

Swimming Pools on the Moon: Problems in Evaluating the Impact of Software-Based Local Accident Information Systems on the Public Perception of Road Safety

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Abstract

The World Health Organization (WHO) estimate that road traffic accidents represent the third leading cause of 'death and disease' worldwide. Many countries have, therefore, launched safety campaigns that are intended to reduce road traffic accidents by increasing public awareness. In almost every case, however, a reduction in the total number of fatalities has not been matched by a comparable fall in the total frequency of road traffic accidents. Low severity incidents remain a significant problem. One possible explanation is that these road safety campaigns have had less effect than design changes. Active safety devices, such as anti-lock braking, and passive measures, such as side impact protection, serve to mitigate the consequences of those accidents that do occur. A number of psychological phenomena, such as attribution error, explain the mixed success of road safety campaigns. Most drivers believe that they are less likely to be involved in an accident than other motorists. Existing road safety campaigns do little to address this problem; they focus on national and regional statistics that often seem remote from the local experiences of road users. This paper, therefore, describes the design and development of a software tool to provide the general public with access to information on the location and circumstances of road accidents in a Scottish city. We also present the results of an evaluation to determine whether the information provided by this software has any impact on individual risk perception. Local government and road traffic agencies are keen to demonstrate the benefits that can be obtained by developing these localised information sources. However, the experience of validating the system not only raised questions about the benefits of localised information systems but also about the use of human factors 'psychometric' techniques in the software development cycle. A key finding in this work has been that we cannot take metrics from cognitive science and directly apply them to support software design and interface development. Our experiences provided a salient lesson to an established team with a background in human-computer interaction.

1. Background

Every year, around 3,500 people are killed on Britain's roads and 40,000 are seriously injured [1]. The American Automobile Association estimates that road traffic accidents claim a life every 13

minutes in the United States. The WHO calculated that 38,848,625 people were injured in motor vehicle accidents in 1998. In the UK, road traffic accidents are the leading injury-related cause of death among people aged 15-44 years. Successive governments have launched initiatives, such as “Think!” [2] and the Scottish Roads Safety Campaign [3]. The aim of these projects has been to reduce traffic accidents by increasing public awareness of road safety issues. There have been some notable successes. The UK Department of Transport monitors progress in road traffic safety against a series of baseline averages established during 1994-98. The 2002 fatality figures, cited above, represent a 17% reduction compared to this baseline period. 179 children were killed in road accidents and 4,417 were seriously injured. This is 33% below baseline. However, the total number of road accidents and the number of slight injuries has not declined at a similar rate. For slight injuries the reported rate in 2002 was 12% below the baseline. This may partly be due to a drop in reporting of less serious accidents and casualties.

1.1 Software Support for Local Access Initiatives

It is difficult to underestimate the complex nature of road traffic accidents. Previous research initiatives have established a wide range of causal factors, including but not limited to drivers’ mood and behaviour, weather conditions, passengers’ unsafe activities, incomplete road infrastructure, speed, alcohol, drug etc [4, 5, 6, 7, 8]. Many of these research initiatives focus on specific causal factors. However, regional and national statistics are also used to inform more wide-ranging reviews of road safety. These reviews guide traffic management strategies and road planning initiatives. It can, however, be difficult to gain an overview of this statistical information. In consequence, many regional agencies have developed software applications that can be used to identify patterns in road traffic accidents. These systems, typically, connect Geographical Information Systems to data that is derived from national accident databases.

The initial requirements analysis for the project described in this paper found problems with existing software for analysing local road traffic accident information. For example, there is a lack of integration between the initial data sources and the visualisation tools. Hence, it can be difficult to ensure that the map based Geographical Information Systems provide access to the most recent data. Further problems arise because these existing systems cannot easily be used to query the underlying data sets. In consequence, planners can readily see a cluster of accidents in particular locations but cannot then easily determine whether there were common factors, such as poor weather conditions or driver ‘error’, that led to these adverse events. In some of the systems we observed, map-based displays were used to extract accident identification codes that were then written onto slips of paper so that additional SQL queries could be made on the underlying databases.

The focus of this paper is not, however, to analyse the strengths and weaknesses of these existing tools. In contrast, we want to build on a number of projects that use software-based tools to provide access to very localised information sources. For example, Wise et al [20] have developed a number of systems that they term ‘regionalisation tools’ to support exploratory data analysis. Applications have included the spatial and temporal clustering of health data to support very fine grained forms of epidemiological analysis using their software. Similarly, Don Brown’s group at the University of Virginia have recently implemented a Regional Crime Analysis Program (ReCAP)

for use in small cities and towns. This system uses a client-server architecture so that local officers can monitor patterns in crime reports across time and geographical locations. The key contribution of this tool is that it enables law enforcement agencies to analyze crime data down to the level of individual districts and even blocks. This is increasingly important when police initiatives to address criminal activities in one area or district can displace those activities to other areas.

Software tools, such as ReCAP, shift the focus from the macro level of regional and national information systems down to the micro level of individual districts and locations. This shift in focus creates a number of computational problems. For instance, the frequency of adverse events within any particular location can be relatively low. This makes it difficult to determine whether, for example, a particular crime forms part of a dispersed pattern or is simply a random event. This micro view also raises questions about event trajectory. It is not enough simply to look for clusters of events within particular areas. It is also important to look for patterns of change over time, which can be masked at higher levels of aggregation in regional data sets.

The following pages describe the development and evaluation of a software system for analysing road traffic accidents. Following the model proposed by systems such as ReCAP, the intention is that users should be able to drill down through a map-based display to identify patterns of these adverse events. In particular, rather than presenting information about accidents within a region, city or neighbourhood, it should be possible to trace incidents down to particular locations, down to junctions, streets and pavements. There is, however one important difference between this project and the previous work in this area. ReCAP was designed for use law enforcement officers. Existing accident information systems are, typically, tailored to particular groups of road traffic professionals. In contrast, however, this paper describes the development of a tool that enables members of the general public to view accident data as they plan their routes across a major Scottish conurbation. The intention is not simply to persuade motorists to revise their journeys. This may simply shift the risk of an incident to other areas of the local network given that accident frequencies correlate with traffic density. It is also hoped that we may be able to influence wider driving and pedestrian behaviour by providing additional information about the contributory and causal factors in road traffic accidents within their local area. It is hypothesised that this precise regional information will have a greater impact than abstract leaflets or web sites that simply describe national road traffic priorities.

1.2 Structure of the Paper

This section has introduced the background to the Local Accident Information system. Section two argues that existing software tools provide members of the public with aggregated statistics that have very little impact upon individual behaviour. We provide evidence to support this assertion by using psychometric risk assessment techniques. In contrast, it is argued that greater benefits can be obtained by providing tools to access accident information about the particular roads they use everyday. Section 3 describes the UK Data Archives that provide access to an on-line data source for this project. This includes a mass of information that is typically gathered by the police in the aftermath of road traffic accidents but that is not in a format that can be readily accessed by the general public. Section 4 provides more detailed requirements analysis by describing consultations with local and regional road traffic safety professionals. Their insights guided the detailed software

design, described in Section 5. The interface to the web-based system was developed using Shneiderman's Task by data Type Taxonomy for visualisation. This section also described how the software uses the 10-meter Ordinance Survey Grid Reference format to locate each incident in the data archives onto a location in our Java-based Geographical Information System. Section 6 goes onto describe the evaluation of our work. The results of an initial study show that many of the expected benefits associated with localised accident information were **NOT** realised. The experience of developing this tool and then validating it raised questions not simply about the value of localised information software but, more importantly, about the criteria that might be used to assess their effectiveness.

2. An Initial Evaluation of Existing Road Safety Information

Most regional and government agencies use a variety of techniques to provide information to the general public about the dangers associated with road use. These include media broadcasts, leaflet campaigns, school visits by police officers, training programmes both for motorists and cyclists. These traditional techniques have a short-term effect in increasing consciousness about 'appropriate' behaviour. They also direct attention towards the likelihood and consequences of road traffic accidents. However, the effectiveness of driver and cyclist training programmes can decline over time as 'bad habits' return and the lessons are forgotten under the pressures of circumstance. These traditional techniques can also involve significant costs to the agencies that exploit them. The production costs associated with a leaflet campaign must be added to the logistics involved in disseminating the publications to the general public. Even when these leaflets are delivered to individual households a significant proportion of them will be discarded before they are read [1]. These problems have persuaded many road safety agencies to develop on-line information sources. The intention is not that these websites replace traditional road safety campaigns. However, they are perceived to offer a cost effective means of providing access to information about the causes and consequences of road accidents.

Figure 1 illustrates the main UK Department of Transport portal for road safety information. As can be seen, this web site provides access to information about a range of issues including the use of speed cameras, child safety and alcohol limits. Statistical information is provided, however, this data is almost entirely aggregated to a national level.

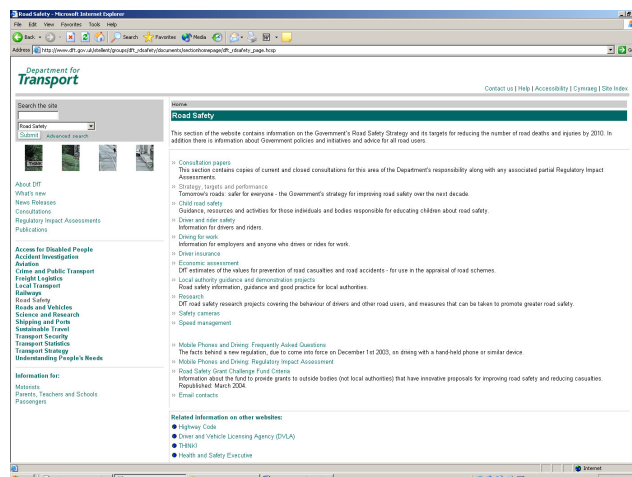


Figure 1: UK Department of Transport Road Safety Site

Within Scotland, it is possible to access local accident data published by the Scottish office. There are, however, a number of usability issues associated with this information source. Members of the public must use a series of interlinked Excel workbooks to navigate between different views of the regional statistics. This data has the benefit of providing detailed information about the frequency of accidents in particular, generic types of road geometry. Table 1 illustrates the Scottish Executive data from mean accident frequencies at different severity levels for built-up (urban) junctions between 1998 and 2002.

	Fatal	Serious	Slight	All Severities
Junction	45	772	2,995	3,812
Roundabout	3	60	521	583
Mini-roundabout	-	6	42	48
T/Y/staggered junction	31	596	2,994	3,621
Slip road	-	9	55	64
Cross roads	10	172	1,014	1,197
Multiple junction	-	22	115	138
Private drive	1	18	93	112
Other junction	2	40	202	244
Total	93	1,695	8,032	9,820

Table 1: Scottish Executive Accident Frequencies for Urban Junctions (1998-2002).

At a local level, individual city and municipal organisations will also issue information about road safety issues. For example, Glasgow City Council developed a road safety action plan. This publicised the various direct steps that they were taking to reduce the accident rate within the areas under their control. This argued “In 1997, 22 people were killed, 496 were seriously injured and 2597 were slightly injured on the roads in Glasgow. Although, this was the lowest total of casualties in modern times, it is 22 deaths too many”. Figure 2 shows how the review of their strategy presented aggregate local accident statistics to members of the public.

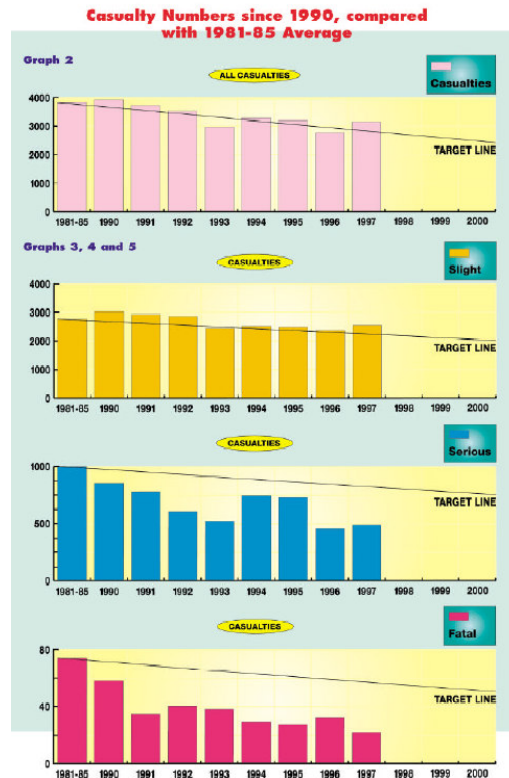


Figure 2: Excerpt from Glasgow City Council’s Review of Road Safety Strategy

The emphasis in this campaign is important because local initiatives can add a focus and relevance that is often missing from national strategies. As can be seen, however, this data source is still a long way from providing members of the public with specific localised information about the nature of road traffic accidents in the streets where they travel each day. In the past, this localised information has only been available in the form of large printed digests. However, the development of software visualisation techniques and geographical information systems create the opportunity to make this data much more widely available.

It is difficult to determine whether existing electronic publications, such as that shown in Figure 2, have any measurable impact either on the attitudes or behaviour of road users. We, therefore, conducted a series of studies using psychometric techniques to assess general attitudes towards the risks of road accidents. The participants in our baseline study were then encouraged to browse two road safety web site. These were the ‘Think!’ campaign site coordinated by the UK Department of Transport¹ and the web site for the Scottish Road Safety Campaign², mentioned in previous paragraphs. We then retested them to determine whether their exposure to this information had any short-term impact on their expressed attitudes towards the risks associated with road use. Our evaluation used a questionnaire that amalgamated elements of three existing road accidents risk perception forms [17, 18, 19]. The resulting question asked a total of nine questions. For instance,

¹ <http://www.thinkroadsafety.gov.uk/index.htm>

² <http://www.srsc.org.uk/>

the first question asked individuals to use a ten point Likert scale to rate how 'safe' they felt when using the local road system. The final question asked them to rate their perceived ability to control the potential risk of involvement in a road accident. Figure 3 summarises the findings for two of the questions in a random subset of our initial sample of potential users for these road safety web sites in the Glasgow area.

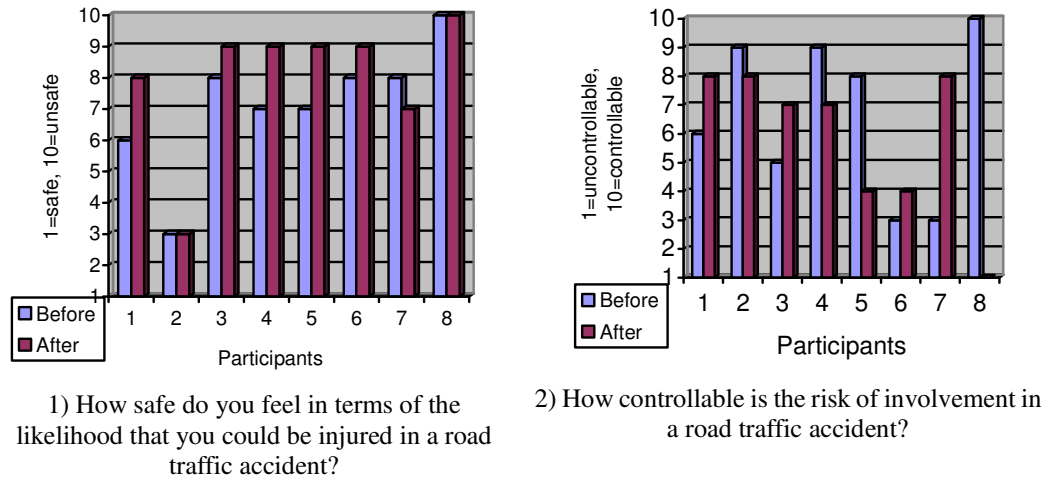


Figure 3: Sample from Risk Perception Study of Existing On-line Road Accident Information

As can be seen, access to the two road safety web sites had relatively little impact on the participants in this initial study. The graph on the left of figure 3 shows that most participants (5 out of 8) felt that they had a small increase in likelihood after accessing the web sites. The graph on the right of figure 3 is harder to interpret. Half of the participants felt that the risk of involvement in a road traffic accident was more controllable after studying the on-line road safety campaigns. The other half felt the opposite; the risk was less controllable after exposure to the web sites. Some of the changes were extremely marked. In particular, participant 8 indicated a complete swing from a position in which they felt they had total control over the risk to a position in which they felt they had no control. Participant 5 moved from 8 to 4 on the same scale.

This lack of consensus raises a number of concerns about both the use of psychometric risk assessment and about the effectiveness of on-line information sources in this area. One interpretation for our results is that participants found it difficult to interpret the questions or to apply them to their own experience of road usage. We had decided to use existing psychometric instruments to minimise the possibility of such influences. However, our observation of individuals completing the questionnaire did reveal some problems here. For instance, we included a question about the 'equity' of risk in terms of whether the person or group who benefits from taking the risk of a road traffic accident is also the most likely to suffer any adverse consequences. We have not reported the results of this question because many participants struggled to apply these concepts to their everyday experience of road use. A further issue is that we have only collated the results for a limited portion of our total sample. It remains to be seen whether the inclusion of additional data from further participants will yield further insights into the effectiveness of existing on-line information sources for road safety campaigns. In particular, it seems likely from our initial

analysis that there are strong individual differences in the manner in which we perceive the risks of involvement in road traffic accidents. In anticipation of this work and having raised the previous caveats, we would argue that our initial results indicate considerable potential for alternate on-line information sources about the risks of road accidents. In particular, qualitative responses to subsequent interviews revealed a strong interest in accessing software that would provide localised information about road traffic accidents. This level of interest provided a strong contrast to the relative ambivalence about the national and aggregate web-based information sources.

3. Data Sources for Localised Road Accident Information

The opening sections of this paper argued that ‘attribution error’ is a significant problem for road safety campaigns. Individuals feel that adverse events are less likely to occur to them than they are to their peers. One way of addressing this bias is to provide information about those accidents and incidents that occur in their neighbourhood rather than simply providing access to national and regional aggregate statistics. The UK Data Archives provide an important source for information about individual road accidents [25]. In contrast, to the UK Department of Transport and Scottish Executive sites this source is not primarily intended to support public access to road safety information. It provides a more focussed resource for ‘raw’ data on road accidents from 1991. Each entry in the UK Data Archive has three sections. The first acts as a meta-record for information about each accident. The other records can be used to store information about the vehicles involved and any casualties. The resulting data structures are capable of storing a wide range of incident data. For example, there are 30 fields in the meta-level accident record. These include timing information, a police force reference code, and general information about the vehicles and whether or not pedestrians were involved. Figure 4 provides an overview of the accident fields.

Accident Records			
Variable	Character Position	Integer /Alpha	Variable Label
ACCYR	1 - 4	(I)	Accident Year (YYYY)
ACCREP	5 - 13	(A)	Accident Ref. No.
1.2	20 - 21	(I)	Police Force Code
A3	22	(I)	Accident Severity
1.5	23 - 25	(I)	No. of Vehicles
1.6	26 - 28	(I)	No. of Casualties
ACCDAY	29 - 30	(I)	Accident Day
ACCMTH	31 - 32	(I)	Accident Month
A7	33	(I)	Day of Week
A8H	34 - 35	(I)	Hour of Accident
A8M	36 - 37	(I)	Minute of Accident
1.10	38 - 40	(I)	Local Authority
A10	41 - 45	(I)	Location - Easting
A11	46 - 50	(I)	Location - Northing
1.12	51	(I)	1st Road Class
1.13	52 - 55	(I)	1st Road Number
1.14	56	(I)	Road Type
1.15	57 - 59	(I)	Speed Limit
1.16	60 - 61	(I)	Junction Detail
1.17	62	(I)	Junction Control
1.18	63	(I)	2nd Road Class
1.19	64 - 67	(I)	2nd Road Number
1.20A	68	(I)	Pedestrian Crossing - Human Control
1.20B	69	(I)	Pedestrian Crossing- Physical Facilities
1.21	70	(I)	Light Conditions
1.22	71	(I)	Weather Conditions
1.23	72	(I)	Road Surface Conditions
1.24	73	(I)	Special Conditions at Site
1.25	74	(I)	Carriageway Hazards
1.26	75	(I)	Place Accident Reported

Figure 4: Format for Accident Records in UK Road Traffic Accident Data

The vehicle and casualty record formats can be used to provide additional information about each road traffic accident. 24 fields are provided for vehicle specific data. These can be used to include information about whether the vehicle skidded or overturned. It can also record whether it was towing anything at the time of the incident. This record also provides means of denoting the compass direction from which the vehicle was heading and to which it moved during the adverse event. Vehicle data includes the age and sex of the driver. It also records whether it was a ‘hit and run’ incident and whether or not a breath test was conducted to detect alcohol consumption. Similarly, the casualty record provides 16 fields that capture the ‘severity’ of the casualty, whether they were a pedestrian or a passenger on a bus or coach, whether they were wearing a safety belt etc.

Figure 5 illustrates the raw format used by the UK Data Archive. The first field represents the year of the accident. The second provides the accident reference number that acts as a key to the associated vehicle and casualty records and so on according to the format described in Figure 4. The key issue here is that the archive provides a valuable resource for researchers and for road safety managers in local government. However, additional tools must be used to analyse this data before it can inform the work of these professionals far less provide usable information to the general public.

ACCYR	ACCREF	A1_2	A3	A1_5	A1_6	ACCDAY	ACCMTH	A7	A8H	A8M	A1_10
2001	97AB00102	97	3	1	1	3	3	2	7	12	10
2001	97AB00103	97	3	1	1	2	3	3	6	11	30
2001	97AB00111	97	3	1	1	1	11	5	3	35	30
2001	97AB00112	97	3	2	1	1	12	7	22	30	30
2001	97AB00201	97	3	1	2	3	1	4	15	37	40
2001	97AB00204	97	3	1	1	1	4	1	1	18	0
2001	97AB00205	97	3	1	1	3	5	5	15	45	15
2001	97AB00206	97	3	1	1	2	6	7	14	15	5
2001	97AB00209	97	3	1	1	2	9	1	17	5	20
2001	97AB00301	97	3	2	1	5	1	6	11	30	20
2001	97AB00303	97	3	1	1	3	3	7	19	20	20
2001	97AB00307	97	3	2	2	2	7	2	16	55	5
2001	97AB00308	97	3	2	1	3	8	6	23	0	20
2001	97AB00309	97	3	1	1	2	9	1	15	20	0
2001	97AB00311	97	3	1	1	3	11	7	16	0	20
2001	97AB00407	97	3	1	1	4	7	4	15	20	0
2001	97AB00411	97	3	1	1	3	11	7	15	5	5
2001	97AB00601	97	3	1	2	8	1	2	17	50	0
2001	97AB00602	97	3	2	1	7	2	4	16	0	20
2001	97AB00603	97	3	2	1	4	3	1	17	50	0
2001	97AB00606	97	3	2	2	2	6	7	11	5	20
2001	97AB00612	97	3	2	2	10	12	2	13	30	20
2001	97AB00803	97	3	1	1	5	3	2	18	30	20
2001	97AB00805	97	3	2	1	4	5	6	17	20	0
2001	97AB00806	97	3	1	1	7	6	5	17	20	0
2001	97AB00808	97	3	2	1	1	8	4	17	0	20

Figure 5: Sample Accident Information from the UK Data Archive

4. Requirements Elicitation

We had initially intended to directly elicit requirements from the general public. However, a key aim of the final system was to increase awareness about the causes of road traffic accidents. A two-step approach was, therefore, adopted in which we began by contacting existing road traffic ‘experts’ before going on to validate key design issues with a wider audience. The initial requirements elicitation focused on the local police force. They provide the immediate response in the aftermath of a road traffic accident. However, the formal elicitation focused on two agencies with a longer-term responsibility for road traffic safety: the Land Service Department in Glasgow City Council and Amey Highways Ltd. These two organisations each had responsibility for safety on minor and major roads respectively. They also had experience of using an existing geographical

information tools to review road traffic accident data. One of the key concerns that we had at this early stage in the project was that the existing forms of interaction with map-based systems were largely through SQL interfaces or through a form of spreadsheet interaction. Neither of these was considered suitable for our more general user group. We, therefore, developed a system prototype using direct manipulation techniques to access incident information through the map interface. This design is described in more detail in subsequent sections. For now, it is sufficient to observe that we based our requirements analysis around a two-part questionnaire. Section 1 elicited background information about the participants. Section 2 focused on requirements for the system. We were particularly concerned to identify the causal information that they felt was more important for the potential end-users of the system. As mentioned, this use of 'expert' advice represents an initial compromise before subsequent validation with a wider class of potential end-users.

The initial part of the questionnaire revealed the depth of the respondents' expertise. Six of the analysts had spent more than five years working with road traffic data. One had less than a year's experience and another had between one and three years. All of them used a computer in their everyday activities. Seven respondents stated that their main task was the analysis of historical data about road traffic accidents. One respondent reported that their occupation was centred on preparing reports for higher (regional) government so that they could perform further analysis with the data.

The second part of the questionnaire revealed a number of requirements that the road safety professionals felt to be important in the success of any tool that would provide local accident information to a wider audience. Firstly, their experience with the existing information sources, listed above, made them advocate the use of graphical interaction techniques, for instance based on road maps, rather than spreadsheets or traditional histograms. It was also argued that users should be able to distinguish between different types of roads. As mentioned accident frequencies typically correlate with traffic flow and this, in turn, can differ between motorways and UK category A and B roads. In the UK, A category roads refer to divided highway and controlled access roads divided highway but not controlled access (dual carriageways) or two-lane two-way roads. They can be thought of as US Highways and State Highways. B roads are, typically, narrower, winding country lanes and are roughly equivalent to American County Roads. The requirements elicitation exercise also identified the need to filter the data given the large number of low severity incidents in the UK data set. One means of doing this would be to initially provide the users with access to the most recent data but with the option to provide additional years as required.

The open-ended questions failed to identify specific information requirements that the experts predicted to be most significant to the general public. Instead it was felt that potential end users should have some means of accessing all of the available information in the three records described in the previous section. As we shall see, however, initial field trials later identified the need to tailor this mass of data to support particular groups of end users. The road safety professionals also advocated the use of prepared queries. They argued that it could be difficult for many users of existing systems to form their own information requests until they have gained a significant degree of expertise with an application. This requirement raised the difficulty of determining what queries to provide for novice users. Some seemed relatively uncontroversial, such as a request to display

all fatal accident. Beyond this it was less clear whether the general public might want to display all accidents that happened on a Monday or those adverse events involving casualties over 60 years old. Initial focus group discussions revealed that these queries were important to particular individuals but it is less clear that they will have a wider significance for the potential user population.

5. Design

A number of key observations emerged from the results of our initial requirements elicitation with road safety professionals and from focus groups with potential users. In particular, the mass of data available about road traffic incidents within even relatively well defined locations created considerable problems. It is for this reason that almost all public information campaigns only provide access to highly aggregated regional and national statistics. In contrast, we decided to use computer-based visualisation techniques to provide users with means of interactively exploring more detailed information about adverse road events in their local area.

There are many different principles for information visualization. For example, both Tufte [14] and Spence [15] have developed theories that support the visual display of quantitative information. In contrast, we chose to focus on the more general guidelines provided by Shneiderman's TTT (Task by Data Type Taxonomy for Information Visualizations) theory [16]. According to the TTT theory, seven broad categories can be used to distinguish between the various tasks that users perform with information visualization systems. The first set of tasks provides an overview of the entire collection. Overview strategies include zoomed out views of each data type to see the entire collection plus an adjoining detail view. The second set of common tasks with any visualization involves zooming in on items of interest. Users typically have an interest in some portion of a collection. They need tools to enable them to control the zoom focus and the zoom factor. Smooth zooming helps users preserve their sense of position and context. A third class of tasks filters out irrelevant information. Our initial requirements elicitation also confirmed this as an important attribute of any implementation. The fourth of Shneiderman's items describes tasks that enable users to access additional details on demand. Once a collection has been trimmed to a few dozen items it should be easy to browse the details about the group or individual items. A fifth set of tasks should help users to view relationships between the items in a data set. The sixth focuses on the maintenance of a history or log to support undo, replay, and progressive refinement. Information exploration can involve iterative refinement of an initial search, keeping the history of actions and allowing users to retrace their steps is important. The final class of tasks focuses on the extraction of sub-collections and of the query parameters. Once users have obtained the item or set of items they desire, it would be useful to be able to extract that set and save it to a file in a format that would facilitate other uses such as sending by email, printing, graphing, or insertion into a statistical or presentation package.

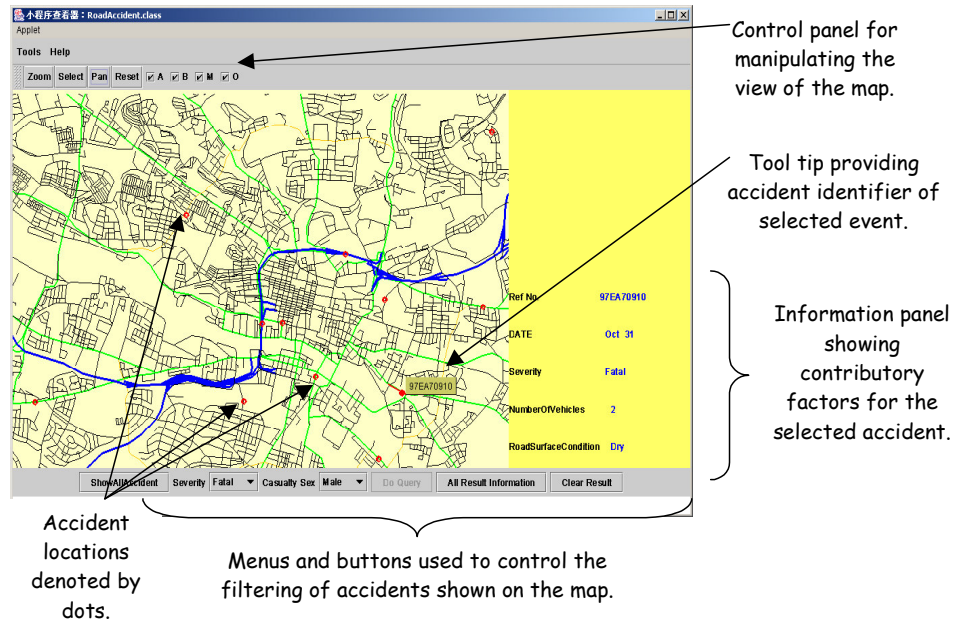


Figure 6: Overview of the Map-Based Interface

These guidelines together with the initial requirements elicitation helped to inform the design of our visualization system. Our design was based on a number of recent software tools that have been developed from professional road accident investigators where each incident is displayed on a map by the location in which it occurred. This raised a number of important issues; in particular we were concerned to ensure that we could log the position of each accident as accurately as possible based on the data provided in the national archive. We, therefore, engineered the system using the 10-meter Ordnance Survey Grid Reference (OSGR) reference format rather than the more familiar concepts of Longitude and Latitude. OSGR can be thought of as a flat grid overlaid on Britain. The grid is measured in meters and the point of origin is defined to be south west of the Isles of Scilly. Points on a map are given Easting and Northing values. These co-ordinates denote the distance from between a location and the origin. For example, the centre of Manchester city is approximately 383,000 meters east and 398,000 meters north of the origin. This reference format acted as a means of translating between the location data provided in the national accident archive and the position of the Geographical Information System that we developed for the centre of Glasgow.

We decided to focus the development of the system around the area of Glasgow that falls between the middle of national grid references NS56 and the middle of NS66. This decision was partly determined by pragmatics. We wanted to focus our initial evaluation within a precise geographical location where we had access to a wide range of potential end users and to road safety professionals who can validate our findings. Linking this geographical area back to the national data archive using the OSGR indexing system yielded a total of 1486 incidents for 2001 alone. These resulted in 3568 vehicle records and 2731 casualty records; recall that each incident can involve several vehicles and casualties. The associated accident data file was 134k, the vehicle data file was 291k and the casualty data was 181k. The widespread problem of underreporting led us to exclude damage-only incidents. However, the available data could be included in subsequent versions of the

system given the relatively modest size of the data files that we have compiled from the national data sources. The introduction of additional years' information or a decision to scale-up from a local to a regional or national level would force a careful review of this decision.

Figure 6 illustrates the resulting interface. Accidents are shown by the red dots. The user can select an individual incident by moving the mouse over one of these dots. A tool tip then appears with the individual incident identifier to provide feedback on their selection. If there is no record of an incident under the mouse location then the tool tip provides contextual information about that location by giving the name of the nearest road. The system uses these techniques to enable the user to access 'details on demand'. A summary of the accident information about each selected incident is presented in a panel on the right hand side of the screen.

The system enables the user to filter information by selecting a number of preformed queries accessed through the menus and buttons at the bottom of the screen. In particular, it is possible to specify the severity of the incidents to be displayed. This filters the mass of red dots that would otherwise overwhelm the user. Our initial requirements analysis with road safety professionals also identified the need to distinguish between incidents that occur on different categories of A and B roads or motorways. Users can select the category of roads that they are interested in by selecting check boxes.

In addition to these filtering features, the design also provides facilities for users to explore accident statistics over a wider area. The map display can be panned to examine incidents in adjacent locations. This is combined with an area based zoom facility. A dragged left-click on the mouse will zoom into the map at a rate that is proportionate to the area of the drag. A long and sustained drag will result in a larger change than a short drag. The direction of the zoom is determined by the direction of the drag. A movement from bottom left to top right zooms into the map while the opposite movement will zoom out. Experience with Geographical Information Systems has shown that the combination of navigation and information filtering facilities can appear to complex to many users. We have, therefore, also included a reset facility so that any actions should be easily reversible back to a known initial state.

As mentioned, users can exploit the menu options and checkboxes provided by the system to filter the mass of incident data held about road accidents in the Glasgow area. However, the successive refinement of these queries can still yield a significant number of 'hits'. It would be extremely laborious if users had to manually view each set of contributory factors using the tool tip and panel combination illustrated in Figure 6. For this reason we have implemented a facility to review all of the information that is associated with the currently highlighted set of incidents. Users can gradually read through accident, vehicle and casualty information with each incident presented on a different 'page'.

A client-server architecture was adopted. The client interface issues MySQL queries to update the visualization of accident information held by a database server. A small amount of preprocessing is required to translate the information held on the national data archives into a format that can be held within the server's relational model. However, this process can be automated to ensure that

accident data can be updated with each new release of information. At the start of the project, this software architecture seemed like the most rational implementation strategy. It provided a modular format where we could easily change the visualization or the data server implementation without necessarily propagating knock-on changes into the other components. However, experience in the development of this system has encouraged us to review this decision. For example, we have begun to develop 'dynamic querying' techniques. These enable the user, for instance, to select the ends of a double headed slider to specify time intervals of interest within a twenty-four hour period. By moving either end of the slider, the user can reset the start or end time of the interval they are interested in. However, each time the slider is adjusted a new query will be issued to the server to update the accident information presented on the map based display. The computational overheads associated with this dynamic 'direct manipulation' style of interaction are forcing us to reconsider whether we can retain the modular distinctions between the client and the server without implementing a local caching strategy.

6. Evaluation

Previous sections have argued that several biases, including attribution error, result in drivers and pedestrians underestimating the likelihood that they will be involved in a road traffic accident. It has also been argued that previous initiatives to improve road safety might be supported if software tools could provide the general public with more direct information about the frequency of accidents within their local area rather than through regional or national aggregate statistics. We were, therefore, concerned to determine whether using our application would have any measurable effect on an individual's perception of their likelihood of being involved in a road accident. Government agencies and road traffic organisations are anxious to demonstrate the utility of these new forms of interactive system.

6.1 Method

The formal evaluation was conducted in three stages. First, each participant completed a benchmark risk perception questionnaire. This was based on three existing general road accidents risk perception forms, described in the previous sections [17, 18, 19]. The second stage provided users with an opportunity to interact with the system described in the previous section. We offered a scripted introduction to the functions offered by the application and then left them to browse the accidents. Each user was told that they could use the system for as long as they wanted. After they had finished using the system they were again requested to complete the same risk perception questionnaire. They were also asked to provide feedback on the user interface to the tool.

We deliberately started with a relatively small sample of 17 potential users. The main reason for this was that we did not want to place undue time constraints on the familiarization period that was available for users as they learned how to use the system. However, we used a different sample from that involved in our risk perception study of existing web sites. This decision was also justified by the objectives for our initial feasibility study. We were concerned to determine whether users could interact with the incident data through the Geographical Information System interface. We were also interested to obtain preliminary results that might support our hypothesis about changes in the perception of accident likelihood. The initial study was intended to provide feedback on the suitability both of our design and of our validation methodology prior to the

full-scale evaluation.

6.2 Results

The feedback from open-ended questions about the usability of the software included several negative comments. These have formed the focus for our redevelopment efforts. In retrospect, we realize that we should have anticipated some of their criticisms earlier in the development cycle. For example, accident records in the UK archive use a number of predefined types to represent certain values. These types have an important and relatively clear meaning to safety professionals. Our more general users were not, however, familiar with some of these distinctions, for example between road types and local authority codes. In consequence, many of our participants reported high levels of frustration whenever they had to crosscheck the codes in the accident records with an explanatory table.

A number of further criticisms related to significant details in the presentation of the user interface. For instance, several users complained that the font used to display the detailed information about each accident was too small. Others complained that it was difficult to distinguish between incidents because the associated location markers on the map began to overlap when they viewed the system at a low level of 'magnification' or 'zoom'. Other common criticisms reflect previous studies into the usability of geographical information systems by a relatively wide user population. Several people found it difficult to distinguish between the pan and zoom actions. Others became lost as they traversed the map and requested the provision of additional landmarks.

A final cluster of adverse comments focused more on the information content that was provided by the system. Some of the users argued that the 'cause' of the accident was not clear from the information provided. This is a key observation and there are several explanations. It is important to stress that the national archive does not directly record the cause of each adverse event. This is justified both for legal and ethical reasons. Instead, the data focuses on contextual details such as the prevailing weather conditions and whether or not alcohol was involved. Some police agencies do retain causal information in a format that can be linked to the national archive data. However, we could not obtain public access to these data sources during the initial development of the prototype interface. Several other factors can explain end-user criticisms about the presentation of causal information. In order to track the geographical distribution of common contextual factors users must first select the incidents that they are interested in, using the map-based display, and then access the individual records associated with each accident. Post-evaluation debriefs helped to identify the basis for current redesign where the icon used to represent an incident on the map will be changed to reflect particular values for contextual factors selected by each user.

The evaluation also helped to elicit criticisms that the prepared queries were too restrictive and that the data provided by the national archive was too limited. In particular, users wanted the software to provide more information about the mental and physical state of the driver or pedestrian who was involved in the adverse event. This last point raises a number of important issues. It can be difficult for investigators to elicit personal information, for instance about the mental state of a driver, in the aftermath of an adverse event. Informal comments made by the participants indicated that these sorts of details would have a profound impact in any individual assessment about how

likely they were to find themselves in a similar situation in the future.

Likert scales were used to assess the overall ‘usability’ of the prototype. In an initial sample of seventeen potential users, eleven ranked the overall usability at 4 on a scale from 1, denoting that the system was ‘terrible’ to 5, denoting that the system was wonderful. Five users scored the system as 3 on this scale while another user ranked the system in the highest category. Similar results were obtained for a range of additional usability questions. Including the clarity of the interface and the ease with which participants learned to interact with the system. However, a number of important caveats were revealed by the quantitative analysis of these Likert scales. Figure 8 presents the results of questions about the speed of the system and about frustration levels. As can be seen, several users found that the system was too slow, even though the dataset that we used was limited to approximately 1,500 incidents in Glasgow within a twelve-month period. Part of this problem stems from the relative ease with which users could generate queries. Small changes in the area selected using the zoom function would result in update calls being made to regenerate incident data from within a MySQL database. Further work is required to determine whether predictive caching might help to scale interaction up to acceptable levels both in terms of speed and a wider geographical coverage. The associated frustration levels illustrated in Figure 8 can also be explained in terms of these delays.

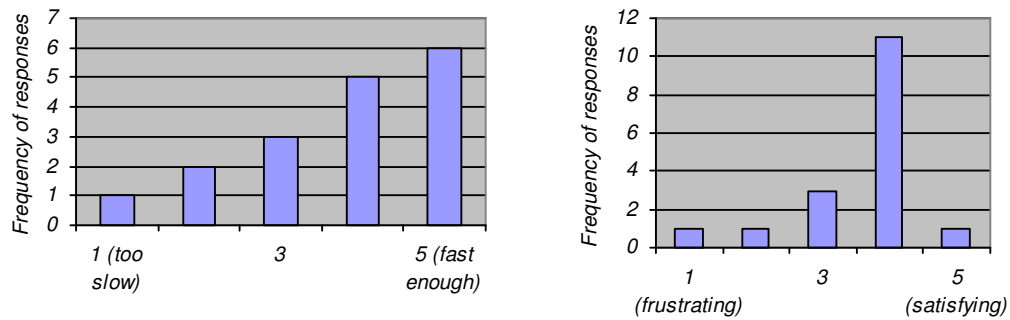
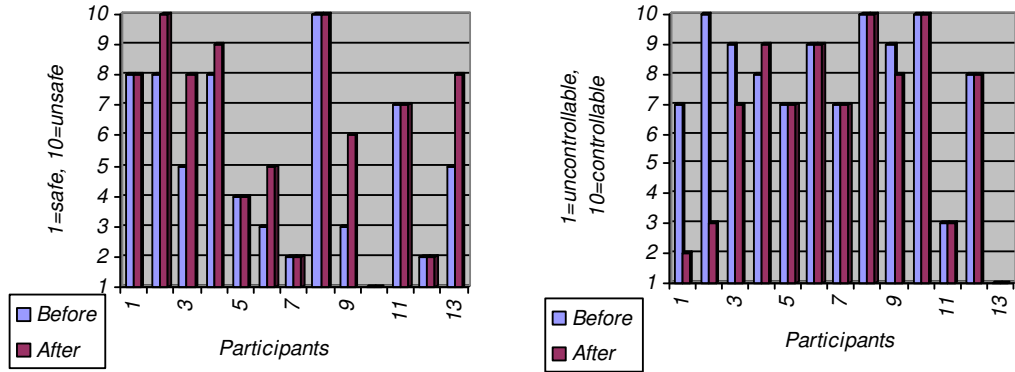


Figure 8: Quantitative Results from the Initial Usability Evaluation

Figures 9 and 10 present some of the results from the second stage of our evaluation. As can be seen, four of the users in the initial sample failed to complete this stage of the validation. The reasons for this will be discussed in the following paragraphs. For now it is sufficient to observe that this study was based on the same procedure that had been initially used to sketch the impact that existing road safety web sites might have upon the potential users. In this instance, the participants were given a questionnaire that was based on three previous psychometric studies of road accident risk perception *before* they interacted with our map-based visualisation systems. They were then encouraged to use the prototype for as long as they wanted. After they completed the more general interface evaluation questions, described above, they were then asked to repeat the risk perception questions. As in the previous examination of national and regional web sites, the intention was to determine whether interaction with our information source had any measurable effect on their risk perception scores.

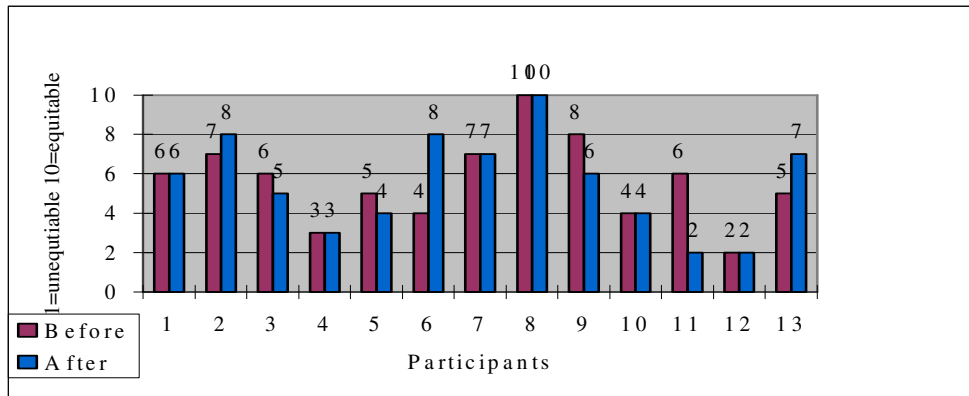


1) How safe do you feel in terms of the likelihood that you could be injured in a road traffic accident?

2) How controllable is the risk of involvement in a road traffic accident?

Figure 9: Sample of Risk Perception Study of Road Accident Map Visualisation

Interaction with the new system increased the perception of the likelihood of an accident in 5 of the participants. The remainder showed no change in their expressed perception. However, the magnitude and frequency of this effect is broadly similar to that observed with the exiting on-line resources. The graph on the right of Figure 9 shows the results for a question about the controllability of risk in road traffic accidents. Interaction with our system had no effect on eight of the participants. Four felt that the risks were less controllable and one felt that they had greater control. This diversity is again similar to the effects noted in the pilot study. In both cases, however, further tests are required over a larger population to determine whether these observations are not artefacts that stem from an inappropriate sample from a far larger population. For example, we observed several patterns in our responses that suggest individual traits and attitudes to risk may be having more of an impact that exposure to the systems that we have developed. For instance, user 10 in Figure 10 felt that there was absolutely no likelihood that they would be involved in a road accident even after they had used our system. They also felt completely in control of the associated risks. Conversely, participant 8 felt that they were extremely likely to be injured and yet also felt that they could control the risk of involvement. It is possible to hypothesise about the different attitudes that motivate such expressed perceptions. For example, the attitude of participant 10 might reflect a high tolerance for risk. Participant 8 might have a low threshold for risk. Their sense of control might, in part, reflect steps that they have taken to limit their exposure to road related risks. It is difficult to validate these assertions. However, it seems clear that further research is required if we are to understand the individual factors that affect our perception of the risks of road related incidents. For instance, none of the previous psychometric tests that we adopted account for the strong effects that must be introduced when individuals have recently been involved in an adverse event. Similarly, they fail to account for the different risk profiles that are associated with different forms of road use. Individuals who never drive may have different attitudes towards the risks of road accidents than individuals who regularly use high-powered motorcycles.



Q5 Please rate the risk, in terms of whether those who receive the benefits are the same people who carry the risks

Figure 10: Sample of Risk Perception Study of Road Accident Map Visualisation (Cont.)

Figure 10 presents the results that were obtained when we asked about the ‘equity of risk’. This question was included because previous psychometric studies have argued that this can have an important impact on individual decision-making [17]. For example, drivers may obtain the greatest benefits by increasing their speed in built-up areas but the risks of serious injury from their increased speed may be greatest for other road users, including pedestrian and cyclists. However, this question illustrates the problems that we had in applying psychometric techniques to support the evaluation of our localized information software. Most participants asked what the question meant. Even after it had been explained, they expressed great difficulty in answering questions about such abstract concepts using the software tool. In consequence, we have very little confidence that results such as those shown in Figure 10 provide an accurate reflection of the impact that interacting with our prototype software had upon potential users.

6.3 Postscript

In the weeks since we conducted our evaluation, we have endeavored to identify other metrics that we might use to support the validation of our localized approach to the provision of accident information. In particular, we are looking for techniques that might both demonstrate the utility of the approach to sponsoring organizations and which might produce results that can drive subsequent iterations in the development cycle of our tools. This search has involved discussions with a number of cognitive psychologists and safety engineers. The title of this paper comes from an observation made by John Davies, Professor of Psychology and a specialist in human error in accidents at Strathclyde University. He argued that in this context asking users about the costs and

benefits associated with the risks of road usage is like 'asking someone whether they would like a swimming pool on the moon, it has simply never occurred to them before'.

The experience gained from the development of the software tools has convinced us of the benefits of localized information provision. However, we have learned valuable lessons about the criteria that might be used to validate these systems. We cannot simply take metrics from cognitive science and hope that they can be directly applied to support software design and interface development. In retrospect we realize that we may have been naïve in ever expecting that this would be so straightforward even though we had consulted cognitive psychologists prior to conducting the evaluations. Our experiences provided a salient lesson to an established team with a background in human-computer interaction.

This area raises considerable practical and ethical problems. The ultimate measure of success might be to demonstrate that those who had access to this localized information were statistically less likely to be involved in road traffic accidents. Ethical and practical considerations make it unlikely that we will be able to conduct such tests. However, we continue to look for surrogate measures. For instance, in related work we have examined driver behavior in simulators. The results obtained from these studies are questionable given that we are measuring very short-term effects rather than longer-term changes in behavior. We are also increasingly aware that many of these metrics may be inappropriate for such software. In particular, the popularity of the system has come as a considerable surprise. Many of the participants in the study wanted longer-term access so that they could monitor the impact of road planning policy and lobby for changes in traffic management within their neighborhood. It might, therefore, be argued that this increased sense of engagement with road safety issues is a greater benefit for this type of software than any transient changes in risk perception.

7. Conclusions and Future Work

This paper started from the hypothesis that existing road safety advice depends too much upon the use of national and regional statistics. Aggregate values are presented in a range of graphs and tables. The resulting documents and web sites may have little impact on problems such as 'attribution error' where individuals feel that these adverse events will not happen to them. We also argued that such biases could be reduced if individuals were provided with direct access to local accident statistics. This was motivated by the existing use of road site signs in a variety of countries that tell drivers about the number of recent accidents in that vicinity. Instead, we designed an interactive system that enabled users to navigate a Geographical Information System to browse detailed information about those accidents that occurred in their neighbourhood. This interface also provided detailed data about the contextual factors, such as weather conditions and some aspects of driver behaviour, which may have contributed to each incident.

The design of our system was informed by a series of consultations with road safety professionals who were familiar with traffic related problems in the area under consideration. They provided valuable insights into the types of information that potential end users might need to access in order to understand why an incident has occurred. We also conducted a usability study of the final prototype. This revealed numerous minor defects in the interface to the system. In particular, users

were anxious for the system to provide a clearer guide about a more limited number of specific causes in the case of each incident. Such causal information is not readily available. There are considerable ethical and legal issues involved in publishing causal hypotheses about each road accident that occurs within a local area. Many of the more recent incidents continue to be the subject of active litigation.

The greatest problems arose when we attempted to assess the impact that exposure to existing road safety campaigns had on risk perception. We exploited a hybrid methodology that combined questions from three previous psychometric studies. The results proved problematic because some participants felt that they were at greater 'risk' after accessing the on-line information, while others seems to show a reduction in their perceived risk. In particular, our findings could not readily be used to inform subsequent software development. These results indicate the need to consider a far broader range of information about baseline risk thresholds than were considered in the previous study. The discrepancies in our data justify our decision to run small-scale pilot studies before progressing to a more sustained analysis to assess the statistical significance of the effects that we observed. Our current work focuses on a factor analysis based on an extended form of the initial questionnaire. Similar comments apply to the psychometric analysis of our map-based interface. In particular, we failed to recognise the diversity of profiles in risk exposure within the local population for our study. More recent work is analysing the way in which we can tailor incident information so that it reflects the individual's particular profile of road usage. For example, we anticipate greater effects on risk perception if motorbike riders can directly access information about local incidents involving this class of road vehicle. Similarly, taxi driver and pedestrians might be more influenced if they could easily search for accidents involving these road users. Our initial study has, therefore, raised more research questions than it has answered.

Our current research is working on an accident prediction model using statistical techniques originally pioneered by the US Federal Highways Agency. Again, the focus of their work was to enable road management professionals to anticipate the risks posed by changes in the layout of a road system. In contrast, we would like to make these risk assessments available to the general public as an aid in planning a journey. The risk of involvement in an accident might be considered alongside other more conventional metrics, such as distance and cost that are traditionally displayed by route planning software. We are currently using generalized linear modelling techniques to identify patterns in the mass of accident statistics. The output from this analysis will be embedded in the software to inform our future predictions. It remains to be seen whether we can develop appropriate visualisations to communicate these risk assessments to the general public.

Many other comments can be made about this work. In particular, our research has created considerable local interest. Road users are often very motivated to access this data given that they have previously not had any clear means to access it. Local pressure groups can use it to argue for road improvements and traffic calming measures. Local vehicle hire firms and taxi companies have been keen to determine whether their 'local knowledge' about accident hotspots is confirmed in the official data. Members of the public have also argued that they might review their regular routes if they had access to local accident data. This final point is the ultimate criterion for the validation of our work. It is less important to achieve particular changes in expressed risk perceptions than it is to

alter those behaviours that lead to the accidents displayed on our map-based interface. We have only just begun to explore ways in which such behavioural changes might be encouraged by the provision of localised accident information.

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