Home Office
BUILDING A SAFE, JUST AND TOLERANT SOCIETY

PEDESTRIAN/VEHICLE COLLISIONS

COLLISION INVESTIGATION IN THE 21ST CENTURY

Getting it Right

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Foreword

Collision investigation within the UK was first introduced in a limited way in the late 1940's by the West Yorkshire Constabulary. It was however not until the late 1960's that it was further considered but on this occasion by the Metropolitan Police Service, initially in conjunction with University College and then latterly by the Metropolitan Forensic Science Laboratory.

Since this initial formative period of Collision Investigation development of various methodologies have evolved to assist the range of reconstruction tools available to the investigator. As changes and developments in technology occur collision investigators must continue to review their approach and where appropriate adapt their procedures to reconstructing collisions. One particular area of research that has occupied the minds of many is the relationship between the speed of a vehicle and the distance travelled by a pedestrian following impact from a striking vehicle, to an investigator this is known as 'pedestrian throw'.

In this research, the researcher has reviewed the methodologies of numerous published papers and compared them to a dataset of known 'real world' incidents to assist in refining the science that can often be obscured by noise in data. Pedestrian throw will always be an imprecise science however, this research helpfully provides guidelines for practice and appropriate use of calculations to establish an appropriate range of upper and lower vehicle speeds.

I am grateful for the effort that Police Constable Field has put into refining our work in this vital area where public safety and the pursuit of justice meet.

Nigel Yeo

Nigel Yeo
Assistant Chief Constable

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Executive Summary

This report describes a 3 year research project that was funded by the Home Office Police Research Award Scheme to investigate the accuracy of current methods in reconstructing pedestrian/vehicle collisions.

The aim of the project was to

- ➔ Collect real world data on current pedestrian/vehicle collisions
- ➔ Identify current methods of practice throughout the country
- ➔ Compare real world data with previously published research results

The project achieved these aims by collecting data from Collision Investigation Units working in 29 police services across the United Kingdom. In total these units attended the scenes of 6,503 collisions involving 2054 pedestrians, cyclists or motorcyclists. Scene evidence from 71 of these collisions was found to contain sufficient data to independently calculate the speed of the striking vehicle and to calculate the post impact speed of the pedestrian, cyclist or motorcyclist involved.

This data was used to compare the accuracy of current reconstruction methodologies in estimating the vehicles speed from the distance the pedestrian was thrown post impact.

It was found that

- ➔ Current methods could overestimate the collision vehicles impact speed in 30% of the cases investigated
- ➔ The generally accepted deceleration rate for a sliding/tumbling pedestrian was found to be too high

This document suggests a method of reconstructing these types of collision which is more accurate and takes into account the factors which affect the deceleration rates applicable to pedestrians, cyclists or motorcyclists involved in these types of collisions.

This work was carried out through funding by the Home Office Police Research Award Scheme. Any views expressed in this document are those of the author and do not necessarily represent those of the Home Office or any police service. Grateful thanks must go to Mr Steven Gray (Project Manager) and to all of those police personnel who contributed to the study (See Appendix A). Without their help and support the project could not have taken place.

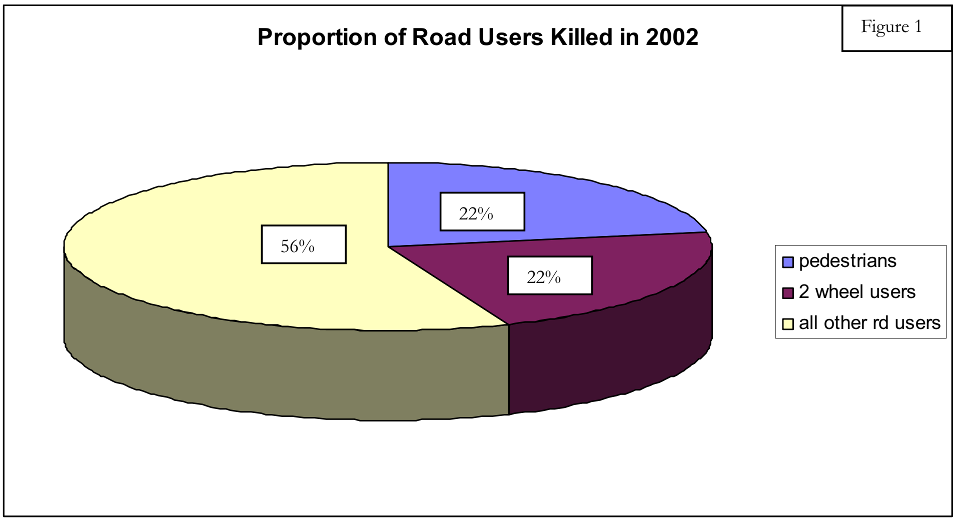
Chapter
1

Introduction

In 2002 the Department for Transport reported that 302,605 people were killed or injured in road vehicle collisions reported to the police in Great Britain[1], 37,489 (12%) involved pedestrians. However, pedestrian fatalities account for 22% of all road deaths (fig.1).

In the same year 44,874 motorcyclists or pedal-cyclists were also killed or injured resulting in 738 deaths – a further 22% of road deaths. Whilst these figures describe a decreasing number of fatalities on previous years data there is a significant rise of 3% in the number of two-wheeled road users killed or seriously injured compared with the 2001 data.

Figure 1



The purpose of this document is to highlight the changes that have taken place over the last ten years in the forensic investigation of motor vehicle collisions since the proliferation of vehicles equipped with anti-lock braking systems. This has presented the collision investigator with new challenges as the calculation of a vehicles speed from locked wheel tyre marks has become more and more difficult as these vehicles leave less and less visible marks.

Particular attention is needed in the field of pedestrian/vehicle collisions, as the design of vehicles continues to change, as vehicle manufacturers strive to produce more pedestrian friendly structures. Research carried out in the 1980's is now less relevant to modern vehicle design and can result in the over-estimation of vehicle impact speeds when there is little scene evidence available.

A New Challenge

The forensic reconstruction of road traffic collisions in the United Kingdom is a relatively new challenge for the police service. Up until the early 1970's there were no police personnel trained in any form of collision investigation in the UK, although research was taking place at the Metropolitan Police Forensic Science Laboratory. Gradually over the next 10 years this research filtered into mainstream policing and began to become widely accepted throughout the criminal justice system.

During this time training procedures were formalized and a national qualification in 'Road Accident Investigation for Police Officers' was developed by the City & Guilds of London Institute. Five training centres were established and granted training certificates by the City & Guilds Institute; these centres are based throughout the country and are responsible for training all police personnel to the standard, minimum requirement.

The forensic reconstruction of pedestrian/vehicle collisions began in the United States of America in the 1960's and continues to attract attention throughout the world. Since 1963, when Derwyn Severy[2] published the results of his initial research into pedestrian impact experiments, there have been hundreds of technical papers published examining all aspects of this field. In the United Kingdom there are numerous research studies taking place annually which places further demands on the police collision investigator to remain current and up to date.

Collision investigators often have to decide which research paper is the most accurate for the particular circumstances of a case. Whilst almost all authors agree that it is possible to calculate vehicle impact speed from the pedestrians post-impact displacement there is widespread disagreement about how and when this should be done. A review of some of the published research has shown a clear disparity between the results found by different researchers[1-93]. Some of the reasons for these disparities are discussed in detail in later in this chapter.

If the collision reconstruction, from evidence available at the scene is to be accepted, then the collision investigator must be able to show that the methodology and mathematics used are both accurate and robust. Since the majority of the published papers use historical data (some of which now dates back to the 1960's) or data obtained from testing using North American vehicles, there is a need to concentrate on the findings obtained from collisions in the UK involving modern European vehicles.

The findings of this report will be disseminated to all United Kingdom police services, ACPO and ACPOS for their information and distribution as necessary.

Review of Current Practices & Published Research

See Appendix B

A substantial part of the pedestrian study was a comprehensive review of the practices carried out by differing police services in the reconstruction of pedestrian/vehicle collisions. Each participating police service was sent 6 copies of a best practice questionnaire and asked to complete them and return them via a free-post address; further copies were available upon request.

A copy of the questionnaire was also placed on a website used to publicise the study, jimfield.pwp.blueyonder.co.uk which could be completed and submitted confidentially. Further details of how the project was publicised are contained in chapter two. In total, 53 replies were received outlining the current practices of 20 police services. Three of these replies were anonymous but were sufficiently detailed to be identified as being genuine responses. Between them, the respondents had been trained at all of the training centres throughout the UK and the replies indicated that there did not appear to be any difference in the level of training or the methods taught.

One fact that was very apparent from the best practice questionnaire was the general lack of knowledge that collision investigators had about current research in this field.

Brief details of 8 recent research papers were included in the survey and respondents were asked if they were aware of them or had used them to assist in their collision investigations. Details of their replies are shown below in table 1.

Table 1	Evans, A. K. & Smith, R	Wood, Denis & Simms Ciaran	Happer, Andrew et al	Hague, D. J.	Han, I. & Brach, Raymond. M.	Fugger, Thomas. F. Jr. et al	Randles, Bryan. C. et al	Toor, A. & Araszewski, M
Year	1999	2000	2000	2001	2001	2002	2002	2003
	Vehicle Speed Calculations from Pedestrian Throw Distance	Coefficient of friction in pedestrian throw	Comprehensive Analysis Method for Vehicle - Pedestrian Collisions	Calculation of impact speed from pedestrian slide distance	Throw Model for Frontal Pedestrian Collisions	Pedestrian Throw Kinematics in Forward Projection Collisions	Investigation and Analysis of Real-Life Pedestrian Collisions	Theoretical vs Empirical Solutions for Veh/Pedestrian Collisions
Read	8	18	1	11	3	5	3	1
Used	2	0	0	0	0	0	0	1
No Comment	1	1	1	1	1	1	1	1
Not heard of	42	34	51	41	49	47	49	50

TRAINING

Whilst training issues are always a matter for individual police services the responses to the survey indicate a clear training need in this particular field. This matter can be addressed in relation to this area of collision investigation through this document but, without further research into other areas, it will not be established if they too are lacking.

ACPO are currently carrying out research to establish the training standards nationally for police collision investigators but it is not known when this research will be published.

It is general practice that police collision investigators are trained in two stages prior to sitting the national examination set by the City & Guilds of London Institute. After initial training has been received, the collision investigator returns to their respective police service and works under the supervision of a qualified officer until such time as the Senior Collision Investigator is satisfied that they are competent to work alone. Personnel who have only completed the initial training course are generally designated as being 'Standard' or 'Basic' trained. After completion of the final module of training they are generally referred to as

'Advanced' trained until they are successful in passing the City & Guilds examination when they can cite the qualification in reports or statements.

The City & Guilds Institute require that a candidate must pass the national examination within 5 years, candidates who do not successfully complete all components are required to re-qualify again by completing an initial training course. It is a matter for individual police services as to the qualification level accepted for operational collision investigators.

The level of training of the respondents to the best practice survey are shown in table 2

Table 2				
Level of training	Standard/Basic	Advanced	City & Guilds	MITAI
No. of respondents	3	5	45	7*
* Only C & G or equivalent are eligible for membership				

In the UK the Institute of Traffic Accident Investigators (ITAI) are the main professional body for collision investigators, with membership being offered to independent (non police) civilian collision investigators, and to suitably qualified police personnel. An interest in collision investigation is deemed acceptable for a police collision investigator to be accepted as an 'Affiliate Member' of the Institute. Affiliate memberships is not a qualification and cannot be quoted as such, it is a disciplinary offence for any member to do so and could result in their dismissal from the Institute.

Personnel who have obtained the national City & Guilds of London Institute qualification may apply for full membership of ITAI and are then allowed to use the designation 'MITAI' in reports and statements.

The City & Guilds qualification is only available to personnel employed by police authorities. Because of this an alternative qualification is offered by one training centre, Accident Investigation Training Services (AiTS), the University Certificate in Continuing Professional Development in Forensic Road Collision Investigation. This is an equivalent qualification to the City & Guilds qualification and is also used by some police services who require the greater flexibility afforded by this course as it is presented via distance learning.

CONTINUED PROFESSIONAL DEVELOPMENT & EMERGING RESEARCH

Post-qualification development is the responsibility of individual personnel as guided by force policy. There are numerous ways in which an individual can continue developing their skills, one way is by subscribing to one of the many technical publications such as the Society of Automotive Engineers or the International Journal of Crashworthiness, or membership of a professional body such as the Institute of Traffic Accident Investigators. ITAI produce a quarterly magazine - 'Impact', which is circulated to all members. The best practice survey found that the most well known piece of research was identified as being that presented by Denis Wood[91] in 2000 which discusses the coefficient of friction in pedestrian throw calculations and was published in this magazine. This paper is discussed in more detail below.

The second most widely known paper was presented at the 5th ITAI International conference in 2001 by David Hague[35] and addresses the reconstruction of pedestrian impact speed from slide displacements. This paper is discussed in more detail later in this section and again in chapter four.

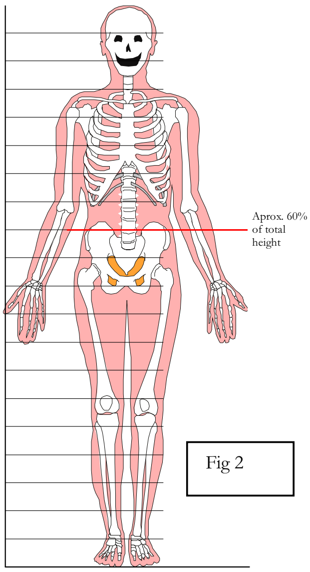


Fig 2

The determination of the pedestrian throw displacement was also investigated in the survey. Measurement of this displacement should be ascertained from an approximated position of the centre of mass of the pedestrian. Whilst upright the centre of mass appears to act vertically downwards from a point approximately level with the pelvis, generally accepted as 60% of total height[23] (fig 2).

This point acts through the feet of the pedestrian and therefore provides an indication of their position when struck. The measurement to the final rest point of the pedestrian should then be measured to the same point i.e. in the region of the pelvis.

Figure 3 shows the idealised scenario from the questionnaire and website, respondents were asked to state what displacement would be used in calculations.

Fig 3

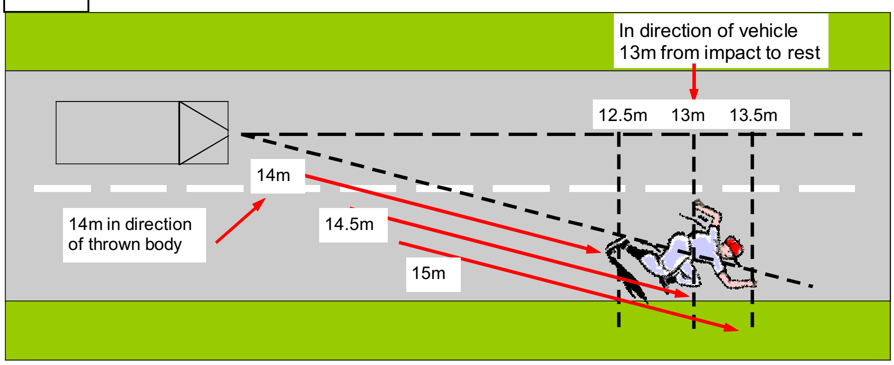


Table 3 details the responses given and indicates that 60% would correctly measure the displacement with 30% under-estimating it. Only 3 respondents (6%) would over-estimate the throw displacement all of whom came from different police services. This does however highlight the fact that personnel from within the same police service are measuring different pedestrian throw displacements for the same given data.

Table 3

Displacement (m)	12.5	13.0	13.5	14.0	14.5	15.0	Not Stated	Total
No of Respondents	1	7	0	8	32	3	2	53
% of Respondents	2	13	0	15	60	6	4	100

See Appendix B1

A further aspect of the study was a review of the published research available. This was undertaken by obtaining previous research papers from the Society of Automotive Engineers (SAE), the International Council on the Biomechanics of Impact (IRCOBI), the Institute of Mechanical Engineers (IMechE), the European Enhanced Vehicle-safety Committee (EEVC) and discussions with Dr John Searle and Dr Stephen Ashton who have pioneered research in this field. Full details of the literature review are given in appendix B1.

One of the major problems faced by any collision investigator is the fact that new research may be published several times in any year and may be published in many different countries by different publishers. In the main these papers are then cited by defence experts and used to cast doubt on the work carried out by the police collision investigator.

COEFFICIENT OF FRICTION

The coefficient of friction used in pedestrian throw calculations has been a major source of dispute between authors for decades. In 'The Trajectories of Pedestrians, Motorcycles, Motorcyclists, etc., Following a Road Accident', published in 1983, John & Angela Searle[72] suggested that a coefficient of friction of 0.66 would be appropriate for a person in normal clothing on a wet or dry asphalt type surface.

Hill [39] in 1994 published the results of further testing on pedestrian sliding rates in 'Calculations of Vehicle Speed from Pedestrian Throw' and suggested a coefficient of friction of 0.80 for a normally clothed pedestrian. This data is listed in the appendix to chapter 4 for completeness because it was analysed again as part of the study and also because it has been mis-quoted by other authors.

In 2000 Denis Wood and Ciaran Simms published a paper entitled 'Coefficient of Friction in Pedestrian Throw'[91] which examined the work of several authors, including Searle and Hill. Hill's data was only partly used in the analysis and the range of values quoted is incorrect. However, Wood & Simms conclude a range of 0.39 to 0.87 from all of the sources listed.

Also in 2000 Happer et al published a 'Comprehensive Analysis Method for Vehicle/Pedestrian Collisions'[38] which discusses several aspects of assessing vehicle speeds by differing methods. Discussed in the paper is the applicable coefficient of friction for a pedestrian and it is noted that various authors define this value differently.

Table 4 illustrates this data and produces the range of values found by the different authors.

Table 4

Trajectory	Minimum Coefficient	Maximum Coefficient	Surface Type
Slide (1)	0.45	0.72	Dry Asphalt
Tumbling (2)	0.7	1.2	Dry asphalt
Whole Displacement (3)	0.37	0.75	Wet/dry asphalt

1. Pedestrian slide coefficients do not take into account the loss of speed which occurs when the pedestrian strikes the ground. The value is simply obtained from dragging 'pedestrians' (cadavers, dummies etc.) along the road surface.

2. Tumbling rates do take into account the loss of speed in multiple impacts with the ground and are therefore considerably higher values when compared to any other pedestrian coefficient.

3. The coefficient found from the examination of the whole pedestrian displacement takes into account the period in time when the pedestrian is airborne, the impact with the ground, and then the slide/tumble to rest.

Each coefficient is used in different formula to provide an accurate assessment of the pedestrian post-impact speed.

In 2001 David Hague presented a paper entitled 'Calculation of Impact Speed from Pedestrian Slide Distance'[35] in which he obtained coefficients for pedestrian sliding on different surfaces ranging from open coarse tarmac to anti-skid treatments. The range of values for sliding pedestrians was found to be 0.59 to 0.85 for normal clothing and 0.54 to 0.65 for nylon. This paper is discussed in greater detail in chapter 4.

2001 also saw the publication of a paper entitled 'Throw Model for Frontal Pedestrian Collisions'[37] by Han & Brach. This paper challenged the results obtained by Hill and suggested that the coefficient suggested by him was too high as he had not taken into account the dummies vertical impact with the road surface, recalculating his data they suggested a coefficient of 0.74.

However, the coefficient suggested by Hill was for use in a whole displacement calculation using the Searle equations, not for the application suggested by Han &

Brach. A slight reduction in the value of the coefficient is perfectly correct when using the methodology and equations suggested by them in their paper.

In 2002 Thomas Fugger et al published the results of research examining just one type of pedestrian impact, 'Forward Projections'. These are explained later in chapter 5 in more detail. In 'Pedestrian Throw Kinematics in Forward Projection Collisions' [31] the paper discusses coefficients of friction found for the slide phase of 141 staged tests involving forward projection dummy impacts, and concludes that a range of between 0.31 and 0.41 should be used for wet asphalt and 0.43 for dry asphalt. As is the case in most of the published research there is no direct comparison made between the coefficient found for a pedestrian and that applicable for a car skidding under the same circumstances.

In 2003 Toor and Araszewski published 'Theoretical vs. Empirical Solutions for Vehicle/Pedestrian Collisions'[85] comparing the work of several authors. They examine pedestrian coefficients and conclude that values between 0.37 and 0.45 are applicable dependant on the type of impact.

With so much variance in the values found for the coefficient of friction for a pedestrian, the accuracy of all pedestrian/vehicle reconstruction methods are subject to scepticism. Chapters 3 and 4 discuss this value again and suggest methods whereby a more accurate value may be estimated.

OTHER PUBLISHED RESEARCH

Bryan Randles et al published a paper in 2001 entitled 'Investigation and Analysis of Real-Life Pedestrian Collisions'[67] which examined video data from Helsinki in Finland where the collisions had been recorded by the cities engineers. These collisions were analysed and the known impact speed was compared to existing pedestrian throw formulae. Only three respondents to the survey had any knowledge of this paper. The paper concludes that the current methods of reconstructing collisions are satisfactory for some types of impact (wrap – see chapter 3) but that more research is required for other types of impact.

This document offers the results of further research into all types of pedestrian/vehicle collisions.

Chapter

2

The Study

In July 2001 the United Kingdom Home Office funded a 3 year research project examining real world pedestrian/vehicle collisions in the UK. The aim of the study was to establish if the current reconstruction methods for pedestrian/vehicle collisions were accurate and also to try and establish a national policy of best practice that collision investigators could use in their investigations.

See
Appendix C
Appendix C1

A letter was sent to each of the 55 Chief Officers in the UK asking for permission for their staff to contribute to the study. A standard reply was enclosed with this letter for them, or a designated person to sign to indicate that permission had been obtained.

Chief Officers from 47 services responded saying that they were prepared for their personnel to participate in the study. The start of the data collection phase of the study was set for 1st November 2001 and scheduled to last for 18 months. As part of the publicity phase a presentation was given at the National Senior Crash Investigators Conference in Stafford. After the presentation there was the opportunity for all attendees to raise anything connected with the study and either the data collection or the best practice proposals.

See
Appendix C2
Appendix C3

A comprehensive newsletter was circulated to all participants at the conference and also to all nominated contacts who were unable to attend, asking for details of their experience of pedestrian/vehicle collisions and for proposals or suggestions of examples of best practice.

A website was also created to further publicise the project to as wide an audience as possible (www.jimfield.pwp.blueyonder.co.uk) and also to provide a point of contact for any service with web access. Details of the aims of the study were included together with e-mail addresses to contact.

Nominated contacts or the Senior Collision Investigator were then sent details of what the study was hoping to achieve, written instructions on how the data was to be selected and recorded and asked to provide monthly returns on the number of incidents dealt with. These monthly returns identified cases that were potentially suitable for inclusion in the study.

CASE SELECTION

See
Appendix C4
Appendix C5

Only incidents that were attended by a qualified collision investigator were deemed suitable for inclusion in the study. To prevent any possible bias over the data selected, the collision investigator attending the scene made an independent decision as to the suitability of the case for inclusion in the study based on the criteria listed below. They were then asked to complete a comprehensive data collection form.

Data collection forms were submitted for any collision that was suspected of being suitable for inclusion by the collision investigator attending the scene. Upon receipt the form was given a unique reference number which then identified a probable case. A case was only confirmed as being suitable for the study if all of the following criteria were known

- Speed of striking vehicle at impact
- Point of impact with pedestrian
- Total pedestrian post impact displacement

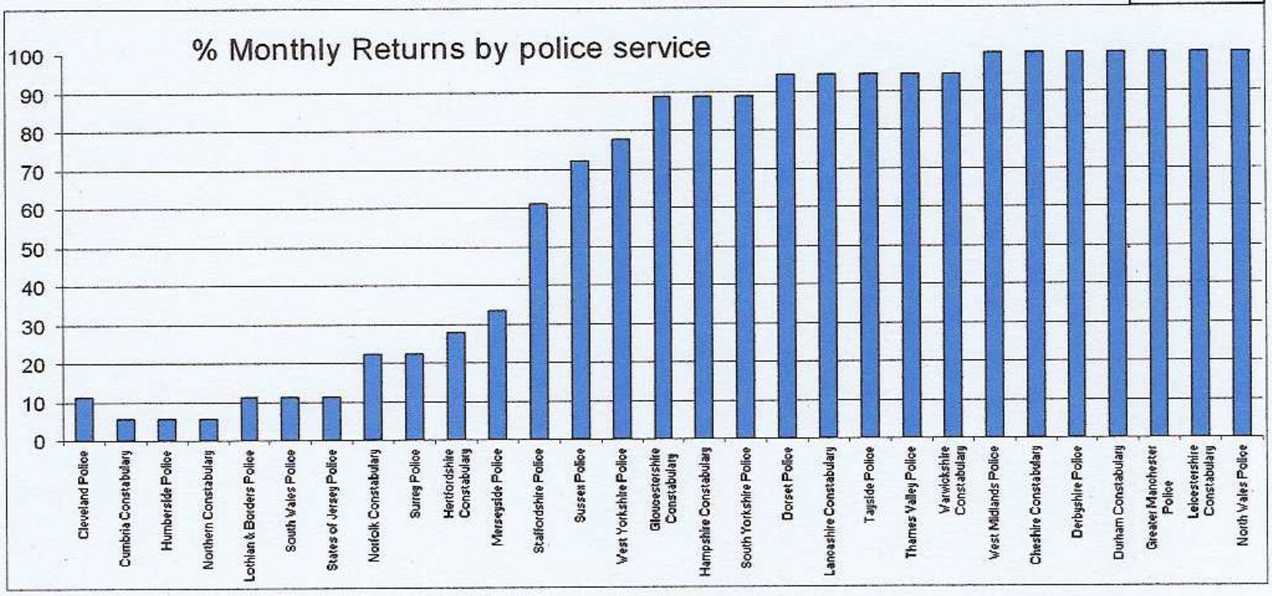
The speed of the striking vehicle was estimated mainly by using standard 'speed from skid mark' calculations or where vehicles were fitted with tachographs. Once a suitable case had been identified, the collision investigator was asked to submit copies of the completed evidential report. To ensure that the Data Protection Act was not breached, any case files that were submitted were anonymised on receipt, matched to the unique reference number from the data collection form and the details entered in to a secure, encrypted Microsoft Access™ database. Original photographs were scanned, vehicle identifying marks removed, and all of the case papers were shredded and disposed of via confidential waste procedures.

The general amount of interest shown throughout the country was extremely high and the fact that a particular police service did not submit any data should not be construed as a criticism. Several police services attended numerous collisions involving suitable subjects, but were unable to provide the specific data required for the case to be included in the study, simply because of lack of scene evidence.

This lack of scene evidence clearly indicates that there is a need for a better methodology for investigating cases of this type.

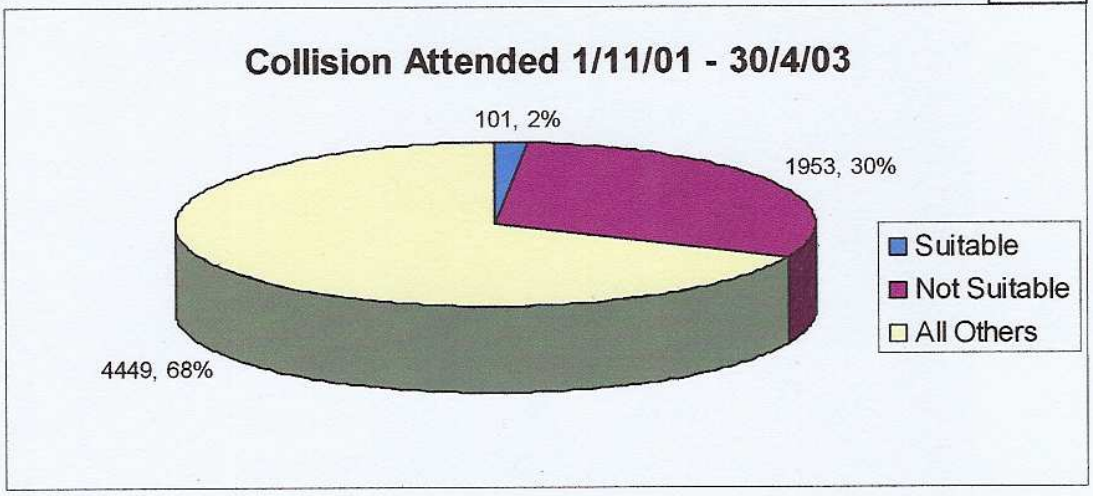
During the 18 month data collection phase, monthly returns or data collection forms were actually submitted by 29 services (see figure 4 overleaf). Some police services chose not to submit monthly returns but still submitted scene data for cases that were relevant to the study, details of all of these participants are also listed in the acknowledgements section.

Fig. 4



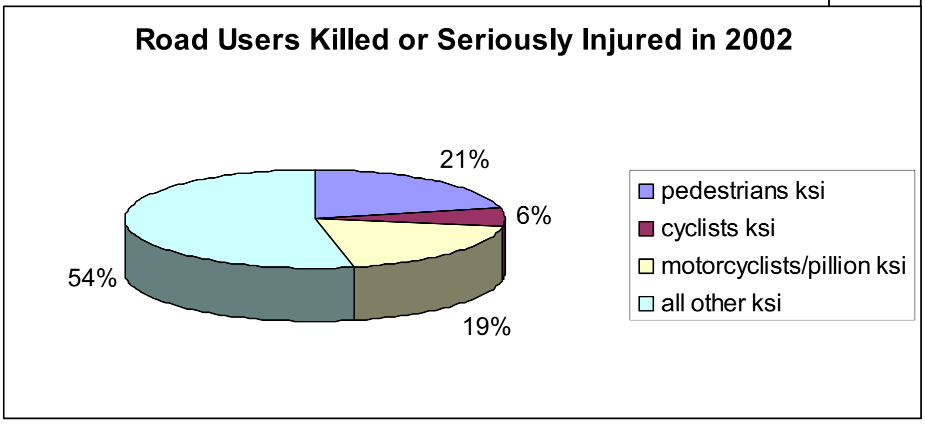
During the data collection period police collision investigators reported attending 6503 collisions involving 2054 pedestrians, cyclists or motorcyclists, figure 5 graphically illustrates these results.

Fig 5



However, figure 6 indicates that the number of collisions that were attended involving pedestrians or two-wheeled road users was actually less than the 2002 national average of 46% [1], since not all collisions that are recorded as serious injury are attended by collision investigators.

Fig 6



In total, 101 cases were reported as potentially being suitable for the study. Detailed examination of the evidence showed that critical data was missing from some of the submissions.

Examples of these types of omissions included;

- Unable to establish vehicle speed at impact
- Point of impact/pedestrian rest unknown
- Pedestrian throw displacement not measured

In total 30 cases lacked the detail required to carry out further analysis but 71 cases were found to contain sufficient evidence to be analysed in detail.

Chapter 3

Data Analysis

CLASSIFICATION OF IMPACTS

In 1981, in a study of 460 pedestrian/vehicle collisions in Northern California, Ravani et al[68] were able to classify the impacts from 241 collisions into 5 distinct categories –

1. Fender (Bumper) Vault
2. Wrap
3. Somersault
4. Roof Vault
5. Forward Projection

These classifications have become widely accepted throughout the world and are used to describe the kinematics of the struck pedestrian post-impact. Although five categories are identified they actually reflect three types of kinematics with variations being produced as a result of whether or not the striking vehicle was braking at impact and whether or not the pedestrian was struck a glancing blow.

FENDER VAULT

Fender, or bumper vault, is a classification where the pedestrian is struck by only a corner of the vehicle and subsequently falls to the side of, and generally behind the vehicle. As a result of this the pedestrian does not achieve a velocity equal to that of the vehicle. These types of impact are not usually reconstructed in the UK as any calculation of the vehicle speed could be a significant under estimate making a reconstruction unreliable for evidential purposes.

WRAP

Wrap trajectories involve vehicles that generally have a leading edge at or below the centre of mass of the struck pedestrian. In these cases the impact causes the pedestrian to wrap onto the bonnet of the vehicle. In cases where the vehicle is braking at impact the pedestrians legs then continues to rotate as the two bodies separate. At low speeds, generally in the region of 20mph or less, the pedestrian lands feet first as they strike the ground – see figure 7.

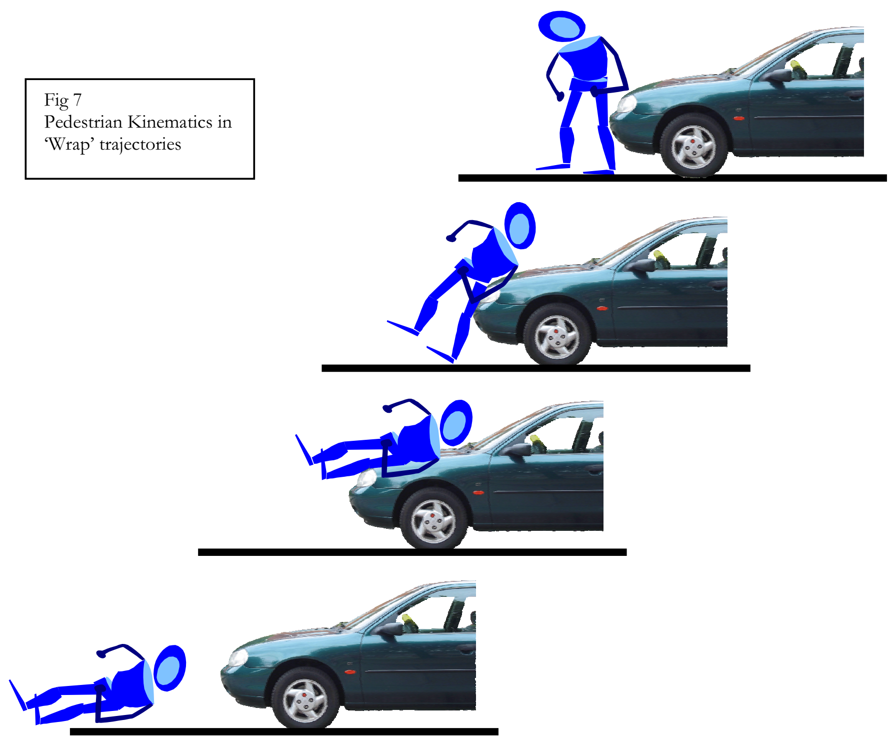


Fig 7
Pedestrian Kinematics in 'Wrap' trajectories

SOMERSAULT

Somersaults are a variation of the wrap trajectory and occur when the impact speed of the vehicle is greater than around 35mph. In these instances the vehicle is still braking at impact but, because of the greatly increased impact speed, the pedestrian continues to rotate post-impact, rising higher into the air. They will sometimes strike the vehicle again as they fall to the ground before landing in a head first attitude – see fig 8.

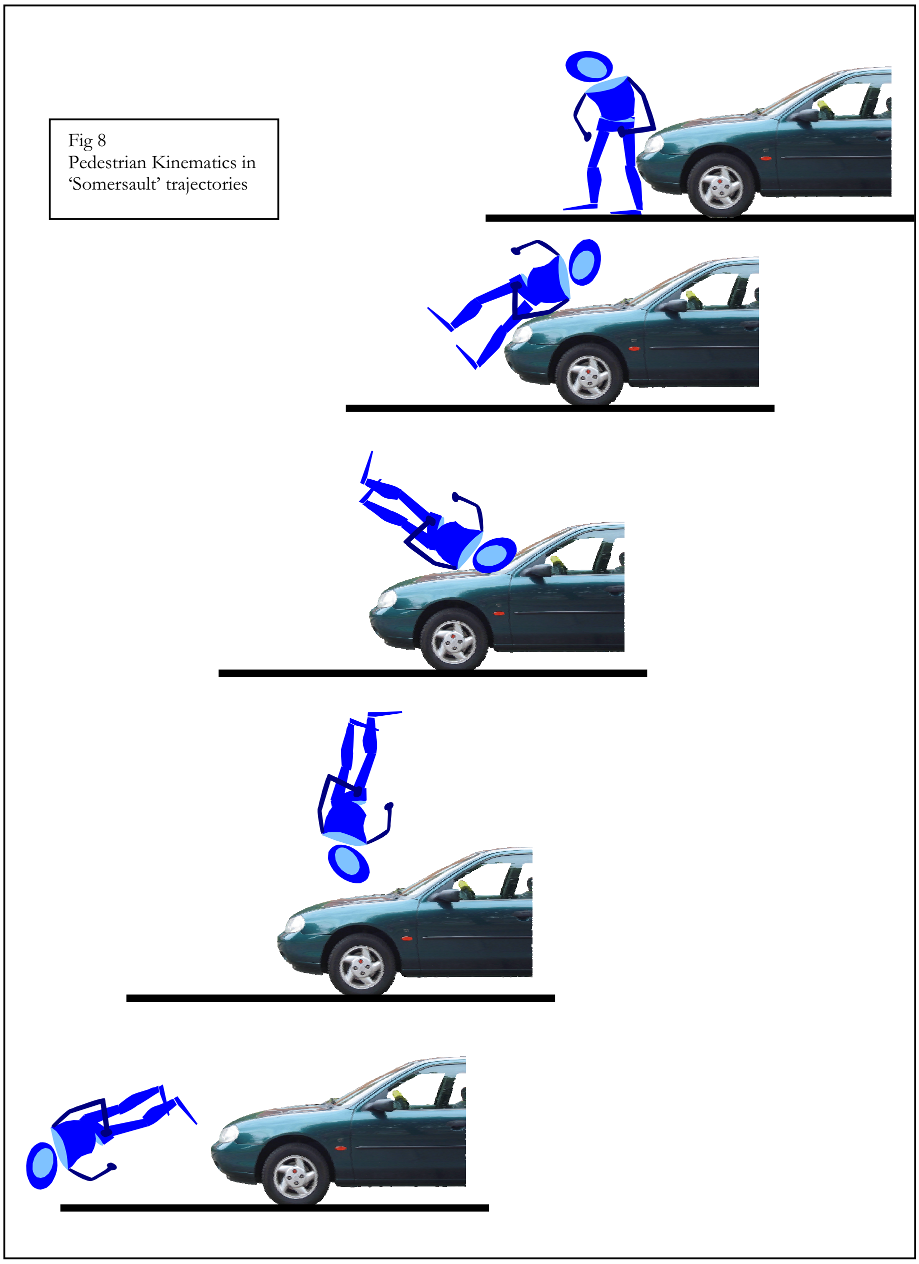


Fig 8
Pedestrian Kinematics in 'Somersault' trajectories

ROOF VAULT

Roof vault is another variation of the wrap trajectory which generally occurs when the striking vehicle is not braking at impact or in cases where the vehicle accelerates through the impact. The pedestrian wraps on to the front of the vehicle but then continues to either slide up the windscreen or begins to rotate as the vehicle passes underneath. Multiple contacts with the vehicle are possible with this type of impact as the vehicle passes leaving the pedestrian to come to rest behind it – see Fig 9.

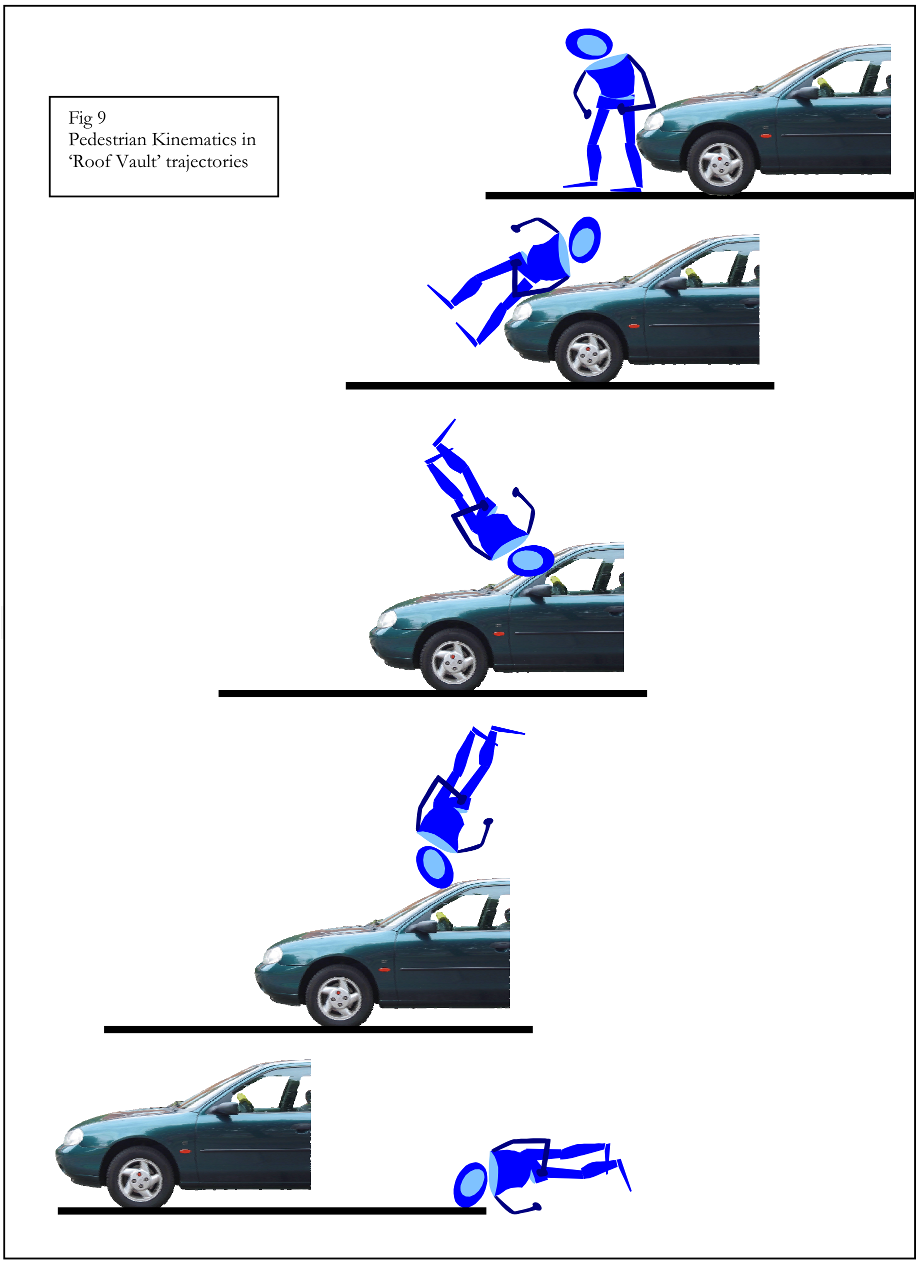


Fig 9
Pedestrian Kinematics in 'Roof Vault' trajectories

FORWARD PROJECTION

Forward projection trajectories generally occur when the height of the striking vehicles leading edge falls above the centre of mass of the pedestrian. Instead of being wrapped onto the vehicle the pedestrian is projected forwards before striking the ground. Small children struck by cars or even adults struck by large goods vehicles or any other type of flat fronted vehicle, such as buses, generally follow this trajectory – see figure 10.

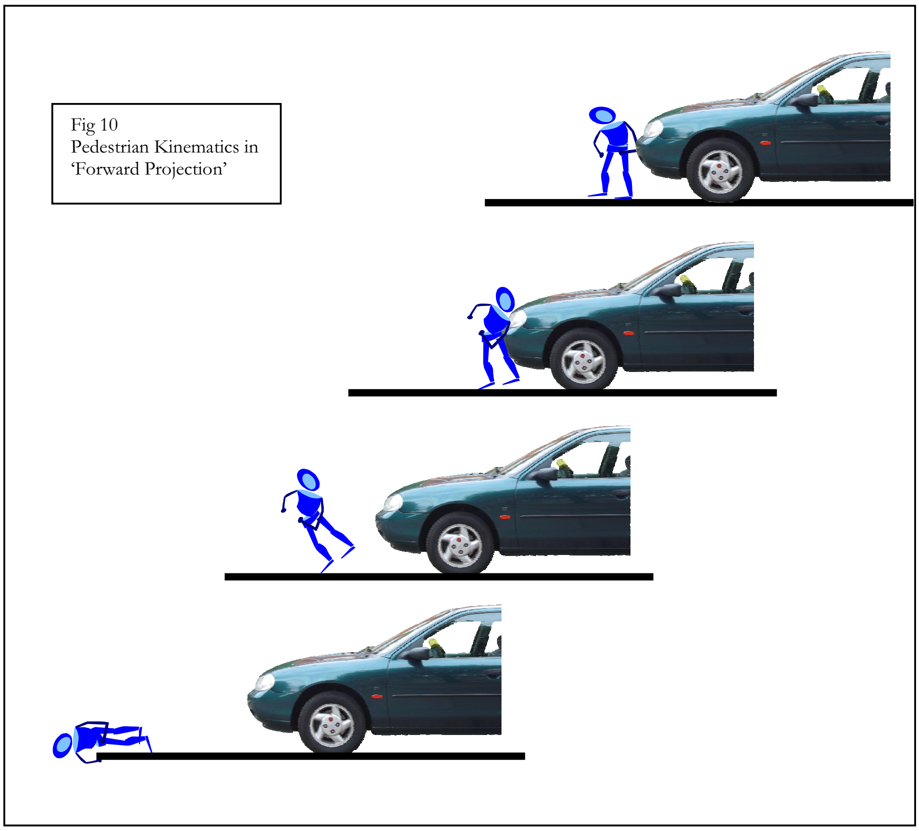


Fig 10
Pedestrian Kinematics in
'Forward Projection'

The data for analysis was obtained directly from the 71 cases found to fit the study criteria. These collisions involved pedestrians and motor vehicles of all types (see table 5) as well as motorcyclists and pedal-cyclists.

Table 5

Type of Road User Involved	Striking Vehicle	Type of Collision
Adult Pedestrian	Car	Wrap
Adult Pedestrian	Goods Vehicle	Forward Projection
Child pedestrian	Car	Forward projection
Motor/Pedal Cyclist	Single Deck Bus	Forward Projection
Motor/Pedal Cyclist	Car	Wrap

For the purposes of this study the type of impacts were classified more generally as either wrap or forward projection. Fender vault was excluded from the analysis because of the inherent errors present. 56 cases were identified as being wrap trajectories and 15 cases were identified as being forward projections.

ANALYSIS METHOD

The work of Searle & Searle has been used by the majority of police services since it was published in 1983[72] and has historically been found to be accurate and robust In their paper they suggested a coefficient of friction for a normally clothed pedestrian on an asphalt type surface as being in the region of 0.66.

In his 1994 research into pedestrian collisions, Hill[39] concluded that the coefficient of friction for a sliding/bouncing/tumbling pedestrian was in the region of 0.800 (for a surface coefficient of friction for vehicle tyres of 0.69 to 0.75). Hill incorporated these findings into Searle's research [72] & [71] and made comparisons with real world data. Hill concluded that Searle's formula for v_{min} was underestimating the vehicles speed at impact and suggested a correction factor of $v_{min}/0.87$ (Appendix D).

See
Appendix D
Appendix D1

Hill's real world data was taken from 26 collisions involving motor vehicles constructed prior to 1985, which have distinctly different front-end structures when compared with modern vehicles (Appendix D1). By 2000 it was found that Hill's adapted formula was overestimating the minimum speed of the vehicle on impact.

If, as Hill suggests, pedestrian sliding friction is higher than a vehicles skidding friction then it should be relatively common, especially in forward projection impacts, for the pedestrian to be overtaken by the vehicle and struck a second time or even driven over. Since it appears that this occurrence is rare, it would seem to suggest that pedestrian friction rates must be less than vehicle skidding rates.

The coefficient of friction found in Hill's skid testing for a motor car was found to be between 0.69 and 0.75, although there is no mention in his paper of when the comparison skid testing was done. Searle & Searle had suggested a coefficient for a pedestrian as being 0.66 on a similar surface, a value obtained by dragging a live human subject. This value is a reduction of 12% of the highest value found by Hill for vehicle tyres to road surface.

DATA ANALYSIS – WRAP TRAJECTORY

From the total of 71 cases identified, 56 cases were submitted involving 'wrap trajectories', these are by far the most common incidents and require the most thorough investigation as factors such as launch angle, height at apex and distance flown before landing are all generally unknown.

Variations in the front-end geometry of the vehicles further complicate the issues as is illustrated below in figs 11 & 12.

Fig 11

Fig 12

This type of collision is usually reconstructed using the formula presented by Searle and Searle and adapted by Hill's recommendations. When this technique was applied to the data from the study it was noted that in 17 cases (30%) v_{min} (the pedestrians' minimum speed post impact) was an overestimate of the vehicle speed at impact.

Hill's suggestion of using a pedestrian coefficient of 0.80 and correcting for projection efficiency was therefore discounted and a value of 88% of a cars skidding coefficient was substituted.

See Appendix D2

This procedure had the effect of reducing the overestimations to 8 cases (14%) with the largest error being 5 mph. For completeness the altered friction rate was applied to Searle's v_{max} equation to provide an upper bound. The results were also compared to the work of other authors (see Appendix D2).

There were no obvious errors in the data relating to the 8 cases which overestimated the impact speed. These cases are shown below in table 6 and graphically in figure 13 overleaf.

Table 6

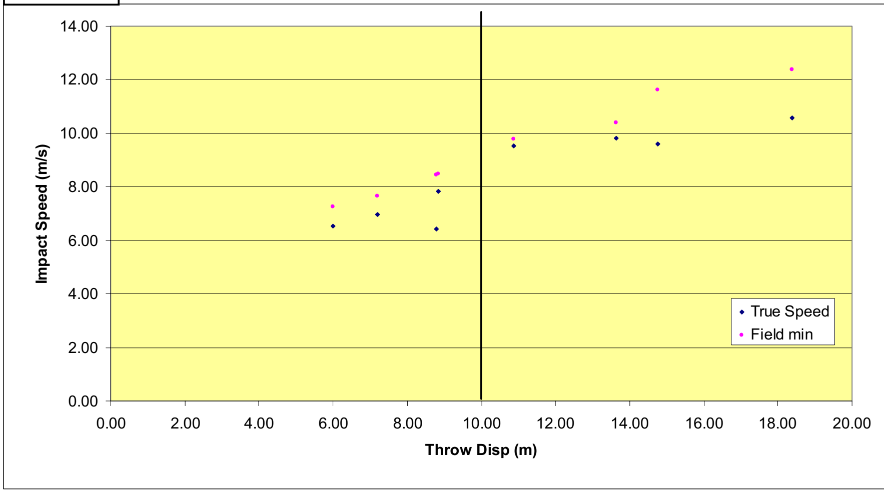
Job ID	Skid Test Mu	Total Throw Disp	Impact mph	Field mph
03/005	0.700	6.00	15	16
02/007	0.604	7.20	16	17
02/021	0.604	8.80	14	19
01/026	0.607	8.85	17	19
95/001	0.700	10.88	21	22
02/001	0.574	13.65	22	23
01/001	0.777	14.75	21	26
02/014	0.634	18.39	24	28

See

Appendix D3

Cases 95/001 & 02/001 overestimate the impact speed by only 1mph and cases 01/001 & 02/014 would be clearly identifiable as being incorrect from an examination of the damage caused to the vehicle concerned. However the cases where the total pedestrian throw displacement is less than 10m are the cause for most concern. It is not always possible to locate the pedestrians' orientation on the ground post-impact if they have been removed prior to the collision investigators arrival – a measurement is generally estimated from body fluid – so the potential margin of error in these measurements could be in the region of 1m or 10% of the throw displacement (appendix D3).

Fig. 13



It is clearly critically important that estimates of the pedestrian throw displacement are made as accurately as possible and their effects on any subsequent calculations are clearly stated.

DATA ANALYSIS – FORWARD PROJECTION

Out of the 71 cases identified, 15 involved forward projections. Of these 15 cases clearly defined pedestrian flight/slide displacements were found in only 3. This typifies the difficulties faced by the collision investigator when attempting to reconstruct these type of collisions, especially if the formulae require detailed data on the flight and/or slide displacements.

A methodology was therefore designed that does not require this evidence to be present providing that there is clear evidence of the point of impact and the final position of the pedestrian.

A collision between a pedestrian and a flat fronted vehicle will cause the pedestrian to be accelerated forwards and, unless they are not in contact with the road surface when struck, they will begin to rotate down onto the road surface as a result of the friction between their feet and the road (Fig. 14).

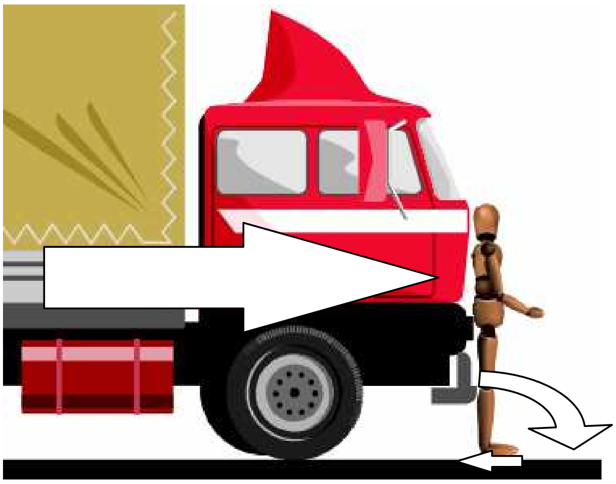


Fig 14

Any acceleration downwards will have the effect of shortening the distance before the pedestrian strikes the ground. Therefore, if it is assumed that the pedestrian is instantaneously struck to the ground then a maximum speed can be calculated for the pedestrian for any given throw displacement.

Using standard reconstruction formula, after adjusting the friction rate for a sliding pedestrian gives

$$v_{upper} = \sqrt{2 * 0.88 * \mu_{car} * 9.81 * S_{total}}$$

This will be an overestimate but provides an upper limit (v_{upper}) above which the pedestrian, and therefore the vehicle should not have been travelling.

In his paper for the 2001 ITAI Conference, Hague[35] offered the following formula

$$u = \sqrt{(2\mu g s)} + \mu\sqrt{2gH}$$

to calculate the speed (u) for a sliding pedestrian known to have fallen from any height H. For pedestrians subjected to a forward projection type impact he hypothesised that they would fall a distance equal to the height of their centre of mass.

For the investigation and reconstruction of cases where the point of impact is known, if the height of centre of mass for the pedestrian can be found or reasonably estimated then it is possible to calculate how long it took for the pedestrian's centre of mass to strike the road surface (modelled as a particle) using the equation

$$t_{topple} = \sqrt{\frac{2 * h_{com}}{g}}$$

where g is the acceleration due to gravity (9.81 ms^{-2}) and h_{com} is the known or estimated centre of mass for the pedestrian. As previously mentioned, this value is generally accepted as being approximately 60% of the total height of the pedestrian with variations being noted with small children and obese adults. The formula is not particularly sensitive to reasonable changes in this value in any case.

It can be argued that, by the time the pedestrian's centre of mass is level with the ground, the pedestrian is fully in contact with the ground too, then full retardation of the pedestrian has begun. Using this time and the overestimate of the pedestrian's speed (v_{upper}) gives a 'topple distance' from

$$s_{topple} = v_{upper} * t_{topple}$$

If this distance is subtracted from the 'throw' distance then the sliding speed for the pedestrian can be estimated using

$$v_{slide} = \sqrt{2 * 0.88 * \mu_{car} * 9.81 * (s - s_{topple})}$$

where s is the total pedestrian throw displacement.

Since it is obvious that, in a horizontal launch, topple should overestimate the flight distance, this calculation will provide the maximum flight distance and therefore the minimum slide distance, thus resulting in an underestimate of the pedestrians sliding speed.

GROUND IMPACT

The loss of horizontal speed for the pedestrian - as a result of the pedestrian striking the ground - can also be estimated (assuming an inelastic impact) using the formula suggested by Hague

$$v_{ground-strike} = \mu \sqrt{2gH}$$

where μ is the adapted vehicles coefficient of friction.

If this value is a true representation of the loss of the pedestrians speed then, as suggested, this can be added to the slide distance speed to estimate the vehicles impact speed using the suggested formula of

$$v_{impact} = \sqrt{(v_{slide})^2 + (v_{ground-strike})^2}$$

No loss of horizontal speed is considered during the 'topple phase' and therefore any contact with the ground by the pedestrian's extremities prior to this point will have the effect of decelerating them and therefore reducing the slide displacement.

Since only the sliding phase of their displacement is used for the calculation of v_{slide} this should result in an underestimate of their true speed.

This methodology was applied to all of the 15 cases identified for the study and was found to approximate the vehicles known travelling speed accurately.

See Appendix D4

There was only one instance of an overestimate of the true impact speed of the vehicle, and where this occurred the marginal error was calculated at being 1mph (see appendix D4).

In their book on pedestrian accident reconstruction Eubanks & Hill [25] detail the results of forward projection testing using dummies. Whilst being the result of collisions with non-European vehicles, the post-impact trajectory of a pedestrian struck by any flat fronted vehicle should be identical. These results, where possible, were also analysed using the above method and the results found to be accurate.

Appendix D4 also shows all of these values compared with formulae presented by other authors and the results are compared. It should be noted that the Searle & Searle equations are primarily designed for wrap trajectories but function well unless the throw displacement is small.

Chapter

4

Suggested Methodology

The results of the data analysis and the best practice survey have shown that there is a widespread discontinuity surrounding the reconstruction of pedestrian/vehicle collisions in the UK which may result in the estimation of different speeds for the same given data.

The reconstruction methods of pedestrian vehicle collisions fall in to three groups

1. Mathematical modelling using computer simulation
2. Modelling based on statistical interpretation
3. Modelling based on empirical real world data

All three methods have sound scientific application when appropriately applied, but for judicial proceedings it may be viewed as more reasonable to use data gathered at the scene of a single, unique collision rather than rely on data collected up to 40 years ago that potentially involves a completely different scenario.

The amount of evidence contained at any scene should dictate the methodology used in the investigation of a particular collision but investigators should not restrict themselves to any one particular method if the available data is poor.

ESTIMATION OF SPEED FROM VEHICLE DAMAGE

See Appendix E

Happer[38] 2000 includes in the paper a summary of various authors work examining the approximation of vehicle speeds as a result of the damage caused to it in either 'forward projection' or 'wrap' impacts. These are included in tables in appendix E with the speeds converted from kilometres per to hour miles per hour. Any estimation of speed based solely on vehicle damage must be treated with extreme caution, but does have its uses, when used to examine the collision scenario as a whole.

The authors also offer formulae to estimate the vehicles impact speed as a result of the throw distance for the pedestrian. Whilst the paper is extremely thorough in its approach it must be noted that the results are based on testing mainly from North America where vehicle profiles differ to those found in the UK and the rest of Europe.

WRAP TRAJECTORY IMPACTS

The use of Searle & Searle's work for reconstructing this type of collision has been tested with current, real world data from collisions in the UK The formulae have been found to work well, within limits, when the coefficient of friction applicable to a pedestrian is correctly judged

A reduction of 12% of a non-abs car coefficient has been tested and found to work well in most circumstances. The value of performing skid tests at the collision scene is that the testing automatically takes in to account

- Any deficiency in the amount of grip available through road wear
- Any incline or decline
- Any reduction in the coefficient caused through weather conditions
- Any difference in the coefficient caused by the time of year

The application of v min and v max must be made for all collisions, the result of the real world testing indicates that v min accurately predicts the minimum velocity of the vehicle at impact so there is no longer any need to adapt this value. Hill's suggestion of a v probable is now obsolete.

Where there is a high degree of pedestrian slide, the work of Hague can be used to approximate a speed from slide marks alone. This will provide an indication as to whether the speed calculated lies toward the upper or lower bounds. Any estimations of vehicle speed can be compared with the damage caused to the vehicle.

Where there is no known point of impact between the vehicle and the pedestrian the methodology of Hague can be applied if the point of landing and final rest is known. Additionally, if the height of the pedestrians' trajectory is known (for example they have been projected over a wall) then the loss of speed from impact with the ground can also be assessed

FORWARD PROJECTION IMPACTS

The methodology for forward projection impacts should be exactly the same as for those involving wrap trajectories if the scene evidence is sufficient. When there is a lack of data then the formulae suggested in this document in chapter 4 have been applied to real world collisions and found to be accurate.

The measurement of a total pedestrian throw displacement can be made and then applied to calculate an upper velocity for the pedestrian/vehicle. From this value it can be estimated how long it took for the pedestrian to strike the ground before sliding to a stop. A lower bound can then be calculated taking into account any speed lost as a result of striking the ground

However, it must be noted that these types of collision generally involve large goods vehicles, which will have a coefficient of friction less than that of a skidding car. In these cases the collision investigator should perform skid tests with a normal, non-abs car to obtain the effective friction rate before applying any modifications.

CONCLUSION

When using any of the methodologies published for the reconstruction of pedestrian/vehicle collisions it is necessary to quote the range of speeds that they produce and to be aware of any limitations in their application.

In criminal cases it may always be open to 'reasonable doubt' that the minimum speed applies. The purpose of presenting the findings of the research in such a format is to produce one value, which will normally be considered as an underestimate of the vehicle's impact speed and a higher estimate above which the vehicle should not have been travelling.

Considerable changes have been made to the design and stiffness of vehicle front structures since the 1980's as manufacturers strive to make vehicle fronts more 'pedestrian friendly' with the result that bumpers are now generally made from high impact plastics and bonnet lines have become more curved.

The methodologies offered in this document have been applied to recent, real world collisions and to historical data collected in Europe and America. European data for 'wrap trajectories' has been used exclusively for this analysis to prevent any margin of error incurred by introducing differing styles of vehicle designs common in other geographical areas.

The use of standard pedestrian throw calculations to reconstruct throw displacements of 10m or less has historically been subject to scepticism in the UK When wrap trajectories are analysed there appears to be good evidence to support this scepticism. Collision investigators presented with these types of collision must ensure that all measurements are accurately recorded and that, where there is potential for error, these errors and their consequence are clearly noted

Forward projection analysis is based on a much smaller sample size with only 3 cases having a throw distance of less than 10m. The methodology suggested is successful in estimating impact speeds for all three cases to varying degrees of accuracy. The application of this methodology assists a collision investigator in accurately reconstructing a pedestrian/vehicle collision within defined limits, without the detailed evidence such as projection launch angle or height of trajectory that are usually unavailable in real world collisions.

If pedestrian vehicle collisions are to be reconstructed to an acceptable degree of accuracy then further research must continue to be carried out

Appendix A

Participating Police Services

Avon & Somerset Constabulary

Cheshire Constabulary

Cleveland Police

Cumbria Constabulary

Derbyshire Police

Dorset Police

Durham Constabulary

Gloucestershire Constabulary

Greater Manchester Police

Hampshire Constabulary

Hertfordshire Constabulary

Humberside Police

Lancashire Constabulary

Leicestershire Constabulary

Lothian & Borders Police

Merseyside Police

Norfolk Constabulary

North Wales Police

North Yorkshire Police

Northamptonshire Police

Northern Constabulary

South Wales Police

South Yorkshire Police

Staffordshire Police

States of Jersey Police

Surrey Police

Sussex Police

Tayside Police

Thames Valley Police

Warwickshire Constabulary

West Midlands Police

West Yorkshire Police

Appendix B

Best Practice Questionnaire

Best Practise Survey

Home Office
BUILDING A SAFE, JUST AND TOLERANT SOCIETY

Dear Colleague,

The purpose of this questionnaire is to try and find the best method of reconstructing pedestrian/vehicle collisions. The practical experience that you have is the best way that all the different methods can be brought together in one document. There are currently over 400 technical papers that have been published on this subject so this, UK based study, will hopefully address the problems faced by British police personnel.

There is no need to include your name or contact details on this survey, although if you want me to contact you then it will be necessary. The idea is to get away from any internal politics and to answer the questions as fully as possible. Once completed, please forward them directly to me using the freepost envelope enclosed, or alternatively at the below address.

Jim Field, FCITU, West Midlands Police, 199 Park Lane, Aston, Birmingham, B6 5DD

Thanks for your time, please feel free to be as candid as you wish.

About you

Name	Force
Collar/Role Number	Contact Number
Current Role	Length of time in post
Level of Qualification (please choose one)	Standard - Advanced - City & Guilds
Other AI/Recon Qualifications	

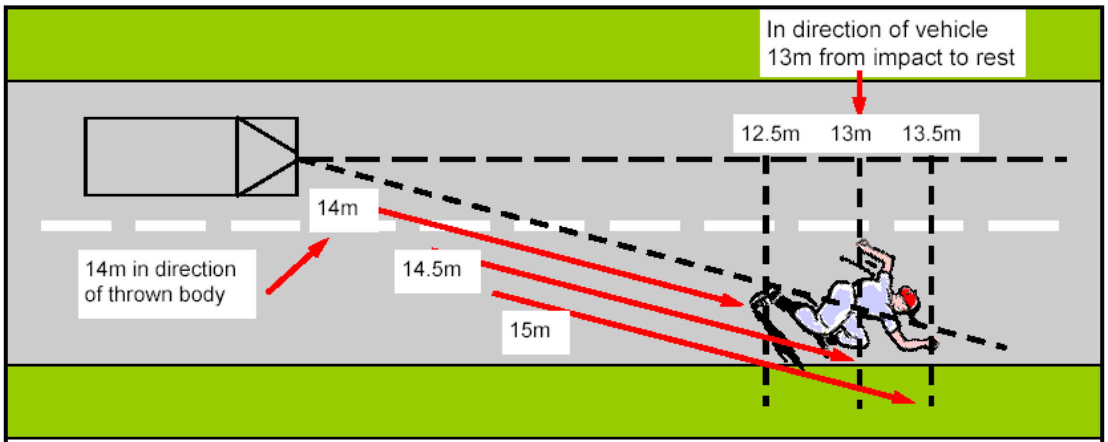
About Recon Training

What Training Centre did you go to ?	
What method was taught (if any) for pedestrian/vehicle collisions, ie Searle, Appel's Graph etc.	
If you use Searle's equations what correction factor do you use for 'adult pedestrians'	87% 84% Other _______
Approximately what is the percentage of the collisions that you attend that involve pedestrians	%
Of all the collisions you attend involving pedestrians, how many can you currently reconstruct	%

Appendix B continued

Do you routinely perform skid tests at pedestrian collisions even if there are no vehicle skidmarks	Yes No
What method of skid testing do you use	Brakesafe Skidman Chalkgun Other - Please State ____________________
Do you measure the distance the pedestrian has flown (ie the distance before landing)	Yes No
Do you measure the distance the pedestrian has slid/tumbled (ie distance after landing)	Yes No
Do you measure the height of the leading edge of the vehicle	Yes No
Do you record the height/weight of the pedestrian	Yes No
If a new method was proposed which needed these measurements, would you use it	Yes No
Do you trust calculations of vehicle speed made only from pedestrian throw	Yes No
Have you been challenged in Court over the way you have reconstructed a pedestrian collision	Yes No
If you have, did you 'win' the argument	Yes No
Do you research other methods for calculating 'ped throw' if your usual method does not fit	Yes No
Below is a list of **SOME** of the recent papers published on pedestrian throw - please indicate if you have read and/or used them	
Theoretical vs Empirical Solutions for Veh/ Pedestrian Collisions (Toor 2003)	Read Used Not Heard Of
Investigation and Analysis of Real-Life Pedestrian Collisions (Randles 2002)	Read Used Not Heard Of
Pedestrian Throw Kinematics in Forward Projection Collisions (Fugger 2002)	Read Used Not Heard Of
Throw Model for Frontal Pedestrian Collisions (Han 2001)	Read Used Not Heard Of
Calculation of impact speed from pedestrian slide distance (Hague 2001)	Read Used Not Heard Of
Comprehensive Analysis Method for Vehicle/ Pedestrian Collisions (Happer 2000)	Read Used Not Heard Of
Coefficient of Friction in Pedestrian Throw (Wood 2000)	Read Used Not Heard Of
Vehicle Speed Calculations From Pedestrian Throw Distance (Evans 1999)	Read Used Not Heard Of
Have you used/read any other technical papers relating to pedestrian collisions (If yes, give details below).	Yes No

Appendix B continued



The above diagram tries to show a typical car-pedestrian collision. Please indicate what values you would use to reconstruct this collision. Skid test were carried out in the collision vehicle and, for a damp road surface, they found the coefficient of friction was 0.585.

For a Pedestrian Throw Calculation

Coefficient of friction applicable would be 0.585 0.800 Something Else ……………

Pedestrian Displacement would be 12.5m 13m 13.5m 14m 14.5m 15m

In this type of collision scenario would you measure the angle between the vehicle direction and the pedestrian rest point	Yes No
Would you measure the incline/decline between the impact point and the pedestrian finish point	Yes No
Would you estimate the pedestrians centre of gravity	Yes No
If the pedestrian had slid only on a grassed area, would you calculate a coefficient of friction for the grass	Yes No
If this collision involved a car and a motorcycle, and the riders path was what is shown, would you use 'ped throw' calculations	Yes No

Please indicate if you would do anything else that I haven't mentioned, and what that would be.

Appendix B continued

Compared to the usual methods of collision investigation (like speed from skid marks), pedestrian throw calculations are relatively new. They have only been around since the 1960's and still evoke very strong reactions both for and against their use. Please indicate below if you have used them in reconstructing collision and, if you did, what method you used and if you felt it was any good evidentially.

Were you aware that this research has been going on since September 2001	Yes / No
Have you dealt with any cases that were suitable for the study during this time	Yes / No
If you have submitted data collection forms, have you forwarded copy case files (NB—Any details identifying living persons are removed on receipt of a file, you don't need to remove them prior to sending them to me).	Yes / No

The rest of this page is blank. Please feel free to give me your opinion of this research and whether or not you think anything else could be done to assist you in the reconstruction of pedestrian/vehicle collisions.

Thank you for your time and effort in completing this survey

Appendix B1

Literature Review

A comprehensive review was undertaken to try and establish how many technical papers had been published examining the area of pedestrian/vehicle collisions. In order to carry this out a search was made of the databases held by the Society of Automotive Engineers (SAE). This search revealed that there were literally hundreds of papers examining different areas of pedestrian/vehicle collisions. In particular the research was divided into the following groups

- Pedestrian Throw Research
- Vehicle front end structures
- Pedestrian sliding rates/Coefficient of friction

A copy of the 2002 Accident Reconstruction Technology Collection Compact Disk (ISBN 0-7680-1041-1) was purchased together with the proceedings of the International Council on the Biomechanics of Impact (CD versions) dating from 1973 to 2003. These databases were then searched for relevant published data. An internet search was also carried out on the databases held by the Institute of Mechanical Engineers (IMechE) and using the internet search engine provided by 'Google'. Papers produced by the European Enhanced Vehicle-safety Committee (EEVC) were also examined for relevance.

Each research paper was examined and it was decided whether or not it was suitable for use and reference in the study. Those papers that were suitable were scrutinized and included in the references using the computer software package Endnote 5™.

Each research paper was also examined for the references contained within it. These were then checked to ensure that those papers had also been taken into account.

The breadth of the research considered ranged from the original paper published by Derwyn Severy in 1963 (thought to be the first research of its kind), to the 2003 paper published by Amrit Toor and also included the original Doctoral Thesis prepared by Dr Stephen Ashton for which the author is extremely grateful.

Appendix C

Letter to all Chief Officers

Sir Edward Crew
Chief Constable
West Midlands Police
Lloyd House
Colmore Circus
Queensway
Birmingham
B4 6NQ

West Midlands Police
Crash Investigation
Training Unit
199 Park Lane
Aston
Birmingham
B6 5DD

Tel 0121 626 5016

28 September
2001

Dear Sir Edward

Improved Reconstructions of Pedestrian/Vehicle Collisions

I am writing directly to you because we need help with this major international project which is already producing potentially highly positive results in the area of crash investigations. The UK Home Office Research Group and my own force have sponsored this project.

What we are looking for is your support with the project and I would ask for your permission to involve your crash/accident investigation officers in the data collection phase. The work required of them will take a matter of minutes at the scene and will not involve them in carrying out any further work on my part.

If you give you permission then I will contact the department directly. All forces that are participating will be acknowledged in the final paper. This will form the basis of a report, which will be forwarded to ACPO for their consideration. Once this report has been accepted it will be circulated to all police services as a model for best practice.

If you agree to this can you please complete the enclosed form and return it to me so that I may contact your officers directly.

Can I thank you in anticipation of your help,

Jim Field
Senior Crash Investigator

Appendix C1

Reply from Chief Officers

Improved Reconstructions of Pedestrian/Vehicle Collisions

Sir Edward Crew
Chief Officer
West Midlands Police

I am willing for personnel from West Midlands Police to assist in the data collection phase of this project.

Signed

If **not** signed by Chief Officer

Name of signatory

Rank of signatory

Contact Details of Crash/Accident Investigation Unit(s)

Designated Senior Crash Investigator

Address

Telephone Number

e-mail address

Once completed please return to - West Midlands Police, CITU, 199 Park Lane, Aston, Birmingham B6 5DD

Appendix C2

Stafford Conference Handout

WEST MIDLANDS POLICE / HOME OFFICE RESEARCH

PEDESTRIAN VEHICLE COLLISIONS

«Police force area 1999» Police Delegates Copy

«POLICE FORCE AREA 1999» HAS «ALL SEVERITIES» ROAD CASUALTIES IN 1999

The data for 2000 is due out any day now and is expected to show the same trends as 1999. If the West Midlands Police area is anything to go by then the numbers of pedestrians injured or killed in road 'incidents' is continuing to grow.

Unfortunately for crash investigators the advent of anti-lock braking systems has simply made the job harder. Yes, under the right conditions vehicles fitted with anti-lock brakes leave tyre marks. But the reality is that, certainly in cities, the travelling speeds of vehicles is sufficiently low to make these marks invisible to the naked eye.

If enough data can be collected nationally then hopefully the life of the crash investigator can be made that much easier.

The aim of the study is to produce a clearer picture of the way pedestrian collisions can be reconstructed using **real world** data.

There are currently more than a dozen different technical papers that give guidance or formulae for calculating vehicle speed from pedestrian throw displacements. Clearly all are not 'correct'. The result of this is that Police Crash Investigators have a hard time in the witness box when all they are trying to do is their best.

Doing Our Best

It might be that none of the current work accurately describes real world crashes. If this is the case then a new set of formulae can be generated, but at least these will have the backing of the whole of the UK. Or it could be that one of the current formulas works perfectly.

Who knows !

Watch this space to find out.

Top 7 Casualty Rates 1999

Metropolitan	48226
Greater Manchester	16488
West Yorkshire	13641
West Midlands	13559
Thames Valley	11865
Merseyside	9959
Hampshire	9490

«Police force area 1999» Police Area

- «Fatal» People Killed
- «Serious» People seriously injured
- «Slight» Slightly injured
- A total of «All severities» Casualties
- Can we do better ?

Home Office

BUILDING A SAFE, JUST AND TOLERANT SOCIETY

HOME OFFICE POLICE RESEARCH AWARD SCHEME COMING TO A FORCE NEAR YOU !

The Home Office Research Award Scheme is open to all personnel from any police service. I approached my own force for support in a pedestrian project and was pointed in their direction. Jennie Cronin and Steve Gray are two of the members from the project management team. I contacted them with my idea and they sent me all of the necessary paperwork. Both Steve and Jennie are really approachable and willing to offer advice on how to apply. The application form is straightforward to complete but must be endorsed by someone within the force of ACPO rank. The awards are given twice a year with successful applicants spending two great days at NPT Bramshill learning the ropes.

Appendix C2 continued

ANOTHER HALF BAKED IDEA ?

I don't think so.

But I'm biased aren't I ? After all, it's my project.

I certainly hope not. I am trying to get as many Police Services involved for one particular reason. That is so that everyone has a direct input. I am as guilty as the rest of looking at something and deciding not to bother with it because I had no input into it.

Not Invented Here Syndrome

I've called it 'not invented here syndrome' for the simple reason that I don't know how good the research was in the first place. If I don't trust the research then I'm not going to use it and end up looking a fool.

If each police force were to find 30 cases over the next 18 months that would equal 1,500 cases. With that sort of data to work with the study would almost be guaranteed to succeed. Most current papers have between 100 and 200 cases at the most !

E-mail me at pedstudy@blueyonder.co.uk

All police services that actively take part in the survey will be fully acknowledged in the published report. Once ratified this report will be submitted to ACPO for approval.

But What Happens To All My Hard Work ?

Once ratified the report will be published to all forces as a model for 'best practice'.

The cost of training officers in different techniques should be obsolete and we can leave them alone to get on with what they want to do, finding out if it was really 'an accident'.

HOW MUCH TIME IS THIS ONE GOING TO WASTE ?

I've already been asked how I think I am going to get the whole UK crash investigation outfit on my side. I've also been asked how much time they will have to waste doing work for someone else (namely me !).

Well, firstly I'm not knocking anyone or any police force for doing things differently to the way I do them. With all of the published data that is around I can't stand up and say that the way I'm doing it is right and they are wrong. I, like everyone else, am doing my best. I hope that, by taking this approach, I will get through to more people than by ranting and raving. We'll see. Secondly the data that I am asking for is readily available. I estimate that the additional stuff I am asking for will take no more than 3 or 4 minutes at the scene. There are copies of the data collection form enclosed for you to examine. Please let me know what you think of it. Please let me know if you think there should be something else included on it.

"Please photocopy it and pass it to as many people as you can and ask them to fill it in."

Most of all though, please photocopy it and pass it to as many people as you can and ask them to fill it in.

ASK FOR HELP—YOU MAY BE SURPRISED AT THE RESULT

West Midlands Police have agreed to co-sponsor this project by proving the time for me to do the work as part of normal duty time. Whilst working as part of the 'Gang of three' at the crash investigation training unit in Birmingham the West Mid's have sanctioned up to 17 hours a week for the study. The rest of the time will be from my 'off duty' time.

I am also looking at the idea of submitting the work as part of a PhD supervised by Birmingham University Accident Research Centre under the supervision of Professor Clive Neal-Sturgess. His team have worldwide recognition for the work that they have done into accident investigation and road safety.

If the study passes the scrutiny of them, the Home Office and ACPO then we can be assured that it will have credence in the real world too. At the time of writing America, Poland and Australian crash investigators have also expressed an interest in the project. If you know of any 'foreign' forces who may be interest then please let me know and I will contact them.

Co-Sponsors
West Midlands Police

Who knows, by the time of the next conference this could be a global project !

Volume 1, Issue 1

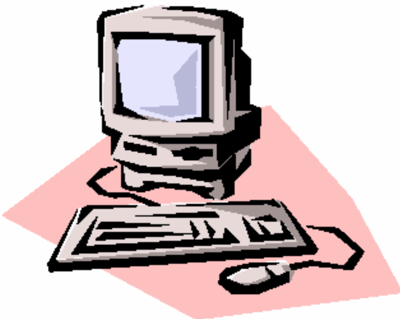
SHOVE YOU DATA FORMS …….. IN THE POST

I am trying to keep the work of the operational crash investigators to a minimum. The data collection forms have been designed to cover everything that I need for the study. By all means send them in as you get them completed, but there are other ways too.

I am currently negotiating for web space so that I can post an online version of the data collection form. People with access to the web can visit the site and complete the form online and send it straight through. This should cut down on time and postage costs.

For those of you without internet access I am setting up an e-mail version of the form too. Once this is done I'll send it direct to those who want it where it can be filled in and e-mailed back.

If you are already on e-mail then contact me at pedstudy@blueyonder.co.uk and I will, with your permission, add you to the mailing list. Then as soon as there are any developments I can keep you updated.



Send your forms by e-mail, fax or post—I don't care just send them

For those without e-mail and internet you can always fax the forms back to me the CITU office in Birmingham.
The fax number is 0121 626 8371

For those without any of these then I'm afraid it's snail-mail. Please send your completed forms to;

Jim Field

West Midlands Police

CITU

199 Park Lane

Aston

Birmingham B6 5DD

KEEPING RECORDS—THE ONLY WAY TO SUCCEED

Each crash investigation unit that takes part will be busy enough without any added paperwork. If you come on-board then I will do all of the (project) paperwork for you.

Just send me the completed forms without doing any maths. I'll input them into my database and do the work myself. For crashes that fit into the study criteria I may send you an e-mail asking for any other data you may have collected. I am particularly interested in photographs of the striking vehicle. Digital photographs are probably the best as they can be sent electronically without any time wasting. I am looking at the area of damage to the front of the vehicle so a picture taken from in front of the car covering the whole of it would be ideal. I am busy writing a detailed description of tasks for the project so those will be circulated direct to interested parties.

> *"Just Send Me Your Files And I'll Do The Work For You !"*

Each month I will send out an e-mail or fax containing an accident/crash stats enquiry. This will comprise of

- How many crashes have been dealt with
- How many crashes involved pedestrians—cyclists—motorcyclists
- How many fitted the study

This will give me a clear idea as to how the project is going

HOW LONG DO I HAVE TO KEEP IT UP ?

The project began on Friday 14th September 2001 and will run for two years. There is an option to extend the project for a maximum of one more year but that is only if the data collected is poor, unclear or nothing has come in.

The data collection phase begins officially on Thursday 1st November 2001 and runs until Wednesday 30th April 2003. That's a full 18 months. During this time I am also hoping I can bribe you into having a look at historical data too, but that's another story.

Data analysis will begin as soon as the data arrives. Suitable cases will attract immediate scrutiny as I begin to find out which, if any, of the current published papers is the most accurate. I have the assistance of a lady at the Home Office who is a bit of a stat's guru. I have also asked several other 'experts' if they will hep out. Cranfield Impact Centre have also foolishly contacted me so I shall be trying to weedle my way in there to see if they can help.

If you find you have a spare hour or two then please contact me, I can find plenty of work for you if you want it.

Come on folks, I'm trying to make it our project, not just mine !

Appendix C2 continued

Accident Statistics 1999 The Full Picture

Source DTLR 2001

«Police force area 1999» Police aren't the only ones to have 'accidents' here are the others too

All casualties by Police force area for 1999	Fatal	Serious	Slight	All severities
Avon and Somerset	75	778	6,656	7,509
Bedfordshire	49	346	2,441	2,836
Cambridgeshire	76	575	3,742	4,393
Cheshire	75	756	6,108	6,939
City of London	1	61	447	509
Cleveland	22	236	1,959	2,217
Cumbria	62	495	2,433	2,990
Derbyshire	60	690	4,769	5,519
Devon and Cornwall	78	792	6,777	7,647
Dorset	35	469	3,331	3,835
Durham	33	232	2,381	2,646
Essex	106	1,103	7,482	8,691
Gloucestershire	47	306	2,443	2,796
Greater Manchester	89	1,035	15,364	16,488
Hampshire	100	1,188	8,202	9,490
Hertfordshire	47	769	4,898	5,714
Humberside	76	628	3,806	4,510
Kent	100	1,029	6,894	8,023
Lancashire	79	1,126	7,169	8,374
Leicestershire	86	464	4,508	5,058
Lincolnshire	104	662	3,181	3,947
Merseyside	55	633	9,271	9,959
Metropolitan Police	290	6,006	41,930	48,226
Norfolk	71	698	3,206	3,975
North Yorkshire	68	998	3,781	4,847
Northamptonshire	76	662	2,608	3,346
Northumbria	71	681	5,921	6,673
Nottinghamshire	64	871	4,792	5,727
South Yorkshire	50	683	6,028	6,761
Staffordshire	55	385	5,813	6,253
Suffolk	48	432	2,616	3,096
Surrey	57	534	5,556	6,147
Sussex	93	1,072	7,104	8,269
Thames Valley	150	1,564	10,151	11,865
Warwickshire	50	558	2,609	3,217
West Mercia	75	918	5,015	6,008
West Midlands	89	1,664	11,806	13,559
West Yorkshire	111	1,189	12,341	13,641
Wiltshire	49	422	2,955	3,426
England	**2,922**	**33,710**	**248,494**	**285,126**
Dyfed-Powys	48	584	1,855	2,487
Gwent	30	344	2,196	2,570
North Wales	51	417	3,715	4,183
South Wales	62	333	4,712	5,107
Wales	**191**	**1,678**	**12,478**	**14,347**
Central	10	227	748	985
Dumfries and Galloway	13	136	426	575
Fife	15	175	821	1,011
Grampian	35	274	1,276	1,585
Lothian & Borders	52	480	3,631	4,163
Northern	36	330	1,020	1,386
Strathclyde	109	1,729	7,557	9,395
Tayside	40	383	1,314	1,737
Scotland	**310**	**3,734**	**16,793**	**20,837**
Great Britain	**3,423**	**39,122**	**277,765**	**320,310**

Appendix C3

Letter to Collision Investigators

Home Office
BUILDING A SAFE, JUST AND TOLERANT SOCIETY

West Midlands Police
Crash Investigation Training Unit
199 Park Lane
Aston
Birmingham
B6 5DD

Tel 0121 626 5016
Fax 0121 626 8371

e-mail j.field@west-midlands.police.uk

Ps …………
…………….. Constabulary
Collision Investigation Unit
xxxxxxxxxx RPU
xxxxxxxxxxx Road
xxxxxxxxxx
XXX XXX

20th October 2001

Dear Ps ………….,

Thank you very much for agreeing to take part in this research. Enclosed with this letter is a copy of the data collection form that I would ask your staff to complete whenever they attend a suitable case, and specific details of what extra data is required. If your department keeps historical records, I am also collecting details of incidents where an impact speed is known by independent means (speed from tachographs or skid marks etc.), and where any measurements were taken which **could** have been used for pedestrian throw calculations.

As you will see, the extra details that I am looking for will only mean two or three minutes of extra work. I do not want to tie you and your staff up with lengthy investigations on my part. I certainly don't need you to make any calculations on my behalf. If you or your staff forward the completed forms to me I will carry out all of the work.

Also enclosed is a copy of the monthly returns form. All that this asks for are details of all cases that have been brought to your attention in any month. The reason for this form is to see how many cases are reported, how many involve pedestrians, and how many are suitable for 'pedestrian throw' calculations.

The data collection phase begins on Thursday 1st November 2001. Can I please ask that you bring this study to the attention of all of your staff so that they are aware of it before this date?

If you were not able to attend the Senior Crash Investigators Conference in Stafford recently then you will not have seen the presentation I gave. If you want to see it (in Microsoft PowerPoint format) then send me an e-mail and I will forward it you.

Once again, many thanks for agreeing to take part, if you require any further information then please feel free to contact me at any time.

Yours sincerely,

Jim Field

Appendix C4

Scene Data Collection Form

Pedestrian - Vehicle Collisions

Home Office
BUILDING A SAFE, JUST AND TOLERANT SOCIETY

Data Collection Form

Also use this form for cyclists & motorcyclists

Please complete the below details as accurately as you can. If you make an estimate please indicate this very clearly. Thank you for helping with this study. If you have any comments, questions or suggestions please contact me at j.field@west-midlands.police.uk (you may photocopy this form).

Time	Completed by		Force
Date	Location		
Weather			
Road Dry/Wet/Damp		Incline to nearest degree	
Casualty Details		Vehicle Details	
Slight/Serious/Fatal		Reg. No.	
Age	Sex M / F	Make	Model
Weight		Engine Size	Diesel/Petrol
Height		Vehicle braking at impact	Yes/No
Build		Anti-lock brakes	Yes/No
Clothing Normal/m-cycle leathers/nylon		Skid Marks at Scene	Yes/No
Impact Point Shoe Scuff/debris/etc		Longest Skid Mark	m
		Post Impact Skid Mark	m

Angle between vehicle direction & casualty rest point		
Surface casualty slid over	road/pavement/grass/etc & distances if more than one	
Distance Flown	Distance Slid	Total

Skid Tests	Speed or μ		Speed or μ		Speed or μ	
	Test 1		Test 2		Test 3	
	Length	m	Length	m	Length	m
Skid test vehicle			Chalk gun/Skidman/Other			
			No ABS	ABS on	ABS shut off	

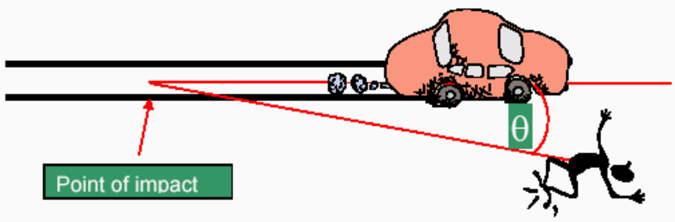
Supported by West Midlands Police and You

Don't do any unnecessary calculations – I will do them on receipt of this form

Appendix C5

Data Collection Form Instructions

Details of **Additional Data** to be collected



Please measure the following

Distance from point of impact to rest for the pedestrian/motorcycle/motorcyclist etc.

The distance the I.P. flew through the air

The distance the I.P. slid along the ground

The pre and post impact length of the skid marks of the vehicle

The angle between the direction of the skid marks and the point where the I.P. ended up

If Possible – A photograph showing the whole front of the vehicle (digital will do).

Appendix D

Results of Hill's Dummy Testing

Body to road coefficient testing between 16-2-89 and 5-5-89

Test	Speed	Displacement	Calculated Mu
1	30	11.7	0.783
2	30	11.4	0.804
3	31	12.9	0.759
4	31	13.1	0.747
5	31	12.9	0.759
6	31	14.0	0.699
7	30	11.7	0.783
8	31	13.2	0.741
9	30	11.9	0.770
10	31	12.3	0.796
11	40	17.6	0.926
12	41	21.0	0.815
13	42	21.6	0.832
14	42	22.4	0.802
15	42	21.2	0.847
16	42	23.5	0.764
17	42	22.1	0.813
18	42	20.2	0.889
19	41	20.6	0.831
20	42	23.0	0.781

Date: 16.2.89 Weather: Fine Surface: Airfield tarmac
Conditions: Dry Clothing: Serge Jacket & Trousers

Test	Speed	Displacement	Calculated Mu
21	28	7.5	1.065
22	29	8.5	1.008
23	31	10.7	0.915
24	30	11.3	0.811
25	30	12.1	0.757
26	30	10.8	0.849
27	30	12.2	0.751
28	30	12.2	0.751
29	31	12.9	0.759
30	29	9.1	0.941
31	42	20.4	0.881
32	41	20.8	0.823
33	42	21.0	0.855
34	40	19.2	0.849
35	41	19.0	0.901
36	42	21.4	0.839
37	41	20.5	0.835
38	43	23.2	0.812
39	43	22.9	0.822
40	42	25.4	0.707
41	51	33.6	0.788
42	50	32.8	0.776
43	50	32.0	0.796

Date: 7.3.89 Weather: Fine Surface: Airfield tarmac
Conditions: Dry Clothing: terelyne jumper trousers & body warmer

Test	Speed	Displacement	Calculated Mu
44	32	18.2	0.573
45	33	18.3	0.606
46	33	17.3	0.641
47	33	18.8	0.590
48	33	16.4	0.676
49	33	15.5	0.716
50	33	15.9	0.698
51	33	16.2	0.685
52	33	16.0	0.693
53	33	15.6	0.711

Date: 05.5.89 Weather: Fine Surface: Airfield tarmac
Conditions: Dry Clothing: Nylon jacket and trousers

Test	Speed	Displacement	Calculated Mu
54	33	12.5	0.887
55	34	12.9	0.913
56	33	12.6	0.880
57	33	13.2	0.840
58	33	12.4	0.894
59	33	12.8	0.866
60	33	13.3	0.834
61	32	11.9	0.876
62	33	13.3	0.834
63	33	12.8	0.866

Date: 05.5.89 Weather: Fine Surface: Airfield tarmac
Conditions: Dry Clothing: Woollen Boiler Suit

Test	Speed	Displacement	Calculated Mu
64	33	11.9	0.932
65	33	11.6	0.956
66	33	13.1	0.847
67	33	15.1	0.734
68	32	13.4	0.778
69	33	12.7	0.873
70	33	11.9	0.932
71	33	12.7	0.873
72	32	15.1	0.691
73	33	13.2	0.840
74	42	21.8	0.824
75	42	20.7	0.868

Date: 05.5.89 Weather: Fine Surface: Airfield tarmac
Conditions: Dry Clothing: Rubberised cotton jacket wool trousers
Tests 44-73 recorded on video

Ave. Mu From Tests Excl. M/cycle Gear 0.832
Ave. Mu (Exclude Two High readings) 0.825

Average Mu From Testing M/cycle Gear 0.659

Appendix D1

Real World Data Hill 1994

Real World Collision Data - G. S. Hill as published in Impact Spring 1994

						Searle/Hill	Mu = 0.8
	Vehicle Mu	Throw	SFSM	MPH	v(min)	v(probable)	v(max)
Hill 1	0.495	67.90	27.80	62	25.49	29.30	32.65
Hill 2	0.907	9.80	11.16	25	9.68	11.13	12.40
Hill 3	0.673	23.50	19.90	45	15.00	17.24	19.21
Hill 4	0.700	25.50	18.53	41	15.62	17.96	20.01
Hill 5	0.664	13.50	12.66	28	11.37	13.07	14.56
Hill 6	0.733	10.90	12.11	27	10.21	11.74	13.08
Hill 7	0.765	21.00	15.74	35	14.18	16.30	18.16
Hill 8	0.766	20.80	17.51	39	14.11	16.22	18.07
Hill 9	0.945	16.10	14.25	32	12.41	14.27	15.90
Hill 10	0.665	6.50	8.92	20	7.89	9.07	10.10
Hill 11	0.945	19.30	14.85	33	13.59	15.62	17.40
Hill 12	0.930	14.50	14.49	32	11.78	13.54	15.09
Hill 13	0.733	15.20	13.57	30	12.06	13.86	15.45
Hill 14	0.760	17.00	14.34	32	12.76	14.66	16.33
Hill 15	0.787	11.30	12.43	28	10.40	11.95	13.32
Hill 16	0.823	12.40	10.93	24	10.89	12.52	13.95
Hill 17	0.764	14.00	13.19	30	11.58	13.31	14.82
Hill 18	0.674	32.00	18.65	42	17.50	20.12	22.41
Hill 19	0.814	23.00	19.25	43	14.84	17.05	19.00
Hill 20	0.694	29.20	19.53	44	16.72	19.22	21.41
Hill 21	0.750	16.00	15.58	35	12.37	14.22	15.85
Hill 22	0.746	24.00	16.54	37	15.16	17.42	19.41
Hill 23	0.798	18.40	15.45	35	13.27	15.25	16.99
Hill 24	0.596	11.30	11.21	25	10.40	11.95	13.32
Hill 25	0.660	17.90	13.12	29	13.09	15.04	16.76
Hill 26	0.767	16.00	15.02	34	12.37	14.22	15.85

Appendix D2

Real World Data - Wrap Trajectories

Job ID	Skid Test Mu	Total Throw Disp (m)	Impact Speed (ms^{-1})	mph	Field min (ms^{-1})	mph	Field max (ms^{-1})	Searle Hill Vmin (ms^{-1})	Searle Hill Vmax (ms^{-1})	Evans Smith Min (ms^{-1})	Evans Smith Max (ms^{-1})	Happer Model Wrap Min (ms^{-1})	Happer Model Wrap Max (ms^{-1})	Wood 2000 Min (ms^{-1})	Wood 2000 Max (ms^{-1})
99/007	0.800	60.21	28.57	64	23.58	53	28.84	24.01	30.74	25.62	29.94	24.15	29.15	19.40	34.92
02/016	0.639	53.00	23.14	52	21.08	47	24.18	22.52	28.84	23.90	28.22	22.46	27.46	18.20	32.76
01/024	0.685	39.10	20.01	45	18.42	41	21.50	19.34	24.77	20.23	24.55	18.84	23.84	15.63	28.14
03/001	0.583	37.60	18.86	42	17.31	39	19.45	18.97	24.29	19.79	24.11	18.41	23.41	15.33	27.59
01/002	0.587	34.60	19.94	45	16.64	37	18.73	18.20	23.30	18.90	23.22	17.53	22.53	14.71	26.47
02/025	0.615	34.04	18.89	42	16.72	37	19.01	18.05	23.11	18.73	23.05	17.36	22.36	14.59	26.25
99/003	0.540	32.15	16.80	38	15.64	35	17.31	17.54	22.46	18.14	22.46	16.78	21.78	14.18	25.52
99/001	0.529	30.30	19.06	43	15.08	34	16.64	17.03	21.81	17.55	21.87	16.20	21.20	13.76	24.77
02/024	0.641	29.00	18.94	42	15.60	35	17.92	16.66	21.34	17.12	21.44	15.78	20.78	13.46	24.23
02/012	0.701	28.15	17.19	38	15.71	35	18.46	16.41	21.02	16.83	21.15	15.49	20.49	13.26	23.88
03/004	0.590	27.91	19.46	44	14.96	33	16.86	16.34	20.93	16.75	21.07	15.41	20.41	13.21	23.77
00/005	0.656	27.50	16.79	38	15.28	34	17.65	16.22	20.78	16.61	20.93	15.28	20.28	13.11	23.60
01/009	0.586	27.20	15.98	36	14.74	33	16.59	16.13	20.66	16.51	20.83	15.18	20.18	13.04	23.47
02/006	0.551	26.50	15.14	34	14.29	32	15.88	15.93	20.39	16.27	20.59	14.94	19.94	12.87	23.17
02/029	0.682	25.70	15.48	35	14.92	33	17.40	15.68	20.08	15.99	20.31	14.66	19.66	12.67	22.81
01/018	0.600	25.10	16.95	38	14.26	32	16.13	15.50	19.85	15.78	20.10	14.45	19.45	12.52	22.54
02/027	0.702	24.45	17.34	39	14.65	33	17.21	15.30	19.59	15.54	19.86	14.22	19.22	12.36	22.25
99/006	0.600	23.41	17.79	40	13.77	31	15.57	14.97	19.17	15.16	19.48	13.85	18.85	12.10	21.77
01/031	0.663	23.16	17.26	39	14.06	31	16.28	14.89	19.07	15.07	19.39	13.76	18.76	12.03	21.66
01/035	0.765	23.00	18.98	42	14.46	32	17.43	14.84	19.00	15.01	19.33	13.70	18.70	11.99	21.58
95/004	0.700	22.90	14.11	32	14.16	32	16.64	14.80	18.96	14.97	19.29	13.66	18.66	11.96	21.53
99/004	0.508	22.05	13.01	29	12.70	28	13.91	14.53	18.60	14.65	18.97	13.34	18.34	11.74	21.13
02/008	0.776	21.00	18.54	41	13.85	31	16.77	14.18	18.16	14.25	18.57	12.94	17.94	11.46	20.62
02/017	0.618	20.77	15.87	36	13.08	29	14.89	14.10	18.06	14.16	18.48	12.86	17.86	11.39	20.51
00/002	0.761	20.75	14.01	31	13.72	31	16.51	14.09	18.05	14.15	18.47	12.85	17.85	11.39	20.50
02/028	0.595	19.96	14.39	32	12.69	28	14.32	13.82	17.70	13.83	18.15	12.54	17.54	11.17	20.10
02/019	0.630	19.70	17.63	39	12.80	29	14.64	13.73	17.58	13.73	18.05	12.44	17.44	11.10	19.97
02/013	0.670	19.70	14.11	32	13.00	29	15.10	13.73	17.58	13.73	18.05	12.44	17.44	11.10	19.97
02/014	0.634	18.39	10.58	24	12.39	28	14.19	13.27	16.99	13.19	17.51	11.91	16.91	10.72	19.30
01/025	0.541	17.58	12.83	29	11.57	26	12.82	12.97	16.61	12.85	17.17	11.57	16.57	10.48	18.87
99/005	0.626	17.00	13.35	30	11.87	27	13.56	12.76	16.33	12.60	16.92	11.32	16.32	10.31	18.55
00/004	0.513	16.50	10.99	25	11.02	25	12.09	12.57	16.09	12.38	16.70	11.11	16.11	10.16	18.28
01/017	0.560	16.00	20.41	46	11.16	25	12.44	12.37	15.85	12.16	16.48	10.89	15.89	10.00	18.00
01/032	0.676	15.51	13.74	31	11.56	26	13.45	12.18	15.60	11.94	16.26	10.67	15.67	9.85	17.72
02/004	0.783	15.00	12.27	27	11.73	26	14.24	11.98	15.34	11.71	16.03	10.44	15.44	9.68	17.43
01/001	0.777	14.75	9.60	21	11.61	26	14.07	11.88	15.22	11.59	15.91	10.33	15.33	9.60	17.28
02/020	0.615	14.60	13.70	31	10.95	24	12.45	11.82	15.14	11.52	15.84	10.26	15.26	9.55	17.19
02/001	0.574	13.65	9.80	22	10.38	23	11.63	11.43	14.64	11.07	15.39	9.81	14.81	9.24	16.63
01/016	0.690	12.90	13.41	30	10.60	24	12.40	11.11	14.23	10.70	15.02	9.45	14.45	8.98	16.16
01/016	0.690	12.90	13.41	30	10.60	24	12.40	11.11	14.23	10.70	15.02	9.45	14.45	8.98	16.16
01/034	0.630	12.00	10.31	23	9.99	22	11.42	10.72	13.72	10.24	14.56	9.00	14.00	8.66	15.59
01/019	0.711	11.39	13.44	30	10.02	22	11.82	10.44	13.37	9.92	14.24	8.68	13.68	8.44	15.19

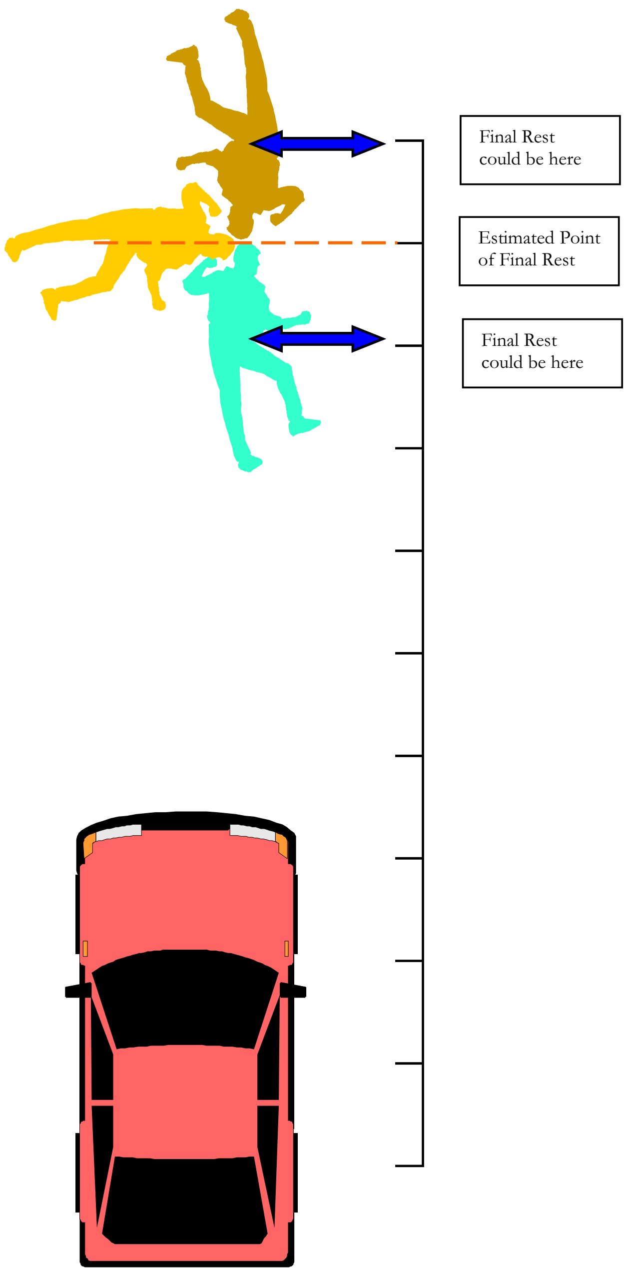
Appendix D2

Real World Data - Wrap Trajectories (Contd.)

Job ID	Skid Test Mu	Total Throw Disp (m)	Impact Speed (ms^{-1})	mph	Field min (ms^{-1})	mph	Field max (ms^{-1})	Searle Hill Vmin (ms^{-1})	Searle Hill Vmax (ms^{-1})	Evans Smith Min (ms^{-1})	Evans Smith Max (ms^{-1})	Happer Model Wrap Min (ms^{-1})	Happer Model Wrap Max (ms^{-1})	Wood 2000 Min (ms^{-1})	Wood 2000 Max (ms^{-1})
01/005	0.700	10.98	11.42	26	9.81	22	11.52	10.25	13.13	9.70	14.02	8.47	13.47	8.28	14.91
95/001	0.700	10.88	9.54	21	9.76	22	11.47	10.20	13.07	9.65	13.97	8.41	13.41	8.25	14.84
01/027	0.566	10.31	10.11	23	8.98	20	10.04	9.93	12.72	9.34	13.66	8.11	13.11	8.03	14.45
01/014	0.726	9.90	9.91	22	9.39	21	11.14	9.73	12.47	9.10	13.42	7.88	12.88	7.87	14.16
01/015	0.617	9.45	9.01	20	8.82	20	10.03	9.51	12.18	8.85	13.17	7.62	12.62	7.69	13.83
01/026	0.607	8.85	7.82	17	8.49	19	9.63	9.20	11.79	8.49	12.81	7.27	12.27	7.44	13.39
02/021	0.604	8.80	6.44	14	8.46	19	9.58	9.18	11.75	8.46	12.78	7.24	12.24	7.42	13.35
01/008	0.652	7.70	8.16	18	8.08	18	9.31	8.58	10.99	7.77	12.09	6.57	11.57	6.94	12.49
02/030	0.770	7.50	9.72	22	8.27	18	9.99	8.47	10.85	7.64	11.96	6.44	11.44	6.85	12.32
02/007	0.604	7.20	6.97	16	7.65	17	8.67	8.30	10.63	7.45	11.77	6.24	11.24	6.71	12.07
03/003	0.750	6.85	14.15	32	7.86	18	9.42	8.10	10.37	7.21	11.53	6.01	11.01	6.54	11.78
01/021	0.694	6.51	10.25	23	7.54	17	8.83	7.89	10.11	6.97	11.29	5.78	10.78	6.38	11.48
01/028	0.725	6.50	9.62	22	7.60	17	9.02	7.89	10.10	6.97	11.29	5.77	10.77	6.37	11.47
03/005	0.700	6.00	6.52	15	7.25	16	8.52	7.58	9.70	6.61	10.93	5.42	10.42	6.12	11.02

Appendix D3

Pedestrian Orientation Post Impact



Appendix D4

Real World Data – Forward Projection Impacts

Job ID	Skid Test Mu	Total Throw Disp (m)	Impact Speed (ms^{-1})	mph	Ped Height (m)	CoM (m)	Flight (m)	Upper Limit (ms^{-1})	Topple Dist (m)	Loss at Impact (ms^{-1})	Slide (m)	Estimate (ms^{-1})	mph	diff
00/003*	0.700	61.01	27.77	62	Est	1.00	0.00	28.21	0.00	0.00	61.01	27.15	61	1
01/007*	0.599	55.60	25.19	56	1.68	1.01	0.00	24.92	0.00	0.00	55.60	23.98	54	2
02/026	0.581	34.04	21.27	48	Est	0.70		19.20	7.25	1.89	26.79	16.50	37	11
02/018	0.540	30.70	21.01	47	1.52	0.91		17.58	7.27	1.93	23.43	14.91	33	14
02/005	0.670	29.20	20.64	46	Est	1.00		19.10	8.62	2.61	20.58	15.65	35	11
02/023	0.708	21.76	14.72	33	Est	1.00	1.90	16.95	7.65	2.76	14.11	13.42	30	3
02/003	0.646	20.85	11.91	27	1.78	1.07		15.84	7.07	2.49	13.78	12.64	28	-1
02/009	0.547	20.50	14.83	33	Est	1.00		14.46	6.53	2.13	13.97	11.68	26	7
02/031	0.682	16.80	14.45	32	Est	1.00		14.61	6.60	2.66	10.20	11.28	25	7
02/011	0.658	13.50	15.66	35	1.63	0.98		12.87	5.49	2.43	8.01	9.84	22	13
00/006	0.673	12.60	11.49	26	Est	1.00		12.57	5.68	2.62	6.92	9.35	21	5
01/012	0.551	11.50	11.59	26	Est	1.00		10.87	4.91	2.15	6.59	8.21	18	8
01/011	0.676	9.00	8.97	20	Est	0.50	9.00	10.65	3.40	1.86	5.60	8.30	19	1
02/015	0.682	8.00	7.13	16	1.63	0.98		10.08	4.31	2.51	3.69	7.06	16	0
98/001	0.677	3.85	6.45	14	Est	1.00		6.97	3.15	2.64	0.70	3.90	9	5
Eubanks 183-3	0.520	18.84	13.63	30	1.75	1.07	9.75	13.51	6.31	2.10	12.53	10.81	24	6
Eubanks 182-2	0.570	5.79	6.08	14	1.75	1.07	4.51	7.84	3.66	2.30	2.13	5.12	11	3
Eubanks 175-4	0.720	11.89	10.37	23	1.14	0.64	7.07	12.63	4.56	2.25	7.32	9.80	22	1
Eubanks 139-3	0.810	10.74	10.15	23	1.75	1.07	6.50	12.74	5.95	3.27	4.80	8.82	20	3

* Denotes body on ground for entire displacement

Appendix E

Estimation of Vehicle Speed from Damage

(From Happer[38] 2000)

Table 5.1		**Forward Projection Impacts**
Approximate Vehicle Impact Speed	KPH	General Damage Summary
Less than 12 mph	<20	Surface Cleaning Marks
Around 22 mph	35	Leading edge of bonnet dented. Deformation to front of vehicle
Around 37 mph	60	Denting to centre of bonnet

Table 5.2		**Wrap Impacts**
Approximate Vehicle Impact Speed	KPH	General Damage Summary
Less than 12 mph	<20	Surface Cleaning Marks
Around 16 mph	25	Head contact near bottom edge of windshield when pedestrian C.G. ~60 cm above low-fronted vehicle's bumper assembly; otherwise, head contact near middle of bonnet for average-sized vehicle and pedestrian. Body contact on roof when pedestrian C.G. ~85 cm above low-fronted vehicle's bumper assembly.
Around 16 - 25 mph	25 - 40	Head contact near trailing portion of bonnet; slight body panel deformation
Around 25 mph	40	Head contact near bottom edge of windshield for impacts significantly below (~50 cm) pedestrian's C.G. (i.e. typical braking low-fronted vehicle).
Around 25 - 31 mph	40 - 50	Clearly defined dents on body panels
Around 31 mph	50	Head contact near bottom edge of windshield when pedestrian C.G. ~40 cm above low-fronted vehicle's bumper assembly. Body contact on roof when pedestrian C.G. ~60 cm above low-fronted vehicle's bumper assembly.
Around 31 – 34 mph	50 - 55	Head contact near middle of windshield for typical braking low-fronted vehicle.
Around 37 mph	60	Head contact near bottom edge of windshield when vehicle's upper leading edge near pedestrian's C.G.
Greater than 37 mph	>60	More probable body to roof contact.
Around 43 mph	70	Head contact near upper frame of windshield; significant deformation of body panels.
Around 50 mph	80	Pelvic contact with roof; roof deformation (unbraked vehicle).

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Can ‘Pedestrian Throw’ Calculations be Carried Out ?

Aide Memoir

Impact Point ✓	Impact Point ✓	Impact Point ✗
Landing Point ✓	Landing Point ✗	Landing Point ✓
Slide/Final Rest ✓	Final Rest ✓	Slide/Final Rest ✓
Use	Use	Use
Searle & Searle (Modified vehicle Mu)	Field (Modified vehicle Mu)	Hague (Modified vehicle Mu)