conspicuity enhancements.
9 Summary of D3 findings for future work packages

The data concluded in the previous section is summarised in tabulated form to provide an easy reference for input into future PISa work packages.
<table>
<thead>
<tr>
<th>SAFETY DEVICE</th>
<th>STATUS</th>
<th>RELEVANT ACCIDENT SCENARIOS</th>
<th>RIDER CONSIDERATIONS</th>
<th>USABILITY</th>
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<tbody>
<tr>
<td><strong>MOTORCYCLES – CONVENTIONAL TECHNOLOGIES</strong></td>
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<tr>
<td>Crash helmet <em>(page 16)</em></td>
<td>Further protection required against fatal and severe injury. Increased levels of helmet retention are required. Increased compliance is required.</td>
<td>Where head impacts with other vehicle/object/roadway</td>
<td>Physical characteristics</td>
<td>Behaviour</td>
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<td>Age</td>
<td>Impairment</td>
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<td></td>
<td>Good inclusive design practice recommends design solutions accommodate all ages.</td>
<td>Need to consider how intoxication, drug use and fatigue may impact on system use</td>
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<td>Growing prevalence of older riders in accidents needs consideration.</td>
<td>Risk-taking</td>
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<td>Dependency</td>
<td>Need to consider if the system will encourage risk-taking (risk-compensation) and design against this</td>
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<td>Training</td>
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<td>Ease of use</td>
<td>In the design of systems, training needs need to be identified</td>
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<td>Ease of use</td>
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<tr>
<td>Rear-view camera.</td>
<td>Impacts to rear of motorcycle.</td>
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<tr>
<td>Head-up displays have potential to reduce eyes-off-the-road time.</td>
<td>Straight, intersection, curve/bends Frontal impacts.</td>
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<tr>
<td><strong>Cervical spine brace (page 20)</strong></td>
<td>Reduces injury risk to neck, cervical spine, spinal cord and collar bone resulting from hyperflexion, hyperextension and lateral hyperflexion (overflexion of the head when forced forwards, rearwards and sideways) and also compression of the spinal column.</td>
<td>Where head impacts with other vehicle/object/roadway</td>
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<tr>
<td><strong>Rider clothing (page 21)</strong></td>
<td>Protective clothing is less effective in reducing injuries associated with: - Severe bending, crushing and torsional forces to the lower limbs, - Massive penetrating injuries to any part of the body, - High energy impacts to chest and abdomen causing injuries through shock waves and severe bending forces</td>
<td>Where body impacts with other vehicle/object/roadway</td>
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<tr>
<td><strong>Leg protectors (including crash bars and fairings) (page 27)</strong></td>
<td>Design recommendations include: - Mitigation against the direction of force against the rider’s leg and the loading of that force - Coverage of the foot to the front and side - Elimination of compression effects - Frontal protection to the tibia by an energy absorbing</td>
<td>Where leg crushed between motorcycle and other vehicle/object/roadway</td>
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<td>SAFETY DEVICE</td>
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<tr>
<td>Enclosed PTW – BMW C1 (page 28)</td>
<td>Integral safety frame, seat-belts and a crumple zone have the potential to offer improved safety benefits.</td>
<td>Most accident scenarios.</td>
<td>Physical characteristics</td>
<td></td>
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</tbody>
</table>
| Braking systems (Linked, Combined and Anti-braking systems) (page 30) | Design recommendations include:  
- Brakes only operated by one control  
- Automatic co-ordination between front and rear wheel braking and combine with  
- An appropriate anti-lock system | Straight, intersections, curves/bends  
Frontal impacts | Age  
Good inclusive design practice recommends design solutions accommodate all ages.  
Growing prevalence of older riders in accidents needs consideration. | Behaviour  
Impairment  
Need to consider how intoxication, drug use and fatigue may impact on system use  
Risk-taking  
Need to consider if the system will encourage risk-taking (risk-compensation) and design against this | Ease of use  
The system needs to be easy to use (physical ease) and intuitive to use (cognitive ease) |
| Roll Stability (page 33) | This system advises riders when a pre-determined lean angle during cornering has been reached thereby reducing the potential occurrence of rollover. | Curves and bends which can lead to run off the road accidents. | Gender  
Dominance of male riders.  
Good inclusive design practice recommends design solutions accommodate both genders. | Training  
In the design of systems, training needs need to be identified | |
| Conspicuity enhancements (page 33) | Design recommendations include:  
For improved conspicuity:  
- Increase luminance contrast  
- Increase colour contrast  
- Maximisation of the motorcycle’s apparent size  
- Strengthening the shape or pattern recognition  
- Employing changes of state  
For improved speed and distance estimation:  
- Maximise distance between two or more parts of the motorcycle to assist triangulation | Intersections when motorcycle viewed to front (head-on/obliquely) | Dependency  
Need to consider if the system will encourage an element of dependency which may be unfavourable | |
<p>| Emergency lighting (page 39) | A strobe light is automatically activated when the PTWs tyres loose contact with the ground. | Post-accident | | |</p>
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<tr>
<th>SAFETY DEVICE</th>
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<tbody>
<tr>
<td><strong>MOTORCYCLES – INTEGRATED SAFETY DEVICES</strong></td>
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</tbody>
</table>
| Rider airbag  | Two methods of activation: -Direct activation when cord attaching rider to motorcycle is disengaged from the motorcycle when rider falls - Wireless activation when pre-collision parameters met | Where body impacts with other vehicle/object/roadway | Physical characteristics  
Age Good inclusive design practice recommends design solutions accommodate all ages.  
Growing prevalence of older riders in accidents needs consideration. | Behaviour  
Impairment Need to consider how intoxication, drug use and fatigue may impact on system use | Ease of use  
The system needs to be easy to use (physical ease) and intuitive to use (cognitive ease) |
| (page 22) | | | Gender  
Dominance of male riders. Good inclusive design practice recommends design solutions accommodate both genders | Training In the design of systems, training needs need to be identified |
| Motorcycle airbags  | Potential to extend in terms of intelligence and number of locations on motorcycle (see Pedestrian Protection below) | Where body impacts with motorcycle/other vehicle | Risk-taking  
Need to consider if the system will encourage risk-taking (risk-compensation) and design against this | |
| (page 24) | | | Dependency  
Need to consider if the system will encourage an element of dependency which may be unfavourable | |
| Intelligent Speed Adaptation  | Concept proven in field trials. Aside from assessing speed in relation to the speed limit, further considerations include: - Speed in relation to surrounding vehicles - Speed in relation to road/traffic/weather conditions (appropriate speed which may be higher or lower than speed limit) | Where speed is a factor  
Straight, intersection, curve/bends  
Frontal impacts | | |
| (page 37) | | | | |
| Braking control systems  | Automatic Stability Control and Brake Assist can further enhance braking performance. | Frontal impacts | | |
| (page 32) | | | | |
| Advanced/active lighting  | Currently implemented on some motorcycles. Car developments may trickle down where applicable. | Where there is poor visibility on bends  
Frontal impacts | | |
| (page 38 ) | | | | |
| Vision enhancement  | Views from front and/or rear cameras displayed to advise rider of presence and heading. | Where there is poor or no visibility  
Frontal, lateral and rear impacts | | |
<p>| (page 39) | | | | |</p>
<table>
<thead>
<tr>
<th>SAFETY DEVICE</th>
<th>STATUS</th>
<th>RELEVANT ACCIDENT SCENARIOS</th>
<th>RIDER CONSIDERATIONS</th>
<th>USABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter-vehicle communications</td>
<td>Detects approaching vehicles and advises if it is safe to proceed through intersection.</td>
<td>Intersections</td>
<td>Physical characteristics</td>
<td>Behaviour</td>
</tr>
<tr>
<td>(page 40)</td>
<td></td>
<td></td>
<td>Age</td>
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<tr>
<td>Pedestrian detection systems</td>
<td>Detects pedestrians who may in conflict with course of motorcycle.</td>
<td>Frontal impacts</td>
<td>Good inclusive design practice recommends design solutions accommodate all ages.</td>
<td>Impairment</td>
</tr>
<tr>
<td>(page 42)</td>
<td></td>
<td></td>
<td>Growing prevalence of older riders in accidents needs consideration.</td>
<td>Need to consider how intoxication, drug use and fatigue may impact on system use</td>
</tr>
<tr>
<td>Curve speed warning</td>
<td>These systems warn the rider of the presence and nature of upcoming curves and bends. Advisory only.</td>
<td>Loss of control and run-off road accidents</td>
<td>Risk-taking</td>
<td>Need to consider if the system will encourage risk-taking (risk-compensation) and design against this</td>
</tr>
<tr>
<td>(page 42)</td>
<td></td>
<td></td>
<td>Gender</td>
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<tr>
<td>Impact sensing cut-off</td>
<td>These systems automatically disable fuel and electrical systems in the event of an accident.</td>
<td>All accident scenarios</td>
<td>Dominance of male riders.</td>
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<tr>
<td>(page 42)</td>
<td></td>
<td></td>
<td>Good inclusive design practice recommends design solutions accommodate both genders.</td>
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<tr>
<td>Vehicle diagnostics</td>
<td>The vehicle diagnostic system discussed monitors and advises the rider of the status of the tyres.</td>
<td>Specifically accidents involving braking</td>
<td>Dependency</td>
<td></td>
</tr>
<tr>
<td>(page 42)</td>
<td></td>
<td></td>
<td>Need to consider if the system will encourage an element of dependency which may be unfavourable</td>
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<tr>
<td>Alcohol interlock</td>
<td>Prohibits riding above the legally prescribed limit.</td>
<td>Accidents caused by intoxication</td>
<td>Potential relevant to most accident scenarios but particularly run-off road accidents</td>
<td></td>
</tr>
<tr>
<td>(page 42)</td>
<td></td>
<td></td>
<td>Good inclusive design practice recommends design solutions accommodate both genders.</td>
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</table>

D3 Powered two wheeler Integrated Safety (PiSa): Review of PTW safety technologies and literature
### Electronic Stability Control (ESC) (page 50)

**The concept of ESC holds great promise for motorcycle application, but simple transference of the system is unlikely to be possible.**

When combined with navigation information and other advanced systems, performance could be enhanced through appropriate speed selection and course maintenance.

**Relevant Accident Scenarios:** Where the motorcycle becomes unstable and/or skids

**Run-off road**

**Rider Considerations:**

#### Behaviour
- **Impairment:** Need to consider how intoxication, drug use and fatigue may impact on system use
- **Risk-taking:** Need to consider if the system will encourage risk-taking (risk-compensation) and design against this

#### Physical characteristics
- **Age:** Good inclusive design practice recommends design solutions accommodate all ages.

#### Training
- **Dependency:** Need to consider if the system will encourage an element of dependency which may be unfavourable

**Usability:** Ease of use
- **The system needs to be easy to use (physical ease) and intuitive to use (cognitive ease).**

**Other Transport Forms – Integrated Safety Devices**

<table>
<thead>
<tr>
<th>Device</th>
<th>Status</th>
<th>Relevant Accident Scenarios</th>
<th>Rider Considerations</th>
<th>Usability</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electronic Stability Control</strong></td>
<td>The concept of ESC holds great promise for motorcycle application, but simple transference of the system is unlikely to be possible. When combined with navigation information and other advanced systems, performance could be enhanced through appropriate speed selection and course maintenance.</td>
<td>Straight, intersections, curves/bends, frontal impacts and run-off road.</td>
<td><strong>Behaviour</strong>&lt;br&gt;- Impairment: Need to consider how intoxication, drug use and fatigue may impact on system use&lt;br&gt;- Risk-taking: Need to consider if the system will encourage risk-taking (risk-compensation) and design against this</td>
<td><strong>Ease of use</strong>&lt;br&gt;The system needs to be easy to use (physical ease) and intuitive to use (cognitive ease).</td>
</tr>
<tr>
<td><strong>Brake assistance</strong> (page 51)</td>
<td>Brake assistance similarly holds great promise for motorcyclists conceptually, but transference of the system may require significant re-design.</td>
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<tr>
<td><strong>Adaptive cruise control</strong> (page 52)</td>
<td>Acceleration and braking is automatically employed to maintain the vehicle at a set distance from the vehicle in front. When this distance is achieved or exceeded, a preset, driver selected cruising speed is maintained.</td>
<td>Straight, higher speed roads.</td>
<td></td>
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<tr>
<td><strong>Safe following system</strong> (page 52)</td>
<td>Some form of headway monitoring may be a useful support device for motorcyclists. May need to consider in terms of absolute distance or rate of change of approach.</td>
<td>Where motorcycle impacts with vehicle in front</td>
<td><strong>Gender</strong>&lt;br&gt;- Dominance of male riders.&lt;br&gt;- Good inclusive design practice recommends design solutions accommodate both genders.</td>
<td></td>
</tr>
<tr>
<td><strong>Automatic steering</strong> (page 52)</td>
<td>Experimental electronic steering system which automatically maintained the vehicle on the road using vehicle dynamic data, digital map and GPS.</td>
<td>Run-off road</td>
<td><strong>Dependency</strong>&lt;br&gt;- Need to consider if the system will encourage an element of dependency which may be unfavourable</td>
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<tr>
<td><strong>Lane change assistant</strong> (page 52)</td>
<td>An adapted version which provides motorcyclists with advanced warning of another vehicle turning into their path would be beneficial.</td>
<td>Where other vehicle filters or turns in front of motorcycle</td>
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<td>SAFETY DEVICE</td>
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<td>RELEVANT ACCIDENT SCENARIOS</td>
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<tr>
<td>Intelligent Speed Adaptation (page 53)</td>
<td>Refer to description earlier in table under the heading – Motorcycles - Integrated safety devices.</td>
<td>Physical characteristics&lt;br&gt;&lt;br&gt;Age&lt;br&gt;&lt;br&gt;Good inclusive design practice recommends design solutions accommodate all ages.&lt;br&gt;Growing prevalence of older riders in accidents needs consideration.</td>
<td>Behaviour&lt;br&gt;&lt;br&gt;Impairment&lt;br&gt;&lt;br&gt;Need to consider how intoxication, drug use and fatigue may impact on system use.</td>
<td>Ease of use&lt;br&gt;&lt;br&gt;The system needs to be easy to use (physical ease) and intuitive to use (cognitive ease).</td>
</tr>
<tr>
<td>Adaptive lighting (page 53)</td>
<td>Various forms of automatic curve illumination are available on cars. Refer to description earlier in table under the heading – Motorcycles - Integrated safety devices.</td>
<td>Rear impacts to motorcycle&lt;br&gt;&lt;br&gt;A rear lighting system which enlarges the brake area when the brakes are forcefully applied.</td>
<td>Gender&lt;br&gt;&lt;br&gt;Dominance of male riders.&lt;br&gt;Good inclusive design practice recommends design solutions accommodate both genders.</td>
<td>Training&lt;br&gt;&lt;br&gt;In the design of systems, training needs need to be identified.</td>
</tr>
<tr>
<td>Automatic crash notification (page 54)</td>
<td>Due to the vulnerability of motorcyclists, automatic notification of occurrence and location of an accident offers benefit.</td>
<td>All accident scenarios especially those where accident was not witnessed eg rural locations.</td>
<td>Risk-taking&lt;br&gt;&lt;br&gt;Need to consider if the system will encourage risk-taking (risk-compensation) and design against this.&lt;br&gt;&lt;br&gt;Dependancy&lt;br&gt;&lt;br&gt;Need to consider if the system will encourage an element of dependency which may be unfavourable.</td>
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<tr>
<td>Lane departing avoidance system (page 57)</td>
<td>Warning systems advise driver of imminent deviation outside of their lane.&lt;br&gt;Autonomous lane keeping systems use visual images to determine the vehicles road position and drive actuators to adjust this if required.&lt;br&gt;Possibly of less benefit to motorcyclists than drivers due to riding style.</td>
<td>Where the motorcycle runs out of lane&lt;br&gt;Frontal impacts and run-off road</td>
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<tr>
<td>Collision avoidance system (page 58)</td>
<td>Due to the vulnerability of motorcyclists, advanced warning of the possibility of impacts with other vehicles/objects/pedestrians would be beneficial</td>
<td>Straight, intersections, curves/bends&lt;br&gt;Forward warning most relevant to motorcycles</td>
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<tr>
<td>SAFETY DEVICE</td>
<td>STATUS</td>
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<td>RIDER CONSIDERATIONS</td>
<td>USABILITY</td>
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<tr>
<td>Road surface condition monitoring system</td>
<td>Such systems could assist the PTW rider by identifying, advising and possibly assisting in the safe negotiation of road surface hazards</td>
<td>Loss of control accidents</td>
<td>Physical characteristics</td>
<td>Behaviour</td>
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<td></td>
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<td></td>
<td>Age</td>
<td>Impairment</td>
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<td>Growing prevalence of older riders in accidents needs consideration.</td>
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<td>Dominance of male riders.</td>
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<tr>
<td>Driver vigilance systems</td>
<td>Systems to monitor rider vigilance i.e. detect rider states which may be indicative of increased accident risk, may be a useful support system for motorcyclists</td>
<td>Accidents caused by drowsiness</td>
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<tr>
<td>Pedestrian protection</td>
<td>Whilst pedestrian protection may not be a particular concern of PISA, the concept of outward deflecting devices may be worthy of consideration to provide additional protection to the motorcyclist</td>
<td>Where body impacts with other vehicle/object/roadway</td>
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</table>

**Road surface condition monitoring system (page 59)**

- Such systems could assist the PTW rider by identifying, advising and possibly assisting in the safe negotiation of road surface hazards.

**Driver vigilance systems (page 60)**

- Systems to monitor rider vigilance i.e. detect rider states which may be indicative of increased accident risk, may be a useful support system for motorcyclists.

**Pedestrian protection (page 60)**

- Whilst pedestrian protection may not be a particular concern of PISA, the concept of outward deflecting devices may be worthy of consideration to provide additional protection to the motorcyclist.
10 References

ACEM. 2004. MAIDS - In-depth investigations of accidents involving two-wheelers - Final report 1.2. ACEM.


APROSYSP SP4. Motorcyclists: Accident national data. Deliverable AP-SP41-0001-C. European funded project TIP3-CT-2004-506503.


BOVERIE et al. 2001. A new class of intelligent sensors for the inner space monitoring of the vehicle of the future.


de ROME & STANFORD. Undated. Motorcycle protective clothing.


MIDTLAND, K. 1993. A cognitive theoretical framework for investigating the presentation of information to drivers. 10 10. TOI.


MIMURO et al. Undated. Functions and devices of Mitsubishi Active Safety ASV.


THIRUMALAI, K. Unknown. ITS innovation challenges for 21st century transportation safety and services market. US Department of Transportation.


