OPTIMAL SIDE IMPACT PROTECTION

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ABSTRACT

A three year collaborative research program was funded recently by the Australian Research Council in conjunction with the Federal Office of Road Safety, Holden and the Australian Automobile Association to develop a procedure to optimise vehicle design for minimal Harm. The research will be undertaken at the Monash University Accident Research Centre and involves research effort by the collaborative partners and its associate investigators. Four main study tasks are involved namely (i), collection of data on a sample of real world crashes and mass data analysis, (ii), establishment of up-dated Australian injury costs and Harm associated with vehicle occupants, (iii), development of Injury Assessment Functions (IAFs) relating crash test criteria with probability of injury, and (iv), construction of a computer package to optimise design. The project commenced in January 1998 and work has progressed on a number of the research tasks. It is expected to be of significant benefit to all international car manufacturers in their attempts to improve side impact protection. In addition, the Federal Office of Road Safety will be able to use these findings to help in the development of a single enhanced side impact standard world-wide.

INTRODUCTION

Previous research has shown that side impact crashes account for a substantial proportion of injuries and Harm to Australian passenger car occupants. Fildes, Lane, Lenard and Vulcan (1994) reported that 25% of serious casualties and 28% of fatalities to vehicle occupants in Victoria occurred from side impacts and that this crash configuration accounted for one-third of vehicle occupant Harm (approximately A$1.2billion annually) during the early nineties. Findings such as these clearly show the severe nature of these collisions and the higher likelihood of sustaining a severe injury, given involvement in a side impact crash.

Side Impact Regulation

Current attempts at providing increased side impact protection for all Australian motorists have been focussed on new car safety regulations. Recently introduced Australian Design Rule ADR72 allows for all new car models to meet either existing American or European standards (FMVSS 214 and ECE Regulation 95 respectively). While the desirability of mandating this standard was shown to be financially beneficial (Fildes, Digges, Carr, Dyte and Vulcan 1995), nevertheless these authors claimed that it was unlikely that either of these standards will guarantee optimum benefits for car occupants. Both FMVSS 214 and ECE Reg 95 have been shown to have serious shortcomings and a more optimal standard has been recently proposed (Seyer & Fildes, 1996; Fildes, Digges, Dyte & Seyer, in press).

It should be recognised, though, that safety regulations will only ever provide minimal levels of safety. First, they are always compromise agreements between governments and automobile manufacturers around the world as these parties often provide contrary evidence of the likely outcomes for a new standard. In addition, standards only specify a single crash type and a crash severity which almost always is aimed at very severe (life threatening) crash situations. While it is important to reduce the number of fatalities, the reality is that most crashes and vehicle occupant Harm occurs at more modest crash severities, which may or may not be benefited from a higher crash performance level (see Figure 1).

In terms of providing maximal societal benefit, therefore, it is necessary to ensure protection at all injurious crash severities. It is assumed that by focussing on more severe crashes, the benefits will accrue at all crash severities below that level. However, this may not necessarily be the case. It is often argued by manufacturers that designing for high crash severities produces cars that do not offer good protection at lower crash levels and that optimal design must allow for a series of crash tests at varying levels of crash severity.

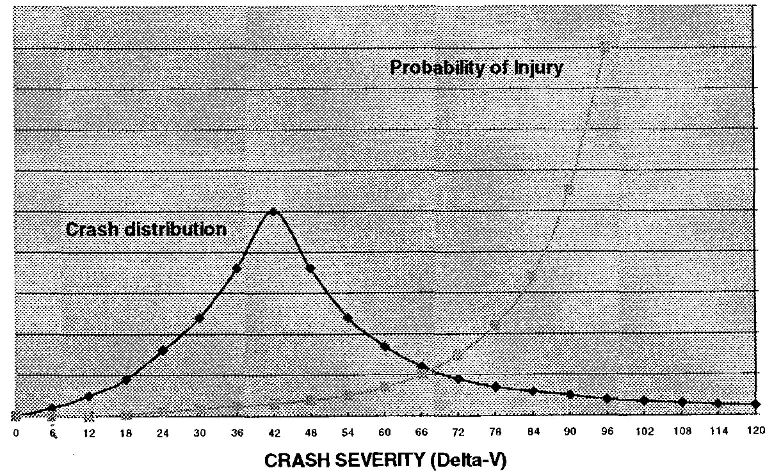

Figure 1 *Conceptual diagram showing the probability of injury and crash frequency distribution by crash severity level.*

The Concept of Harm

Harm comprises both frequency and cost of injury components and thus takes into account injury outcomes that are both frequent and costly to the community. An optimal Harm solution is one that strives to minimise both the number of injuries and those that are most serious and costly. While such an approach does place emphasis on fatal outcomes because of their cost to society, it does so without ignoring the more frequent and often less costly severe injuries to those who survive the crash.

The Harm Reduction Method

The concept of "Harm" was first developed in the US and applied to National Accident Sampling System (NASS) database by the National Highway Traffic Safety Administration as a means of determining countermeasure benefits for road safety programs (Malliaris, Hitchcock & Hedlund 1982; Malliaris, Hitchcock & Hansen 1985; Malliaris & Digges 1987). In its original form, it was used to make global assessments of benefits using known overall outcome data.

In 1990, though, this concept was redeveloped in Australia to enable Harm to be derived using a more systematic summation of a range of body region and contact source savings. This revised "building block" method has proven to be a very useful means of assessing the benefits of new safety measures. Any available test or real world crash data on performance improvements can be converted into likely injury savings for particular body regions and these can then be summed to make an "objective" estimate of benefits for the proposed measure. Where no test data is available (as is often the case), then expert judgements can be used in a more rational way to supplement test or crash figures.

To date, the revised *Harm Reduction* method has been used in Australia to demonstrate the benefits of new occupant protection countermeasures (Monash University Accident Research Centre, 1992), in justifying new vehicle regulations (Fildes, Digges, Carr, Dyte & Vulcan 1995; Fildes, Digges, Dyte, Gantzer & Seyer 1996; Fildes, Digges, Dyte & Seyer 1998), and in developing SAFECAR - a visual inspection crashworthiness rating system (Fildes, Dyte, Finch, Cameron, Le, Vulcan, Digges & Stolinski, 1996).

THE IMPROVED SIDE IMPACT PROTECTION STUDY

Commencing in 1998, the Monash University Accident Research Centre was awarded three years funding through the Australian Research Council's Strategic Partnerships with Industry, Research and Training or the SPIRT scheme. The Australian Research Council of the Department of Employment, Education, Training and Youth Affairs, offers financial support for collaborative research ventures between universities, government and industry partners for fundamental and innovative research that has the potential to make significant advancement in high priority community problem areas.

The Improved Side Impact Protection (ISIP) project is such a collaborative research project and involves Monash University, the Federal Office of Road Safety, Holden Australia, the Australian Automobile Association, Autoliv Australia, and a number of other local and international specialist partners and contributions.

The objective of the project is to develop Harm as a design criteria for new passenger cars. New technology is to be developed that will allow automobile designers to optimise their design of new passenger cars to minimise occupant Harm in side impact collisions. The project is an innovative approach to car design and if successful will be an international first in this area.

Harm and Vehicle Design

The way in which it is planned to incorporate Harm in the vehicle design process is illustrated in a flow diagram in Figure 2 below.

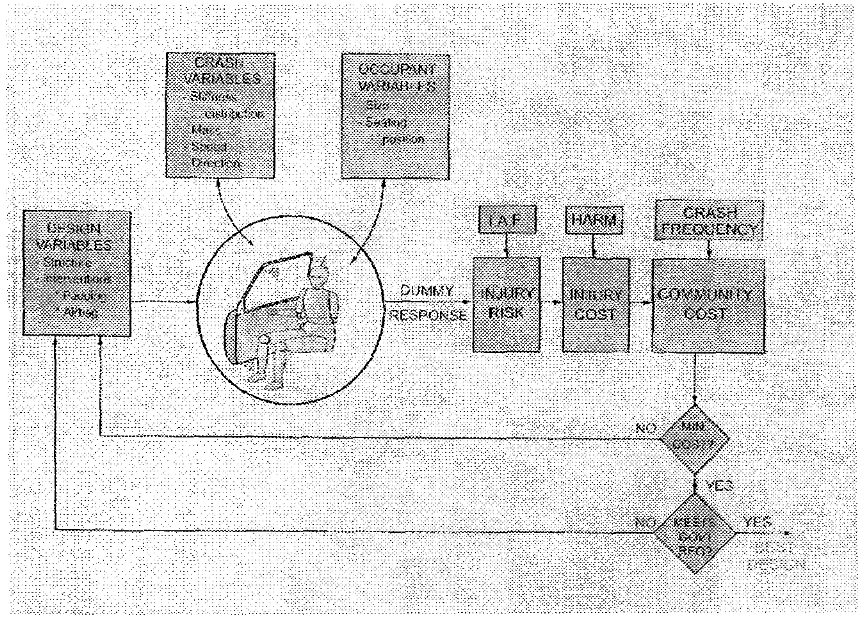

Figure 2 *Flow chart of the optimisation process envisaged for the ISIP project*

The hub of the process will be the vehicle and human model, shown in the diagram as a manikin and a door. A particular set of design parameters and the expected crash distribution and frequencies are then fed into the model, to produce a set of expected injury assessment functions by body regions and injury severities. These are then "costed" from baseline Harm distributions to arrive at an expected Harm outcome for the particular design parameters. These parameters can then be modified and re-assessed time and time again until the best or optimal solution in terms of minimal Harm to the car's occupants, given the expected crash distribution for that vehicle model, is achieved.

While the emphasis of the modelling is to arrive at a minimal Harm outcome for the new car, obviously it still has to meet government regulations that apply. Thus, the final design is then checked against the Australian Design Rule requirements to ensure that it complies with these regulations. If the process is successful, we would expect the final design to be superior to that required by vehicle standards for the reasons expressed earlier.

THE PROJECT TASKS

A single make and model of vehicle (eg; Holden Commodore) will be focussed on initially for developing the optimisation model to make the process manageable. However, it is expected that the process will be generalised to other makes and models of passenger cars for the final product. A number of specific research tasks are planned for the project and these are outlined below.

Task 1 - Injury Distribution Patterns

The first task involves the collection and analysis of a representative sample of crashes and injuries to occupants in Australian passenger cars involved in real-world side impact collisions. A suitable database of mass accident statistics will be assembled using as many states' data as possible, as well as the collection of a minimum of 100 detailed retrospective crash investigation data using the current MUARC (NASS) procedure. These data are necessary given the level of detailed information required for the optimisation model. To the degree possible, other overseas inspection data will be used to supplement local crash data where there is insufficient cases available, taking care to ensure that these data are weighted to match the various crash configurations and crash types in Australia.

Task 2 - Harm Matrices

The next phase will involve the development and further refinement of the Harm matrices at MUARC, taking account of more recent crash patterns. The second task will also involve updating of the Bureau of Transport injury costs to incorporate separate body region and injury severity costs that are not currently available in these data, yet essential for the optimisation process.

In addition, it is generally recognised that the previous injury costs published by Steadman and Bryan (1988) are in need of additional work to update to current price levels and overcome some of the earlier deficiencies. These historical injury costs need to be reworked to include the latest actual treatment, rehabilitation, loss of income and long-term impairment charges, as well as adequate allowance for family, psychological damage and loss of quality of life. It is expected that this work will be undertaken in conjunction with the Bureau of Transport Economics and Roadwatch in WA.

Task 3 - Injury Assessment Functions

The means of assessing injury reductions during the design phase will rely heavily on the formation of accurate Injury Assessment Functions (IAFs) for each body region in side impact collisions. It is intended to construct a family of Injury Assessment Functions (IAFs) that will predict the relationship between the response of a surrogate occupant in a side impact crash test (the most current side impact test dummy available) and the risk and severity of injury to the population of crash involved vehicle occupants.

A number of IAFs have been published and are available for frontal impact analysis from various biomechanical agencies. However, IAFs for side impact are less well formulated and additional work will be required here to address this shortage throughout the project. A number of inputs are planned to provide these functions, including a detailed review of recent developments at key biomechanical research centres around the world, graduate student projects to develop IAFs in particular body regions, as well as new research projects where required. Monitoring overseas developments in this area is critical to minimise the need for undertaking an extensive and time consuming research program in Australia. A number of overseas biomechanical specialists and research houses have already agreed to co-operate with the ISIP team to expedite this task.

Task 4 - Optimisation Modelling

The final phase of the research program will involve the construction of a computational model, incorporating the core human/vehicle model, the Injury Assessment Functions (IAFs), crash statistics, Harm matrices and design parameters to enable optimising solutions to be determined when designing for side impact protection. The full resources of a number of ISIP partners (locally and overseas) have been made available to facilitate this process which will require considerable computer power and programming expertise.

RESEARCH METHOD

Four working groups have been established with group leaders and participants assigned to each working group to undertake the various research tasks. These working groups are all responsible to Chief Investigators of the project. Each group has developed a set of activities for each year of research, bearing in mind the overall plan and expected completion date. The performance of the groups is monitored regularly by the senior researchers at a series of working party meetings held periodically through the project, where they are required to provide regular reports to the main research program committee (at least yearly). The main Project Advisory Committee meets annually to review progress and discuss any particular problems or difficulties that arise.

A number of reports and publications on the outcomes of various aspects of the research are planned throughout the project on key findings emanating from the research. The final product will be the optimisation procedure which will be generally available to the automotive industry and government organisations with an interest in improved vehicle safety.

RESEARCH TIMETABLE

The research timetable is shown in Figure 3.

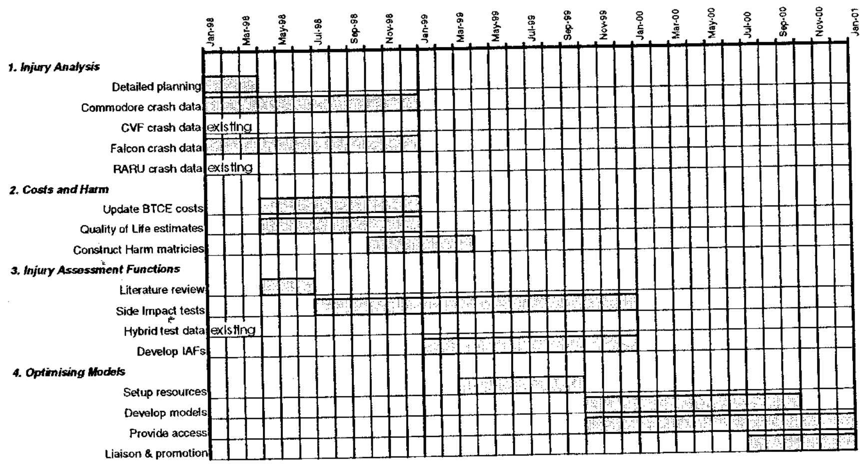

Figure 3 *Schedule of tasks and milestones for the Improved Side Impact Protection project*

PROGRESS TO DATE

Progress during the first year of the project has been significant with considerable progress achieved already in each of the 4 working groups.

Injury Data Collection & Analysis

Data collection of suitable side impact cases commenced during 1997 and detailed information has been collected already on a number of side impact crashes involving Holden Commodores, Barinas, Vectras and Ford Falcons. In addition, detailed analysis has been undertaken of existing side impact data to highlight the types of crashes, severities, frequencies, injury patterns and sources of injury.

Cost of Injury

Discussions have been held with the BTE and with Roadwatch to work towards the development of revised injury costs for use in the new Harm matrices. Dr. Ted Miller of the National Public Services Research Institute, an international expert in injury costing, accepted an invitation to visit Australia during August to hold a series of meetings in Melbourne and Canberra to discuss various aspects of injury costing. He also met with the project team to advise on what was being planned for updating cost of injury in Australia and made a number of valuable suggestions to assist the progress of this activity.

Injury Assessment Functions

A comprehensive review of existing IAFs was undertaken to identify what was available and areas of missing data. A one-day workshop was held in Detroit during the 1998 ESV Conference comprising over 20 of the world's best biomechanical experts to discuss the project, identify unpublished sources of data and ways in which shortages could be overcome. In addition, several visits were arranged with key centres in the USA and Canada in conjunction with the ESV Conference meeting to hold talks aimed at further supplementing this information. A report is being compiled of the results of this activity which should be published early in 1999.

Optimisation Procedure

Following discussions within Working Group 4, a simplified "preliminary" optimisation procedure has been developed and is presently being programmed and piloted at Monash University. This development is aimed at trialing a suitable method for optimisation, as well as identifying the resources required for the procedure and any potential problems or difficulties associated with the model. Discussions have also been held with the suppliers and developers of MADYMO (an existing commercial human/vehicle model) to judge its suitability for inclusion in the optimisation process.

CONCLUDING COMMENTS

As noted earlier, trauma from side impact collisions is still a significant road safety problem in Australia and world-wide. While regulation have been introduced in the USA and Europe to improve side impact crashworthiness, it offers less than optimal protection for passenger car occupants. In short, there is an urgent need internationally for research aimed at improving side impact protection.

The Harm Reduction method initially developed in the USA but more recently expanded and refined by MUARC in Australia for the Federal Office of Road Safety has been shown to be an effective and useful measure of assessing countermeasure performance. Recent Australian papers detailing the approach have received international acclaim from government and industry sources alike.

The Harm reduction approach offers considerable scope for use in vehicle design as a replacement and more accurate measure of the effects of design changes in terms of optimising protection. Such an approach has not been attempted before but recent Australian developments now point to its wider use as a design criterion for passenger cars.

The research program outlined is likely to have a number of immediate benefits to the Australian community. If successful, it has the potential to revolutionise the car design industry and be of national and international significance. Commercial advantages may accrue from this new technology for the Australian automobile and insurance industries, providing an international edge for this country. Through involvement in international deliberations on vehicle safety, the Federal Office of Road Safety will also be well placed to promote this new technology for use in other countries.

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