Forensic collision investigation: finding the order within the chaos

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Forensic Collision Investigation

Finding the Order within the Chaos

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Abstract

This narrative explores three key areas, *Professionalising the Collision Investigation Community, The Wider Demographic* and *The Expert Witness*. It covers a 15-year career of the work of a Forensic Collision Investigator responsible for the investigation of road traffic collisions resulting in catastrophic injuries or fatalities.

Included in the thesis is the development of a series of scientific techniques that have been adopted around the globe. Works within the professional body are also discussed, including the introduction and development of a number of professional elements, such as the introduction of the Certificate of Professional Competence (an assessment of Practitioner's fitness to practice), the Code of Ethics, Equality and Diversity, training programmes and the production of a Best Practice guidance document and development of the Disciplinary Codes.

Also presented are works including the education of the wider demographic, from members of the public to legal professionals by various means, such as authoring a brand-new chapter in the subject in a long-standing forensic textbook for the Royal Society of Chemistry, to producing webinar series for LexisNexis.

Finally, the work as an Expert Witness, not only in the UK but internationally, is described and the act of giving expert evidence and its significance are all combined in this thesis for the Doctorate by Public Works.

Glossary of Terms

Abbreviation	Full Term
CrimPR	Criminal Procedure Rules
CPR	Civil Procedure Rules
CSoFS	The Chartered Society of Forensic Sciences
ESC	Electronic Stability Control
FCIN	Forensic Collision Investigation Network
FSS	Forensic Science Service
FCI/FCIU	Forensic Collision Investigator/Forensic Collision Investigation Unit
FVA	Forensic Video Analysis
ITAI	The Institute of Traffic Accident Investigators
ISO	International Standard Office
PACTS	Parliamentary Advisory Council on Transport Safety
UKAS	United Kingdom Accreditation Service

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I want to thank my wife, and 3 beautiful children for all of the love and encouragement they give me, every day, in support of my work and furthermore their patience with me as I have been writing this synopsis of my work. The area in which I work means that I am routinely exposed to things that are extremely distressing, and it should not be understated the level to which you have and will no-doubt continue to support me.

A special thanks must also be extended to Steve Cash who has worked alongside me in this field for over 10 years and has co-authored a number of texts that are relied upon within this thesis.

Thank you also to my academic supervisors for this programme, Dr Alan Page and Dr Ruth Plume who have jointly provided their boundless guidance when working through this thesis.

Dedication

I wish to dedicate this thesis to my Father, who despite only having 11 short years to impart his passion for science and knowledge, managed to convey the fundamental skills required to figure out ‘how things work’. It is, without question, these skills that have formed the bedrock of my attitude towards the development of analytical techniques contained within the works discussed.

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1 Collision Investigation – Introduction to the Community

1.1 The Field

There was an estimated 1,558 people are killed in 2021 on the roads in the UK (Gov.uk, 2022) with over 25,000 more seriously injured, and there are approximately 550 homicides in the UK (Office of National Statistics, March 2021) a year – therefore there are in the order of triple the number of those killed on the road each year than those murdered.

As with the scene of all incidents, when the scene has been contaminated, there is little opportunity for 'going back'. That is why the Road Death Investigation Manual states:

> *"All fatal collisions should be investigated as 'unlawful killings' until the contrary is proved." (Association of Chief Police Officers and National Police Improvement Agency, 2007)*

Therefore, collision scenes where there has been a fatality are treated in the same way a murder scene would be, until evidence to the contrary is received and processed. The forensic resource and efforts involved in considering the events of a car crash cannot be understated. This is a scientific discipline, and it is important that such matters are dealt with using up-to-date knowledge and, like any scientific discipline, where advancements are made.

In its purest sense, Collision Investigation is the science of a car crash. Collision is defined as:

> *"The action of colliding or forcibly striking or dashing together; violent encounter of a moving body with another; in recent use esp. of railway trains, ships, motor vehicles, aircraft, etc. In Physics, spec. of particles." (Oxford University Press, 2022)*

And Investigation is defined as:

> *"The action or process of investigating a person or thing (in various senses of the verb); examination; inquiry; research; spec. scientific examination, academic research; formal inquiry into a crime, allegation, someone's conduct, etc." (Oxford University Press, 2022)*

The term Forensic is defined as:

> *"Of, relating to, or associated with proceedings in a court of law; suitable for or appropriate to pleading in court. Now chiefly in legal use." (Oxford University Press, 2022)*

The definitions are included deliberately, as they assist in understanding not only the content but the structure of this thesis. This thesis is divided into two areas. Firstly the 'collision investigation' aspect, where an in-depth discussion of how my research and works with professional organisations has impacted on my peers and the way that my professional works have allowed for questions to be answered in collisions where previously they would have gone unanswered.

Secondly the 'forensic' element of this thesis details how the scientific works are then taken in the public sphere, specifically my role as a leading Expert to the Courts.

I specialise in the forensic analysis of road traffic collisions, i.e., matters involving cars, motorcycles, pedestrians etc. whilst there are many road traffic collisions each year, not every crash requires an in-depth investigation. Whilst many collisions will involve some 'low level' assessment (loss adjusters for example), my work as a forensic specialist is almost exclusively reserved for the end of the market where someone has died or is catastrophically injured. It therefore follows that, the nature of my work has very serious consequences, with potentially the rest of somebody's life at stake when charged with Causing Death by Dangerous Driving (The Sentencing Council, 2022) and in the civil matters I am instructed to investigate, tens of millions of pounds in compensation – there are no half measures, and the necessity to get it right each and every time is paramount. One thing that is guaranteed at this end of the discipline, the

scientific findings and opinions will come under utmost scrutiny often culminating with many hours spent under cross examination at Court.

There has previously been a disconnect with the language used when reporting incidents of this type, for example when someone dies on the road it is often deemed an ‘accident’ even though vehicle inputs are controlled (for now at least) by humans. It is only recently that the Department for Transport (Gov.uk, 2022), (after many years of pressure from road victim charities such as *RoadPeace* and *Brake*) has changed the terminology in all of their reports, diagrams and other publications from “accident” to “collision”.

The reason for this change is due to the fact that road deaths are nearly always caused by a driver action (or inaction). Accident implies that no-one is to blame, but in my career to date, having investigated many hundreds of collisions, I am yet to find one that was an ‘accident’, and no-one was to blame.

Early on in my career I was provided with this quote, believed to originate from the FBI, although no-one is entirely sure of the origin.

> *“No greater honour will ever be bestowed on an Officer, or a more profound duty imposed on him, than when he is entrusted with the investigation of the death of a human being. It is his duty to find the facts, regardless of colour or creed, without prejudice, and to let no power on earth deter him from presenting these facts to the court without regard to personality.”*

For me this is absolutely true and core to my underlying principles. It is an honour to investigate how someone met their death, but it is an honour that comes with great responsibility. I would of course add one additional element, that it is not only the dead that we owe this scientific rigour to, but also those who are dependent on financial settlements/judgements that dictate the quality of the future that they are likely to have post-incident.

It would of course be tempting to therefore consider that I would need to try and 'do best' by someone requiring these funds, but this is quite the opposite of the rules that govern the nature of experts within the UK judicial system. Experts must be impartial and have a duty to the Court, as laid out clearly in the Civil Procedure Rules (with a virtually identical wording the Criminal variation of the rules).

> *"It is the duty of experts to help the court on matters within their expertise. This duty overrides any obligation to the person from whom experts have received instructions or by whom they are paid." (www.gov.uk, 2017)*

Being an expert, in my view, has two meanings that ultimately result in the same position. The first is that laid out in the Criminal Procedure Rule (CrimPR) where an expert is defined as:

> *"... a person who is required to give or prepare expert evidence for the purpose of criminal proceedings, including evidence required to determine fitness to plead or for the purpose of sentencing" (Ministry Of Justice, 2020)*.

I also think there is a layman interpretation here also, meaning that someone who is suitability trained and experienced to be opining on a subject (and ultimately, if a Judge had to make a ruling on the admissibility of a person as an expert this is one of the tests that would be applied). Therefore, reaching the standard of and being accepted as an expert by the Courts is something that cannot be understated. You are there to assist the Judge or Jury to understand matters outside of their understanding and assist them with their important task of weighing the facts of the case against the law.

To be allowed to give such evidence is a privilege, which is restricted to all but a few members of society and something that highlights the level of knowledge and understanding gained over the years that has been tested and found to be correct and of value to the judicial system time and time again.

1.2 A brief timeline

In early 2008, having graduated a few months earlier with a Master's Degree in Applied Physics, I started my career with the Metropolitan Police in London, where they were engaged on a 'workforce modernisation' project, directed by the Labour government at the time, whereby those Police functions that did not directly require a power of arrest should be attempted to be civilianised. I was one of the 10 members of this pilot scheme, a role that I performed within the Police for 8 years, and although not a research post I embarked on a number of development projects, which still continue to this day, some of which are discussed within this thesis. In 2016 I left the Policing role to work with the London Ambulance Service as their Head of Driving Standards, whilst at the same time setting up an independent forensic collision investigation company.

It is perhaps important at this stage to highlight why, despite the opportunity to work for other forensic companies, I took the bold step to set up a company from scratch. This was mainly due to the fact that I felt that so much more could be achieved in the industry, more development, more enhancement with respect to the evidence that could be presented to a Court, that I felt it had to come from a completely clean slate, without the restrictions of being told *"you can't do it that way"* or even worse *"that is the way that we do things here"*. I was interested in making a change, one that got the best results out of the evidence available, rather than simply settling for the way things have always been done before.

Therefore, for the past 8 years, I have been working as a private consultant, and running a team of Forensic Collision Investigators. Nearly all of our work relates to Civil Catastrophic Loss matters. It is worth explaining the differences between Criminal and Civil Courts, as this will explain why some of my more recent works have come about.

In Criminal Court, the decisions of guilty or not guilty are made by lay or professional magistrates or by a Jury and the standard of proof is so that *"they are sure"* (formally *"beyond all reasonable doubt"*) that the Defendant committed the offence or offences with which they have been charged. Civil Courts are different in that it is the Judge makes the findings of fact on *"the balance of probabilities."* It may, on face value,

therefore, be considered that Civil work is in some way easier, as the standard to which a point needs to be proved is simply to what is more likely – however, in my experience, this would be an erroneous assumption. This is because the outcome of a Civil trial is not a 'black and white', *"Guilty"* or *"Not Guilty"* verdict, a Civil matter concludes (at trial) with a Judge deciding the portion of blame (known as liability). This percentage split of blame directly translates to the outcome, for example if a claim were to be, say £10m, then every 1% of blame has a 'value' of £100k – for every 1% that a Claimant contributed to their situation, their claim is reduced by one hundred thousand pounds. So, in my experience, the level of detail required, the quality of analysis applied to catastrophic injury road traffic collision claims, and the standards required of an expert are much, much higher. Experts are pressed much harder, their evidence scrutinised in far more detail and the basis for their findings put under the microscope. An attitude of 'that will do,' or 'there is nothing we can do with that evidence' will not be acceptable in the Civil forum. It is challenging the concept of 'there is nothing we can do' that has formed the basis of my Professional Works that run through this thesis.

1.3 The Chaos and the Order

The events of a car crash happen in seconds, indeed that the deformation phase (the time between the vehicles first making contact, crushing to their fullest extent, and then starting to move away from one another) takes in the order of 80*ms* to 200*ms* (Ydenius, 2002) (with the precise crash pulse varying according to deformation and magnitude of collision forces). The scene of a serious and/or fatal collision is often complex with vehicle debris and ephemeral marks spread over tens if not hundreds of meters. There is debris, fluid, and wreckage thrown across large distances. There is somebody dead, or very seriously injured, and the answer to the question about how this all occurred is there, somewhere, within that scene. I, and my colleagues have to find it. It is often the smallest fragment, the tiniest fragment of glass or the smallest of scratch marks on the road surface that solve the problem.

The problem itself is an interesting one. There are a series of pieces of evidence, pieces of a jigsaw puzzle if you will. They only fit together one way and that one way provides the solution to how the collision occurred. Now, you may not have all of the

pieces, there may be some missing, you may have not found them all, but you still need to put those pieces together carefully to understand what the picture looks like.

The industry itself, has historically been divided, by those working in the Criminal or Civil sectors, or by those with a Policing background and those without, but this again requires an alignment, after all, we are working with the same evidence, under the same duty to get at the facts. I will demonstrate within this thesis, when discussing my works with professional bodies, that I have taken steps to join these two elements together.

Making 'the switch' myself from Police to private work, and moving from an academic starting point, through many real-world crash scenes to a position in private practice with both of these skill sets has, and continues to be, a journey that is complex but gives me a unique opportunity to work with peers from all backgrounds and practice forums to advance the industry and better serve the courts and the scientific communities within which I work.

That is why, my journey to this point, from the industry as a whole to each and every case I have been involved in has been all about finding the order that exists within the chaos!

1.4 The Profession and The Professional

Within this thesis there is, as expected, significant discussion of the industry, or 'the profession' and those working within it 'the professionals' and how, through the body of works in which I rely, outlined in *Chapter 2 - Works Relied Upon* have been able to increase the standard and standing of both.

It is recognised that there are two routes be being an expert (not mutually exclusive), whereby an expert can be considered as such by virtue of their qualifications and or experience. The Crown Prosecution Service detail in their guidance:

> *"The individual claiming expertise must have acquired by study or experience sufficient knowledge of the relevant field to render their opinion of value." (Crown Prosecution Service, 2022)*

It is perhaps the phraseology of having 'acquired by experience sufficient knowledge', that is critical in understanding the level to which Collision Investigators now work. Specifically, how their practical knowledge can be 'mapped' to an equivalent academic level. Turning attentions to the descriptors for academic achievement at Level 6 (Degree), is outlined below:

> *"Bachelor's degrees with honours are awarded to students who have demonstrated: a systematic understanding of key aspects of their field of study, including acquisition of coherent and detailed knowledge, at least some of which is at, or informed by, the forefront of defined aspects of a discipline…an ability to deploy accurately established techniques of analysis and enquiry within a discipline…*
>
> *Conceptual understanding that enables the student to devise and sustain arguments, and/or to solve problems, using ideas and techniques, some of which are at the forefront of a discipline and to describe and comment upon particular aspects of current research, or equivalent advanced scholarship, in the discipline an appreciation of the uncertainty, ambiguity and limits of knowledge and the ability to manage their own learning, and to make use of scholarly reviews and primary sources (for example, refereed research articles and/or original materials appropriate to the discipline).*
>
> *Typically, holders of the qualification will be able to: apply the methods and techniques that they have learned to review, consolidate, extend and apply their knowledge and understanding, and to initiate and carry out projects, critically evaluate arguments, assumptions, abstract concepts and data (that may be incomplete), to make judgements, and to frame appropriate questions to achieve a solution - or identify a range of solutions - to a*

problem communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.

And holders will have: the qualities and transferable skills necessary for employment requiring the exercise of initiative and personal responsibility, decision-making in complex and unpredictable contexts and the learning ability needed to undertake appropriate further training of a professional or equivalent nature.

Holders of a bachelor's degree with honours will have developed an understanding of a complex body of knowledge, some of it at the current boundaries of an academic discipline. Through this, the holder will have developed analytical techniques and problem-solving skills that can be applied in many types of employment. The holder of such a qualification will be able to evaluate evidence, arguments and assumptions, to reach sound judgements and to communicate them effectively. Holders of a bachelor's degree with honours should have the qualities needed for employment in situations requiring the exercise of personal responsibility, and decision-making in complex and unpredictable circumstances." (Quality Assurance Agency for Higher Education, 2014):

This resonates greatly with the work of the Collision Investigator, the analytical work particularly 'an ability to deploy accurately established techniques of analysis and enquiry within a discipline'. Indeed the key outcome of being able to 'apply the methods and techniques to review, consolidate, and apply their knowledge to carry out projects, critically evaluate arguments, assumptions, and data (that may be incomplete), to make judgements, and to frame appropriate questions to achieve a solution - or identify a range of solutions - to a problem communicate information, ideas, problems and solutions to both specialist and non-specialist audiences' is the very essence of a Collision Investigators work. From the evidence capture at the scene, the analysis, and the communication of the complex findings. These key attributes are at the very heart of this thesis, and it will be seen throughout this thesis that nearly all of the works relied upon centre upon one (or more) of those elements.

However, it is important to recognise at this juncture that there is a difference between academic ability (where the term 'ability' has been deliberately chosen over the term 'qualification') and being a professional and/or member of a profession. So, before I can lay out in full how my works have demonstrably changed the industry, a discussion of both the profession and the professionals contained with it need to be briefly explored.

But again, what exactly is meant by The Profession? The term Profession is defined as:

> *"An occupation in which a professed knowledge of some subject, field, or science is applied; a vocation or career, especially one that involves prolonged training and a formal qualification..." (Oxford University Press, 2022)*

With the dictionary definition continuing of:

> *"any occupation by which a person regularly earns a living."*

Bridget O'Driscoll is generally accepted as being the first recorded road traffic fatality in the UK, having died on the 17th August 1896, having been killed by a motor vehicle in the grounds of Crystal Palace park in London. However, it was only about 100 years later that specialised dedicated groups of individuals (mainly Police Officers) were tasked with the formal investigation of road traffic matters. The precise date of such specialist taskings are not known in the industry, but it is anecdotally accepted as being in 1988.

Of course, Collision Investigators at the early stages were being paid, and were applying science as part of their vocation, so it would appear to fit the dictionary definition of a profession. However, the Collision Investigators were predominantly Police Officers, who amongst other ordinary policing duties also attended and investigated collisions. Therefore, in many respects their profession was being a Police Officer, rather than a Collision Investigator.

A key pre-requisite of being a professional is outlined, (Belfall, 2019), requires there being a defined entry point to the profession and some form of assessment of competency prior to undertaking any casework. By contrast, a Collision Investigator has historically often been 'born' as a result of being a Police Officer deployed to the scene, and no assessment of competency prior to undertaking the casework, which would mean that in the early 1990's it would appear that the discipline of collision investigation was not in keeping with that model of a professional.

Furthermore, there was no professional body, or combined, common accepted knowledge base. In 1990 The Institute of Traffic Accident Investigators (discussed in more detail in *Section 3.9 - The Institute of Traffic Accident Investigators*) was formed. At this stage, it was an organisation formed primarily to begin to share ideas, knowledge and best practice. It was simply at that time, a collection of like-minded individuals, that felt that there was a need to form a forum where matters relating to the science could be discussed. This was the early stages of introducing a common knowledge base, including steps and processes practitioners could follow in order to investigate certain types of collision, or certainly this would appear to be the intention of those practitioners at the time. I am of the view that these practitioners were attempting to formalise some of the tests and findings that a Forensic Collision Investigator would be looking to employ when investigating a crash. This would appear to almost perfectly fit the description of 'knowledge' outlined:

> *"*[A] *set of organized statements of facts or ideas presenting a reasoned judgment or an experimental result" (Bell, 1973)*

Indeed, the first ever journal of the Institute of Traffic Accident Investigators, to share this practice, engagingly named 'Impact' was published in the summer of 1990. At a superficial glance, this could be considered the beginnings of the profession, or at least a professional body within the UK. Indeed, in *Volume 1, Number 1* (as the naming convention was then), the newly appointed, first Chairman of the Institute wrote:

> *"…One of the main purposes of the Institute is COMMUNICATION, and unless that purpose is actively pursued by each and everyone of the*

> *membership, the organisation will be the poorer to a measurable degree…It is my belief that the organisation which you have helped to create will find itself in a position of considerable influence in many areas relating to Accident Investigation…the Institute of Traffic Accident Investigators should at all times strive for credibility through honesty and integrity. I believe that this can best be achieved by providing a means for COMMUNICATION, EDUCATION, REPRESENTATION and REGULATION. May the pages of Impact, with your help, prove to be a tangible step in that direction." (The Institute of Traffic Accident Investigators, 1990)*

These comments were further echoed by the editor, David Scott (the Assistant Chief Constable of Sussex Police and member of the Association of Chief Police Officers Traffic Committee) who in the same publication stated:

> *"I welcome the establishment on continued of such an organisation because I believe it will enhance the competence and credibility of accident investigators still further. This inaugural edition of your Journal is another positive indication of your commendable thirst for knowledge and professionalism. May you all benefit from the Institute and the Journal so that the vital cause to which you are committed will be even better served. I am confident that will be the outcome."*

At this early stage, this pooling of knowledge was almost exclusively what would be described by commentators as experience, or practice-based learning (Costley, et al., 2009), being more organic than anything formalised or structured (Eraut, 2004).

For a lay perspective, in the early 1990s is unlikely to be what would conjure up ideas of a profession charged with the investigation of someone's death. This certainly falls behind a number of professions whereby a recognised qualification is required (often by law) prior to an individual being allowed to practice (Robertson, 2010).

At best, it could be considered more of 'occupational professionalism' whereby the provision was based on practitioner autonomy, allowing the individual to exercise

discretionary judgement based on vocational relationships whereby there was a trust relationship between the practitioner and the 'client' – the Court (Brough, et al., 2016).

This is of course not a criticism, but a reminder that only some 30 years ago, Collision Investigation was unlikely to have been regarded as a profession. A profession needs to contain systematic theory, authority, community sanctions ethical codes and a culture (Greenwood, 1957). Indeed, it will be documented later that my works within The Institute of Traffic Accident Investigators have specifically centred around the authority, community sanction and ethical codes.

The 'modern-day' collision investigator is required to draw on knowledge and experience from a number of different areas. As will become apparent through this thesis, the 'traditional' requirements of a collision investigator (i.e., that of being a knowledgeable Police traffic officer) is no longer all that is required of a collision investigator.

Historically, the basis of the investigation of collisions was exclusively restricted to physics/engineering and the law, essentially a mono-discipline. It may seem, at first glance that physics *and* engineering discussed as a 'mono-discipline' is odd, but in my view, it is the area of commonality between the two subjects in which collision investigation falls – the overlapping areas of a Venn diagram if you will. However, investigating collisions in recent years is a far more interdisciplinary approach, stepping outside of the area of commonality between physics and engineering discussed earlier, where 'interdisciplinary' is used deliberately (due to the relationship between the multiple mono-disciplines) rather than 'multidiscipline' as there is a very clear link between the constituent parts (Hofkirchner & Schafranek, 2011)

There are existing discussions about the differences between 'multidisciplinary' (where there is a thematic link between disciplines, where they *"co-exist in a context"* (Petts, et al., 2008)), an 'interdisciplinary' approach (where different experts contribute to a single area of enquiry, where each contributor is individually acknowledged (Lyall, et al., 2011)) and a 'transdisciplinary' approach (where the approach is not on a case-by-case basis, but how topics can be studied from multiple viewpoints, leading to an integrated approach (Tress, et al., 2005)). In my view, it is the 'study from multiple

angles' that appears to fit most closely with the role of the modern-day collision investigator.

There are subtle but important differences between these definitions, which means that they should not be used interchangeably (Stock & Burton, 2011). Indeed, the inclusion of 'non-academics' (i.e., the experienced practical collision investigator) would further suggest that the '*trans*disciplinary' term is the correct one to use here (Hinrichs, 2008).

It is this systematic approach, combining knowledge from other specialisms and integrating it with existing knowledge in the field, which forms the 'systematic theory' that is an essential element for a profession.

This approach has only been enhanced by the introduction of the degree programme discussed within this thesis, which moves away from a qualification that was exclusively assessed by an examination paper on the Newtonian Mechanics of a car crash, to a more modular based approach including areas such as 'the driver and the environment' and 'analysis of digital data'. This allows for the specific key elements of a car crash to be understood more fully, but also, and very importantly, gives those collision investigators easier access to academic texts (through the University library) and also by carrying out their own research into pertinent areas of the discipline for those conducting their BSc projects.

Given that there are a number of changes both in the technological developments in vehicles such as autonomous driving (United Nations - Economic Social Council, 2022) and also airbag control module data (The National Highway Traffic Safety Administration, 2008) the skillset of the collision investigator needs to adapt, incorporate the handing of digital data, human factors and highways engineering to name but a few.

In a number of the presentations, I give to new collision investigators and the wider public I often include the phrase *"cars don't crash, people do"*, meaning that it is the driver's actions (or inactions) that often lead to a collision – indeed, it is a driver who is prosecuted for the manner in which they have driven. There is a reasonably recent shift from concentrating simply on 'how' a collision happened (i.e., a driver failed to

give way at a junction) to 'why' a driver behaved in such a way (Bucsuházy, et al., 2020), for example.

However, it is important to differentiate between what is realistically possible for a driver, essentially trying to discern the 'abnormal' behaviours from the 'normal' – or to put it another way, the avoidable from the non-avoidable (Dewar & Olson, 2007) (Muttart, 2023). Therefore, it is critical that the actions of a driver, compared with existing studies and knowledge (National Police Chiefs Council et al, 2021), (The Royal Society of Edinburgh, 2022), are included within an investigation of a collision (much the same as they would be in any other incident or accident (The Health and Safety Executive, 2008)) and also why I have included it as the first Chapter within the Crime Scene to Court publication discussed later.

The 'human factors' element is only likely to become more relevant in the coming years with the introduction of autonomous vehicles. Questions centring around differentiating between what control/input the car did 'itself' against what the driver was doing, are going to become more relevant. Is a driver likely to have the same perception-response time when driving an autonomous vehicle after having period of inaction on a long journey only to be suddenly 'handed back control' of the vehicle and expected to avoid a collision in the same way a driver that had being paying full attention throughout the journey would? These are all questions that are currently outstanding at the moment.

Therefore, it is essential that collision investigation moves from a position of simply using other resources in their analysis (without contributing back), to a position where it actively engages with the furtherance of knowledge in the field, furthering that 'transdisciplinary' approach (Couch, et al., 2012). It follows therefore that forensic collision investigators need to actively engage more with the research community, as we are in a position to significantly contribute to the cutting-edge academic enquiries. Collision Investigation, throughout this thesis, is described as a scientific discipline, but the need for a transdisciplinary approach is needed *"due to the need to study objects of increased complexity without their separation from the environment"* (Mokiy, 2019). This need can arise from both quantitative approaches (in my view, the

historical position of collision investigation) and the qualitative. There is a real need to ensure that this is done from an educational level ensuring there is a systematic approach to this learning (Flogoe & Abersek, 2015), with *"Transdisciplinary coursework and experiences should be distributed throughout curricula, rather than being restricted to elective courses"* (Nicolescu & Ertas, 2013), which is why for example (and discussed in more detail below), the area of human factors in now included in the training provided to collision investigators nationally as part of the CertHE module entitled *"Driver and the Environment"* (De Montfort Univesity, 2020)

Perhaps it is put best by (Morgan, 2017): *"It is important to acknowledge that forensic science is an intersecting discipline that lies at the nexus of practice, science, law and policy"*

Due to a number of the more recent works, I am now of the view that the discipline of forensic collision investigation can now, proudly, be called a profession when measured against any metric, or standard outlined in the studies above. This is further discussed in *Chapter 3 – Professionalising the Collision Investigation Community*.

But it is not simply about the industry having a professional body. There would be little point in a professional body if there were no practitioners. There is of course a link between the profession and the professional, they are dependent on one another (Sullivan, 2000), an industry can hardly be considered a profession if it does not contain professionals. Indeed, the term Professional is defined as:

> *"Of, or belonging to, or proper to a profession… That has or displays the skill, knowledge, experience, standards, or expertise of a professional; competent, efficient." (Oxford University Press, 2022)*

The difference is that when talking about the professional it is more to do with individual people. This is a notable difference that is explored throughout this work. It is my intention to explain how my actions have served to increase professionalism within the industry, by raising the standard of both 'The Profession' (i.e., the 'industry' of collision

investigation) and also the way in which individuals approach the way they conduct individual analyses, i.e., 'The Professionals'.

Together, the combination of the professionals and the profession combine to form part of the broader term of professionalism. Recognised qualifications along with experience, autonomy of function and expertise in the field of Collision Investigation lead to the position where the individual is considered an expert and therefore permitted to be presented to the Court as an expert, assisting the Court in areas outside of their (the Court's) knowledge. i.e., the recognition to be involved in such a critical part of civilisation – the legal process (Mawby & Worrell, 2013).

My endeavours in both introducing professional aspects to some parts of the industry and increasing the professionalism of practitioners in other elements form the basis of Chapter 3 - Professionalising the Collision Investigation Community.

1.5 Communication – The art of presenting a science

> *"Nothing in science has any value to society if it is not communicated." (Roe, 1953)*

As will become apparent throughout this thesis, it is essential that a Collision Investigator is a good communicator. It is primary to their role that they educate the Court – it is a skill that can be learned and developed. It is also perhaps no surprise that in *Section 1.4 - The Profession and The Professional*, the term 'communication' appeared numerous times, from the various sources cited. That is because communication is an essential part of the role of a Collision Investigator, from peers to the lay person in a Court case and everywhere in between. Within this thesis, I have sought to discuss the ways in which I have been able to communicate not only with those engaged in the profession, but also those in a wider demographic. Key examples include teaching others how to be more effective communicators *(Section 5.4 - Giving Evidence Publication*) and also those in other forensic disciplines (*Section 4.2 - Crime Scene to Court – Fifth Edition – Collision Investigation Chapter*), to those in the legal profession (*Section 4.3 - LexisNexis Webinar Series*).

The link between the forensic science and the wider public is beginning to be better understood. The public must have faith in forensic science, the science by which their peers (or even themselves one day) may be held accountable by (The Forensic Science Regulator, 2023). Therefore, it is important to communicate with not only those peers in the field, but also those 'non-experts', in such a way that is useful to the recipient (Newcastle University, 2022). Indeed, it is now becoming more commonly accepted that educating the general public is the responsibility of scientists and the scientific community (Brownell, et al., 2013). For that reason, it is apparent that to make a tangible difference to the industry, it is not simply about communicating well within the industry, but also to the wider public (*Section 4.4 - The wider public – inspiring an interest*).

It would stand to reason, that the wider public would never choose to be in a position where they rely on forensic evidence (as it would mean that they are the subject of a judicial process, either as a suspect or a victim). It therefore follows that most people's understanding of forensic science comes from television fictional works, which has led to a skewing of public expectations of the forensic process, colloquially known as *'The CSI Effect'*. (Chin & Workewych, 2016).

One of the major ways in which this can be combatted is by clearly communicating with the wider public, in a way of 'managing expectations' with respect to the validity, reliability and application of the science. This process of openness and transparency, teaches the public with respect to the science that underpins the discipline (Ibaviosa & Chin, 2022).

Therefore, an expert needs to be able to communicate, and do so effectively, to a wide demographic, from peers to the public. When effectively communicating, a Collision Investigator needs to be accurately aware of their audience. Is it a peer, is it the Court, is it a student of the science? What if the demographic is not that discrete i.e., what exactly is the difference between a 'student' and a jury? You are teaching them both the finer points of the science, so that they can reach the same conclusions as you have! Generally speaking, they are both not free to leave the room you are teaching in, and you only have a short period of time to communicate the message. From the

outset, a Collision Investigator needs to be a teacher that is adaptable to the forum in which they are speaking.

There are a lot of similarities in the way I approach this however, with me as the expert being a 'storyteller' (Cormick, 2019). The term 'storyteller; here requires careful clarification, the fictional connotation of the word needs to be quashed, the science does not lie, and the expert must remain true to the science. Instead, the term 'storyteller' is used to convey the journey the expert must take the audience on. It is important to remember the words below:

> *"If you're scientifically literate the world looks very different to you" (Tyson, 2009)*

Therefore, any journey you take a person on, it is important to remember that the discussions of the facts, must include a relatable reference point for the receiver to 'hook into'. This is true regardless of the target audience, be that the lay person or a peer.

However, there is an important distinction that is drawn out later in this thesis, that there is a difference when I am educating peers in this field. When I am educating my peers, I know that they in turn will go on to educate others (i.e., the Court). In many respects, therefore, this is an exercise in 'teaching the teacher'.

This presents a slightly different prospective – as of course, all of the explanatory steps to be taken as above, but with the slight difference in that training peers is akin to adult learners who are seeking to further themselves. There are a number of theoretical considerations, whereby adults choosing to enter adult education both as a learner and an educator (Karu & Jogi, 2015). It is not the intention of this thesis to place great reliance on the discipline of teaching, as that is not the direct focus of my works, it is however, the backdrop against which my works are located. This multidisciplined audience, lead me to think of the presentation of the scientific forensic evidence as 'The Art of Presenting a Science'.

It is both tempting and erroneous to think that because specialist scientists (in this case Collision Investigators) are experts in their field they are naturally gifted communicators – but that is not a given that talented scientists are excellent communicators of the science (Radford, 2011).

As will be demonstrated throughout this thesis, the analytical work of a Collision Investigator will often culminate in the final stage in the process, a Court appearance, where the Collision Investigator must be able to communicate their findings in a clear way, and also stand up to the scrutiny of having their findings thoroughly and robustly challenged. In a generalised context, it is important for the wider public to understand the basics of any scientific discipline in order to make informed decisions (Brownell, et al., 2013), however this takes on an even more specific meaning in the context of a judicial proceeding, as the entire purpose of a jury is to make that informed decision on the key facts of a case, and ultimately reach a verdict. Therefore, it is imperative that an expert can 'educate' a jury in the science of Collision Investigation.

This is the source of much discussion within this thesis as a whole and also specifically in *Section 5.3 - Expert Witness*, where this 'art' is discussed and also the steps I have taken to improve the standards of the evidence given by those practitioners who find themselves in this privileged position.

2 Works Relied Upon

2.1 Section Format

Presented within this thesis is a discussion of some of the highlights of a 15-year career to date. The works are divided into 3 sections, *Professionalising the Collision Investigation Community*, *The Wider Demographic* and *The Expert Witness*. It is perhaps worthy of note at this stage, that whilst in general terms there is a chronology to the works, this narrative does not follow a strict timeline. For reasons that will become apparent to the reader, there are times when the works are taken 'out of order' to demonstrate the impact on the respective stakeholders.

The first of these chapters deals with the publications and works with professional bodies that have embedded new knowledge into the industry and professionalising those engaged with providing expert evidence to a Court. The second chapter, *The Wider Demographic*, focusses on how additional works have been undertaken to increase knowledge amongst key stakeholders such as Barristers and Solicitors outside of any given investigation – essentially understanding what to expect from a collision investigation expert in any case, gaining a better understanding about how to choose the right expert also. Principally this chapter discussed how my works have impacted on those who have cause to become engaged with collision investigation (either by profession, programme of study or general curiosity), but are not collision investigation specialists themselves.

Finally, *The Expert Witness* which details the importance of my role within the judicial system. There are many people that are considered as experts within their particular field. Only few are in a position to be 'called' as an Expert Witness for judicial processes. Courts, by their very nature, have to make life changing decisions and need my help to make them. I consider this this be a significant public work in its own right, and this section discusses my works in this area including an overview of a select number of the cases I have been involved in.

Also, significantly, this section not only contains my evidence provision, but also a publication that I have produced dealing specifically with raising the standard of expert

evidence. I consider this publication to be unique, as there are a number of documents and training courses (Bond Solon, 2022), (MediLaw, 2022) and (Legal Experience Training, 2022) to name but a few, that are written from the perspective of a barrister/solicitor, but none that I can find that are written from the perspective of an expert. This publication is written from the viewpoint of an expert *delivering* the evidence rather than those *receiving* the evidence.

2.2 Works for Consideration

Dealing first with the works I reference in *Professionalising the Collision Investigation Community* are a combination of published papers and a book dealing with a number of key areas within the field of forensic collision investigation. These focus on key areas of forensic analysis such as CCTV analysis and high-speed loss of control, how these have allowed for more detailed analysis within the field and also how they are now embedded into common practice. I have also included some of my earlier publications, which whilst at the time I did not consider them to make a huge contribution to knowledge, more recently I have found myself called upon to provide expert analysis for international cases. Naturally, these are discussed in more detail within the relevant sections. The works included in this thesis are:

- *Maximum Attainable Braking from a Pedal Cycle* – 'Impact' Summer 2012
- *Calculating Vehicle Speed from Yaw Mark Analysis* – Proceedings of ITAI Conference 2014
- *Quantifying the Uncertainty in Skid to Stop Calculations* – 'Impact' Summer 2014
- *Video Analysis in Collision Reconstruction* – ISBN 978-1788089302
- *Video Analysis in Collision Reconstruction (Second Edition)* – ISBN 978-1800689633
- *Use of the CCTV Frame Interval Timer (Lightboard)* – Proceedings of ITAI Conference 2017
- *Positioning Techniques for CCTV Analysis* – Proceedings of ITAI Conference 2017

Also included in this chapter are my works in the following roles:

- Deputy Chairman for the Institute of Traffic Accident Investigators (ITAI)
- External Examiner for DeMontfort University.

In these roles, my works involve professionalising the industry by being part of the team that introduced the Certificate of Professional Competence for Collision Investigators, Ethics and Professional Standards that members of the community are expected to abide by, along with the formation of the Disciplinary Panel for those within the ITAI's membership that do not comply with the high standards expected of them. Furthermore, the introduction of the webinars from leading industry experts to support the Continuing Professional Development of our membership through the COVID-19 pandemic and beyond.

Beyond this there is a discussion of how ITAI Crash and Research Day's support the membership and, specifically, allow me to demonstrate and teach members to drive a vehicle in such a way as to leave yaw marks. This follows on from my earlier research so that members are no not only able to calculate a vehicle speed, but also assist the Court by being able to state that they have actually experienced what it 'feels like' to drive a vehicle in such a manner.

My works as an External Examiner for De Montfort University, for their programme of study up to BSc level in Forensic Road Collision Investigation within their Technology Faculty are also discussed. In this role, there was significant contribution made to the updating of the programme content in order to deal with the changing expectations of the industry and also the needs of the Student through the COVID-19 period.

The next chapter, *The Wider Demographic*, documents my work to educate the wider demographic. For this I rely on the following:

- *Crime Scene to Court* 5th Edition publication
- LexisNexis Webinar Series
- Media appearances (Netflix documentary, BBC news and Daily Mail article)

Crime Scene to Court is a long-standing book published by the Royal Society of Chemistry, intended to give students studying forensic science a series of 'go to' chapters to for many of the arms of forensic science. Collision Investigation is a new addition to the Fifth Edition, and I have written that chapter.

In addition, I have co-written and presented a series of 6 webinars for LexisNexis intended to provide a resource for those legal professionals wishing to understand some of the key elements of Collision Investigation in bite sized chunks.

Finally, within this section is a discussion of a selection of my works providing information pieces to the wider public. This raises the profile of collision investigation and how it used to analyse a collision. The media works selected are 2 episodes of the *Meet, Marry Murder* series on Netflix, a BBC News interview covering the M25 coach crash and the Daily Mail article relating to the Prince Phillip car crash in 2019.

The penultimate chapter discusses my role as an expert and how I am called upon to assist a Court in determining matters of fact. There are a few elements of this thesis where the reader may find there are a few areas that have limited references – this is deliberate, as I am sure can be appreciated some elements of my work can be freely shared within the public domain, others require a greater degree of care and attention.

In addition, I have included an excerpt of the publication that is designed to assist those engaged in giving expert evidence to do so more effectively. This is a document that I have written covering approximately 19 key areas of giving effective expert testimony from the perspective of the expert. This has been kindly reviewed (and indeed some excellent additions) by a Deputy High Court Judge who has a keen interest in raising the standard of expert evidence.

Finally, I have included a section entitled *The (not so) Final Chapter*, which details works that are currently underway, those planned and also a short reflective piece.

3 Professionalising the Collision Investigation Community

3.1 Introduction

This section is constructed in two parts. The first part details how my published works in pedal cycle braking, error propagation, CCTV analysis and Yaw Mark Analysis have led to changes in understanding within the field of collision investigation. Each subsection details the understanding of the problem prior to my works, the works themselves and finally, where applicable, how my works have led to others furthering research in their specific areas. The second part of this section deals with my involvement with professional bodies and professional roles that have led to a shift in the professionalism of practicing forensic experts. In its purest form, the two parts of this section document how my works have directly impacted on the Forensic Collision Investigator.

Collision Investigation is a scientific forensic discipline, and there are typically two different routes into the industry. By far the most common route is through the Police, whereby an officer may have spent a number of years performing regular Police duties before, being allowed to specialise in road related matters, and becoming a Traffic Police Officer. Whilst there are some slight variations depending on the Police Service in question, across the UK, it means that these officers have been specially selected to work exclusively on matters relating to vehicles be those speeding offences, issues relating to the mechanical condition of vehicles used on the road, and of course perhaps most famously high-speed pursuits. Sadly, it does mean that they attend the scene of many serious and fatal road traffic collisions, securing the scene and having to deliver what is known as ‘the death message’ to loved ones – possibly the worst task a Traffic Police Officer has to perform.

After several years of experience in this role, and with a number of specialist courses under their belt, they can join the Forensic Collision Investigation Unit. This is the unit that is responsible for collecting evidence from the scene of a serious or fatal road traffic collision, conduct testing and compile a report as the events of the collision which they will later present in Court. It takes years of experience to reach even a trainee

position within the unit, and ultimately the Collision Investigator presents the evidence that is seen as critical in any Court hearing.

With the exception of the rarest of occasions, it is the Police that attended the scene of the collisions, and they are the only people to take measurements and secure evidence from the scene itself. As soon as they leave the scene, any evidence not gathered is likely to be lost forever. Any tests that need to be done at the scene have to be done at once.

The second route into this discipline is from the academic route. Those individuals with engineering/physics qualifications are provided with the evidence found by the Police and provide more of a 'desktop' analysis of the evidence. This analysis can range from a very superficial review of the Police findings to an almost granular reconstruction of the events of the collision.

There are two key elements considered prior to being allowed to give evidence at Court (although both are not necessarily required); Experience and Education. It will come as no surprise, given the discussions above, that the Police are typically extraordinarily strong on the 'experience' requirement, having attended hundreds of road traffic collisions, but found are less strong in relation to academic process, finding high-level technical papers inaccessible, either due to the language used, or seeing how they could be practically applied.

Conversely, academics clearly qualify on the education front, with reports heavily reliant on published material, but perhaps are not as conversant with how marks on the road are generated, what they look like and where they are likely to occur. Of course, in two short paragraphs, I haven't given either of these two groups of people full credit and this is merely intended to set out the background of the industry, rather than criticise either group.

In any event, at the scene, the disruption caused by closing a road are significant, with traffic not being able to move freely and limited footfall to businesses. This has a much greater impact than say, closing the corner of a recreational area or a house where a murder has occurred. Therefore, there are time pressures placed on a Collision

Investigator. There are no explicit targets, such as only closing a road for 2 hours, but a road will need to be opened very quickly indeed and therefore tests at the scene must be done quickly, with more lengthy processes being performed within an office environment long after the road has been reopened. Complicated and time-consuming methodologies would not be practical for deployment at the scene of road traffic collisions as they would not be accepted for use in the field, and practitioners would not buy into their use.

Therefore, the thread that runs through the works detailed below in this section follow a simple principle; allowing a more detailed analysis into road traffic collisions, with only minimal additional time spent at the scene of a collision. It has been achieved by taking theoretical 'academic' concepts and shaping them into workable practical tools at the scene of a collision – and the sections below describe how each and every one subscribes to that mentality, and perhaps why they have embedded so deeply into practice.

Feynman (Feynman, 2005), one of my scientific heroes, was once written a letter by a student asking,

> *"How is it possible to reach that high level of preparedness without stifling the creative process that permits the examination of problems in novel ways?"*

Feynman responded

> *"Dear Mr. Stanley, I don't know how to answer your question – I see no contradiction. All you have to do is, from time to time – in spite of everything, just try to examine a problem in a novel way. You won't stifle the creative process if you remember to think from time to time. Don't you have time to think?"*

Just like medicine and other professions, there is often a technical language that is used amongst practitioners (Verema, et al., 2009) – a language that would be

considered ‘technical jargon’ by those not readily involved in the work of collision investigation and/or forensic science. Common terminology is essential to effective communication – not simply to get a point across, but also to make sure there is not any mis-communication. Take for example, the fairly innocuous term *“they were driving on the right side of the road”*. Does that mean the correct side of the road or does that mean on the opposite carriageway? Of course, this is only a high-level example of the need for using jargon such as ‘nearside’ and ‘offside’, but it highlights the need for a specialist language none the less.

Whilst there is a vast amount of commonality that exists in the language used, there is still some variance, which is why the Institute of Traffic Accident Investigators is currently working on a ‘glossary of terms’ – so that all practitioners have consistency in the scientific terms they use, but also as a tool to make collision investigation more accessible to those with an interest (professional or personal) in the industry.

What I find quite interesting is the concept that professional status is not something that you inherit, or something that is automatically bestowed upon you, but instead it is something that is granted by society (Cruess & Cruess, 1997). Therefore, it is incumbent on a forensic expert to meet the obligations that society expects of them. This is of course an important element of the justice system in the UK, to be judged by your peers – and that everyone is equal within the law (The Magna Carta, 1215). It therefore follows quite logically that society should set the standards they expect of their forensic sciences. Society must have faith in their forensic experts, and that is a relationship that is built on trust (House of Lords, 2019).

The trust must be built on the implicit understanding that the expert giving evidence in front of them is competent, a concept routed in the 1920’s educational reforms in America when educational outputs were linked to business/industry needs (John, 1989). Within the works studying international competences in Environmental Health (Konkel, et al., 2008), they defined competence as *“A cluster of related knowledge and attitudes that affect a major part on one’s job (role and responsibility), that can be measured against some accepted standards, and can be improved via training and development*”. They explain this in the context of a staircase, where Competence

is one step below the highest level, Excellence. In order to reach competence, and ultimately strive towards excellence, there are 4 prerequisite steps on the staircase, namely (from bottom to top), knowledge, skills, competencies and capability. This is in itself quite a bare-bones explanatory model which is likely to strike a chord with society and their faith in forensic science, specifically that knowledge is the basis which is then built upon by practice and key skills reaching a level that is deemed by all as being competent.

There is an age old saying (although the exact source is unknown) that "*It's not the job you do, it's how you do the job"*. Normally, such a (slightly flippant) quote would not have a place within a Doctoral Thesis, but I am of the view that it is important here, because if the public lose faith/trust in a forensic expert, because of the way they have perceived the 'job has been done' then the whole of forensic science suffers.

The process of professionalisation must directly mean that there is a process of change, within an industry that 'describes an enhancement of the quality of service' (Hoyle, 2001). Within the collision investigation sphere this can mean the direct 'clients' (the Courts), practitioners (collision investigators) and the wider public (anyone that comes into contact with collision investigation, or the wider forensic science for that matter), experience a better and enhanced quality of service.

Building on the discussion earlier with respect to the Profession and the Professional, it is important to also understand more about professionalism. Within this thesis as a whole, but specifically this chapter, deals with how my works have been critical in the professionalisation of the industry.

There is a distinction between 'organisational professionalism' and 'occupational professionalism' (Evetts, 2009). The former, 'organisational professionalism', is described within the text as having a clear hierarchical structure, with a number of processes and procedures combined with standardised approaches to problem solving. 'Occupational professionalism' on the other hand is more focussed on practitioners having autonomy over their functions, with a 'trust-based' relationship between their clients. There certainly is a trust relationship between an expert and the

Court (Dahlman, et al., 2021), in that, by definition, an expert is there to assist them with matters outside of their own understanding as discussed throughout this thesis.

In many professions, including those within the legal sector (of which collision investigation is a key stakeholder), it has been found that an increased demand for 'associate professional employees' is linked directly to regulatory systems that have shifted dramatically in position (Rodgers & Waters, 2001). There can be little doubt that the works of the Forensic Regulator have, as the name suggests, shifted the regulatory positions greatly, and the processes imposed by the regulator are aimed squarely at the Occupational Professionalism with the clearly defined structures and processes. This is entirely right and expected, there need to be safeguards against the introduction of pseudo-science into the Court system. However, one of the criticisms of such a regulated approach is that it can stifle invention (Amoako & McCartney, 2022) although Courts will always have it within their gift to accept 'novel' scientific evidence from a properly argued position (often referred to as the *Daubert Standard* or *Ruling* (Supreme Court of the United States, 1993)) or that is accepted by the scientific community (the *Frye Standard* or *Ruling* (United States District Circuit, 1923) – two important cases that generally accepted around the world as to the admissibility of a specific forensic technique.

Another well-argued criticism is that a regulated system gives a greater perception of 'forensic authority' which can lead to the incorrect scientific conclusions being favoured by the Court simply because of the regulation 'badge'. Indeed, this summated by a critique of the system which includes the following:

> *"Finally, it is worth remembering practically all the major scandals involving forensic science and forensic scientists have involved reputable mainstream organisations operating to the recognised standards of the day. Those who like to complain about 'charlatans' conveniently ignore this and may be pointing the finger too much in the wrong" (Evison, 2018)*

That is of course not to dismiss the role of regulation and indeed Organisational Professionalism, but it is to highlight that it is not quite a clear cut as simply having an

appointed regulator. Furthermore, there is not a clear definition, certainly in the UK, with respect to what a 'regulated' profession is. For example, regulation can be voluntary (commitment to a non-legal bodies' codes) or statutory (such as the Forensic Science Regulator). In practice, it is often the case that both of these exist as is the case with collision investigation, where the Forensic Science Regulator (very recently) mandates that some areas of collision investigation are regulated, whereas most of the 'heavy lifting' in the setting of standards is done by the Institute of Traffic Accident Investigators (which can be considered more of a membership association) (Lester, 2015)

Without rehearsing the comments made earlier with respect to their being a requirement for a defined entry point and some form of assessed (and continual assessment) of competence, (Belfall, 2019), it is important to understand how the industry itself functions. Specifically, is there a regulating body or a professional organisation that represents, speaks for and where appropriate sanctions those individuals that are in its membership? In the case of collision investigators, the answer to the question is 'yes', this is the Institute of Traffic Accident Investigators – although, it is not a requirement to be a member, meaning that not all practitioners benefit from the collective voice directly.

There are well reasoned arguments with respect to why a crime scene examiner, for example, who uses their professional judgements at crime scenes are of a higher professional standing than laboratory or scene technicians who only follow a process based on the instructions they are given by others (Robertson, et al., 2014). These broadly come down to an argument whether or not the practitioner, within the normal course of their duties, is likely to come across a scenario where they are expected to deviate from a standard operating procedure due to an experienced based assessment of the incident scene. Whereas a laboratory technician for example would only very rarely be put in this position and would likely require further authority prior to conducting a varied test (House of Lords, 2019), (Home Office, APCC, NPCC, 2018).

There is often some debate (such as (Skar, 2010)) over the requirement of acting autonomously as being a key requirement for a 'profession'. However, there is a

distinction between autonomy in a general sense and ‘professional autonomy’ where an individual works within a framework (which can often be quite stringent) but still maintains control over their own decision making (Dingwall, et al., 2014). With reference to the citations above, the common theme that runs through such discussions is that a professional will have the ‘ability to exercise their own judgement’ and use their experience-based opinions to function in their jobs on a daily basis. This is a very close comparator to a forensic expert, in that, whilst a rigorous framework exists (from the Regulator or professional body), the expert is free to exercise their judgement (well-reasoned, of course) as to the test or line of enquiry they are going to make (Forensic Science Regulator, 2023). Indeed, if the measure is simply taken as being able to use their ’experience-based opinions’ then that is, by definition, the special position given to expert witnesses given within the judicial system (discussed later).

Below discusses how examining the problems in a novel way have led to significant changes in working practices within the field. It is divided into subsections relating to the works individually, as they are discrete entities that have dealt with specific problems and discussing these in such a way allows for the impact of each to be explained – then viewing all of those as a continued body of work allows for the level of change within the industry to be understood more readily.

3.2 Maximum Attainable Braking from a Pedal Cycle

My first publication was to consider the maximum level of braking that was achievable on a pedal cycle (Crouch, 2012), which is included in *Appendix 1 – Maximum Pedal Cycle Braking*.

Starting at the beginning, it is perhaps fair to say that in the early stages of my work in this field, I didn’t give a single thought about ‘raising the standard’ of anything in particular. With my head stuck into my own workload, I was concerned with solving the problems on a case-by-case basis.

However, as my case work expanded and as any young professional should, I found myself asking my mentors questions about some of the intricacies of things such as

levels of braking on particular surfaces or why practices were done in such ways. The answers I received did not seem to fully strike at the heart of the problem and left me wanting to understand more about some extremely specific areas (as seen below). Of course, a subjective view, but I wasn't sure that certain areas were well understood, and I could not find any meaningful answers in any literature review either.

So, I set about trying to solve some of these initial problems myself. I should, at this stage, point out that I do not consider these my 'finest works', nor did the works in this subsection contribute in any major way to the industry. The two areas discussed above did contribute a little knowledge to the industry, but this subsection is more to do with setting the foundation for things to come.

The first problem I encountered was a case tragic case in London where a cyclist was severely injured when they cycled into the back of a bus that performed an emergency stop ahead of them. Discussions with colleagues ensued along with the general narrative of 'why didn't the cyclist stop?'. The response from someone came that 'cyclists cannot stop as quickly as buses'. This comment was not supported by any reference material, or anywhere that this had been studied. This bothered me, that comments like this were being made in passing. I was concerned that if it had been said in discussions about a case, it had probably been used in a forensic analysis report, unreferenced and unsupported. This is a problem because as forensic scientists we need to robustly support each and every comment and conclusion we reach, otherwise how can there be any degree of reliability of the conclusions we reach? Perhaps further concern was the fact that in the same discussion, some other of my colleagues were of the view that pedal cycles could be braked as firmly as other two wheeled vehicles (such as motorcycles). Clearly this conflicting position was not acceptable, as the two positions are mutually exclusive.

Also, this was at a time in late 2010 when pedal cycles were being actively encouraged to be used in the capital and the Mayor of London was introducing cycle superhighways and segregated areas (TfL, 2010). I was therefore of the view that it was likely to be scenario encountered that Collision Investigators would need to analyse more. I reviewed literature and found a few loose references in cycle literature to pedal cycles

not being able to achieve a deceleration rate higher than about 0.5*g* (Wilson, 2004). But again, I could not find anywhere that explained why this was, and certainly if I was unable to find an explanation then many of my colleagues were also likely to struggle.

Therefore, the question remained, if correct, 'why is it the case that pedal cycles can only really be braked at about 0.5*g*?'. This was the problem I set about solving.

The solution to this problem was actually reasonably straightforward when considering the turning moments that are introduced when a pedal cycle is braked. When a pedal cycle is braked firmly the turning moments begin to cause the rear wheel of the pedal cycle to lift (and ultimately the pedal cyclist going 'over the handlebars').

The point at which the rear wheel will lift will depend on the mass of the rider and their distance from the front wheel, but in short for some real-world values, I found that *"a pedal cycle could only achieve 0.64g"*.

A typical road/tyre coefficient of friction in good conditions is typically in the range between 0.7 and 0.8 (Bartlett, et al., 2006). This then led me to conclude that *"because the maximum front wheel braking is less than the road tyre coefficient of friction, then as the pedal cycle approaches maximum front wheel braking, the rear wheel will lift, and will begin to send the rider 'over the handlebars', before the front wheel locks."*. This then means that, to avoid the lifting of the rear wheel a rider would need to brake at less than 0.64*g* meaning that a 'safe' deceleration, to avoid a rider going over the handlebars was indeed about 0.5*g*. This would need to be established on a case-by-case basis, but with respect to the research question, it was indeed the case that pedal cycles could not slow on a road surface as quickly as other vehicles – but also the methodology behind.

What was interesting, was that it was possible to further calculate the possible braking effort possible using just the rear brake, which is of use when dealing with a collision with a poorly maintained pedal cycle for example. I was able to establish the mathematical model for the rear-brake only, as seen in *Figure 1*:

$$\mu_e = \frac{\mu[d_{tot} - d_C]}{d_{tot} + \mu\left[\frac{d_{tot} \times h_C}{d_C}\right]}$$

Figure 1: *Rear wheel braking only on a pedal cycle*

Where:

d_C= Horizontal displacement between the combined centre of mass and the road surface, *m*

h_C= Vertical displacement of centre of combined centre of mass from the road surface, *m*

M_B = Mass pf the pedal cycle*, kg*

M_R = Mass of rider, *kg*

This is represented graphically in *Figure 2*:

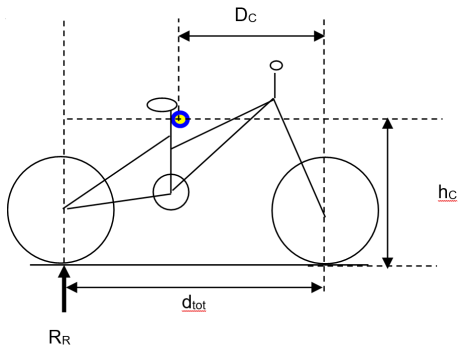

Figure 2: *Pedal cycle variable measurements (graphical representation)*

This led me to conclude that for real world values *"the maximum braking on the rear wheel is* [likely to be in the order] *0.15g"*.

It was quite a neat solution in the end, based on 'first principles' that indeed answered the question that I set out to answer with the detailed explanation as to why, and also the ability to obtain a value more accurately for any specific collision if the details of the rider are known (which can often be obtained within the normal investigation process).

This was published in 2012, in *'Impact' – The Journal of the Institute of Traffic Accident Investigators* which is distributed internationally. It is perhaps noteworthy that this research is still used to this date, indeed in the last few months I have been instructed on a catastrophic loss personal injury matter in Greece [MA v EFSAGI QB-2020-004551], a matter that is still currently ongoing, so details are deliberately brief, where a cyclist was involved in a collision with a car, where the rider had braked so firmly that they had begun to go over the handlebars. On a personal level, it is interesting to reflect as when I was drafting this paper, I was unsure of its impact within the field, and fast forward 10 years, I am instructed as an expert in a multi-million-pound litigation in a collision that happened abroad.

3.3 Quantifying the Uncertainty in Skid to Stop Calculations

The second paper that I published was a mathematical construction of how to quantify errors in one of the fundamental calculations in collision investigation, colloquially known as the 'Skid to stop' formula (Crouch, 2014).

The time it takes a vehicle to stop can be divided into three phases, driver perception-response time (PRT), the vehicle response time, and the braking time (Lyubenov, 2011) – all of which combine to form an overall stopping time, from which a total stopping distance can also be calculated.

My work in the area is concerned with the last of the three components, the braking time/distance. In practical terms, at a collision scene where a vehicle has left tyre marks, one of the key questions asked of a collision investigator is to establish the speed of the vehicle at the commencement of the marks.

'Stopping distance' is a term that can be used in many ways with respect to vehicles and the rate at which they slow, and as a result a body of work exists, such as (Sabri & Fauza, 2018), (Mohajer, et al., 2021), (Wang, et al., 2020) where the rate at which a vehicle is slowed is considered against passenger comfort, an area that is key for the future developments in autonomous driving.

However, what is of importance both with respect to this research and also collision investigation more widely, is the maximum rate at which a vehicle could be stopped. This is a condition under *emergency* braking. This historically, as discussed below, would result in the vehicle 'skidding', and therefore a specific sub-set of stopping distance research has developed – which is known as 'skid to stop' calculations. It is this sub-set, that is discussed below with respect to the existing literature within the forensic sphere.

In order to calculate the speed of a vehicle at the commencement of a set of tyre marks (assuming the vehicle came to rest at the end of the marks) requires two variables to be established – firstly the length of the tyre marks and the average deceleration of the vehicle under emergency braking conditions (Hague & Lambourn, 1999). It is, in essence a 'back calculation', as knowing the rate that an object slows and the distance over which it did so, means that the speed at the commencement of the deceleration can be mathematically calculated.

However, like any calculation, the accuracy of any mathematical result is dependent on how well the two input variables are known. Both of these variables are problematic to a collision investigator.

A 'skid mark' is generated on a road surface as a result of friction generating sufficient heat at the road tyre interface to melt a small amount of the tyre compound into the road surface, and a small amount of the bituminous binder of the road surface into the tyre (Bullas & Hounsell, 2008).

When vehicle wheels initially lock, and the tyre begins to slide on the road surface (skidding), a mark is not generated instantly – this is because the heat required to melt the surface of the tyre at the road tyre interface is building, but not yet hot enough to start melting the surfaces. Any collision investigator who attends collision scenes where marks of this type are found will tell you that the start of the mark is not always easy to define – because the heat building in the system causes the mark to visibly 'fading in'. Certainly, when the marks have been fully established on the road surface, they can be relatively easy to identify to the trained eye, but what a collision investigator needs to establish is the 'start' of the mark.

The assessment of a tyre mark length is done visually, and it is entirely feasible that two collision investigators will assess the same set of tyre marks and conclude a length that differs by some ten, twenty or even at times thirty centimetres – although with experience you would expect the variance to be towards the lower end of the scale. It is therefore important that investigators consider that potential difference in any subsequent calculations they perform. The introduction of Anti-lock Braking Systems (ABS) have served to make the identification of the start of the marks even more challenging due to their often faint and intermittent patterns (Brown, et al., 2017).

Turning attentions now to the accuracy to which the deceleration of a vehicle can be established. There are a number of factors that can affect the achievable deceleration, such as the vehicle, the road surface and environmental conditions (Pagola & Giovanon, 2011), (Manderson & Jennings, 1992). For that reason, it is now common practice for Police collision investigators to use highly calibrated decelerometers placed inside the incident vehicle, which is then driven along the road, in the area of the collision and braked in an emergency fashion. This test is repeated a minimum of three times and a mean and standard deviation (and/or 95% confidence interval) obtained from the testing (Neades, 2013).

The question that then follows is that, with the accuracy of both the distance and deceleration obtained (either subjectively or objectively) how do these ultimately impact on the speed being reported to the Court by the collision investigator? This is where my mathematical derivation comes into play. What is interesting, is that unbeknown to me at the time, this ‘differential variation’ approach to the skid to stop formula had already been conducted a few years earlier (Brach & Brach, 2011) albeit an American study where the equation was based on a derivative of the imperial measurements of feet, and feet per second. Therefore, the derivation I came up with was relevant to the collision investigators in the UK and made accessible via the Institute of Traffic Accident Investigators.

There are a number of factors at play when considering stopping distances, such as road surface, tyre compound and suspension components (Delaigue & Eskandarian, 2004). Indeed, this has been recognised by the introduction of specific validated

emergency brake testing equipment being introduced in the police collision investigation units throughout the UK (Forensic Collision Investigation Network, 2020). The introduction of this specialist equipment allows for a highly accurate measurement of the tolerance in the rate of deceleration, one of the key elements of the formula derived.

The application also has wider uses within the Civil forum, whereby it is not simply a question of identifying how fast the car was going, but establishing what would have been the likely outcome if the driver behaved differently. The derivation explained below is also relevant when answering questions such as *'what would have been the braking distance if the car had approach 5mph slower?'*, or *'had the road surface been given a high friction dressing, what would the stopping distance have been?'*

During my initial training I was taught that 'skid to stop' calculations were subject to an error of ±5% and this was widespread practice applied by Collision Investigators at the time (Forensic Accident Investigation Training, 2005) as it formed part of the mark scheme for the City and Guilds qualification in *Police Forensic Collision Investigation*. As with the pedal cycle braking discussions above, I cannot find anywhere where this is formally written down although there is a reference to it as far back as 1990 (Smith, 1990) where the following phrase can be found:

> *"Allow a 5 % error to get…"*

This was Issue 1, Volume 1 of *Impact* (*ibid*) and therefore is likely to predate this point. This was something that initially struck a chord with me on a conceptual level. How can every single calculation, for every single skid test, for every vehicle, on every surface, in all weather conditions be subject to an error of ±5%? As I understand it, what is meant by this is that given all of the variables the true speed of a vehicle is likely to fall in an error band of ±5%, but that is different to applying an error of ±5%.

The standard of proof in a criminal Court is to prove a matter 'beyond reasonable doubt' with the 'modern' clear direction to the Jury:

"That they have to be satisfied so that they are sure before they convict" (Judicial College, 2020)

In practical terms, this means that a Court will often use the lowest calculated value because, by the very nature of a range, it is possible (even probable) that the speed was not at the top of the range, and the lowest value nearly always gives the 'benefit of the doubt' to the driver – therefore a Jury can be sure the speed was 'at least' the lowest speed that they are presented with. So, considering a theoretical collision where the true speed of the vehicle was 77*mph* on a dual carriageway, and the Police Collision Investigator has calculated a speed of 73.5*mph* ±5% (or 70*mph* to 77*mph*). The Court would nearly always proceed on the basis of 70*mph* and therefore all of the consequences of travelling above the speed limit where the collision could be avoidable had they instead been travelling at the speed limit are lost. Further still, what happens if any testing was conducted in less-than-ideal conditions and the tolerance should in fact have been larger, with the car travelling at 80*mph* or 85*mph*?

Clearly the theoretical discussion above is not designed to discuss the merits of what would happen in any specific collision, but it is simply to highlight the potential danger of not considering things correctly and blankly applying tolerances without thinking. The fact of the matter is that each of the values in a 'skid to stop' calculation (length of braking marks and deceleration) has tolerances, and therefore these can be mathematically considered individually. The way in which errors propagate through a mathematical formula are well established, yet for some reason did not seem to have worked through into the sphere of collision investigation.

Therefore, I authored a short 3-page article on quantifying the errors in a 'skid to stop' calculation that was published in Impact in Autumn 2014 sent to the same readership. I have seen this used, a number of times in reports that have subsequently come across my desk.

In the Spring of 2013, an article was published (Neades, 2013) that detailed a new procedure for conducting skid tests. Previously, adopted practice was to conduct 2 skid tests at the scene of a crash, and take the lowest value. This was challenged in

the 2013 paper which presented an argument (which has now been adopted as customary practice) that 3 tests should be performed, and an average taken. It went further to suggest that a statistical confidence interval approach should be taken to consider a 95% confidence interval for the value obtained. He found that,

> *"If the range of skid test results is reduced to 5% then the 95% confidence interval is reduced…the upper and lower bounds of the confidence interval are no more than ±6% of the mean value."*

This appears to know the accepted position, with errors calculated from the spread of the sampled data. This however, only dealt with one of the elements of the calculation i.e., it dealt with the error in the tested co-efficient of friction but did not cater for any of the errors involved in the measurement of the length of the marks.

In order to establish the total error in a 'skid to stop' calculation both need to be considered and handled in the same way as any error propagation should be dealt with in mathematical calculations. However, whilst such a technique may be well established in other mathematical and engineering fields, this did not appear within the literature commonly associated with collision investigation, which I found personally surprising. Therefore, on the back of the work of Neades, I published a methodology for doing this, which was published in the summer of 2014.

Within this publication, I demonstrated that the error in speed could be calculated as,

$$\partial u = \sqrt{\left[\frac{gs}{u} \times \partial\mu\right]^2 + \left[\frac{\mu s}{u} \times \partial s\right]^2}$$

Figure 3: *Error in Skid to Stop Calculation*

Where:

u= vehicle speed at the beginning of the marks, ms^{-1}
μ= road / tyre coefficient of friction, *dimensionless*
g = acceleration due to gravity, ms^{-2}
s = length of marks, m

In essence, the work of Neades provided the δμ element, and with an assessment of δs (the error in visually assessing the commencement of a tyre mark), I was able to provide a solution for quantify the entire error in a 'skid to stop' calculation.

It is important to reflect at this stage, that this particular publication did not, to me, feel new. Of course, it was new as this had not appeared in the field of collision investigation before, but I was of the opinion that this was just a 'basic' mathematical error handling exercise. What I now realise, is that this was the very essence of my research and publications to come – taking something that is understood in another area of science, and 'converting' it for use in the field of collision investigation. It is exactly this principle that allowed for some of the positioning techniques that form part of my book, discussed in subsection *Video Analysis in Collision Reconstruction (First Edition)*. Whilst this this error propagation paper is basic when compared to the CCTV analysis tools that I have developed, what is striking is that now, looking back, I understand that looking at this error propagation publication above, whilst I still consider it to be more of a formality, it demonstrates the coming together of two knowledge sets, that runs throughout my works in this field.

3.4 Yaw Mark Analysis (YMA)

Vehicles leaving tyre marks at collision scenes is a common occurrence and is one of the key functions of a collision. There is a specific type of tyre mark, left at the scene of high-speed loss of control incidents (Lambourn, 1989), whereby the incident vehicle can leave a set of curved tyre marks. Collision such as these commonly occur at bends in the road, and or where there has been a sudden steering input from the driver. In essence, the vehicle is attempted to be steered on a path that it is unable to follow.

The tyres are the only objects in contact with the road surface when a vehicle is driving along the road, and as these surfaces are in contact, friction exists between them. This is perhaps the limiting factor that controls all of the driving experiences. This friction is exploited when accelerating, slowing, or turning the vehicle, causing the vehicle tyres to slightly deform (Fricke, 1990), and generating the force that ultimately changes the speed or direction of the vehicle. There is, however, a finite limit of friction that exists between the tyres and the road surface.

When a vehicle is being driven at speed, the vehicle reaches this level of friction, and therefore cannot corner further and instead begins to rotate about its centre of mass, known as 'yaw' (*ibid*). This yawing and the heat generated can leave tyre marks on the road surface that are characteristically curved, and can also have a striped, or 'striated' appearance, an example of these is seen below in *Figure 4*:

Figure 4: *Straited Tyre Marks*

Given that these marks are generated when they reach the critical limit of friction, these are known as critical speed marks, or 'critical curves.' (Hague, et al., 1997)

Vehicles displaying critical speed behaviour have been researched. *Lambourn* (Lambourn, 1989) and *Hague et al.* (Hague, et al., 1997) discuss in detail the initial research into such behaviours and the suitability of errors that are now routinely attributed to calculated speed ranges. These were studies conducted in the late 80's and 90's and provided a formula which would correctly predict the speed of the vehicle to a tolerance of ±10%, providing that the following criteria were met:

- The rear tyres were tracking outside of the front (so more than one tyre mark was required),

- the rear tyres were not more than half a track width outside of the front (i.e., the rate of yaw was low), and,

- striations could be seen in the marks.

For important context, they also presented a methodology for those investigators at the scene who used 'sight boards' (metal markers that could be lined up with an investigator's eye level, close to that of the road surface) and a geometrical chord measurement of at least 15*m* was taken and a mid-ordinate of at least 0.3*m* had been obtained. (Lambourn, 1989)

So, what was the problem? This had clearly been tested and was providing the correct result. In short, in the 80's and 90's there was nothing wrong with this whatsoever, the problems arise out of mechanical advancements with vehicles. Indeed, a review of the critical speed formulas concluded that:

> *"Comprehensive studies should be conducted to develop improvements to the critical speed estimation methods which yield improved results." (Sledge & Marsheck, 1997)*

Vehicle sold into the EU market since the latter part of 2014 (proposed originally in 2009) required all vehicle to have Electronic Stability Programmes (ESC) which means that the vehicles themselves are actively trying to prevent a vehicle yawing and do so by rapidly applying and partially releasing the brakes of specific wheels in an attempt to maintain vehicle stability. (Ministry of Justice, 2009). In real terms, changes in vehicle technology have meant that there was often only one mark generated, on the road surface and the presence of striations within a mark all but eliminated. Therefore, marks being found at collision scenes, no longer complied with the three requisite conditions outlined above.

Therefore, Collision Investigators were faced with a dilemma. Marks were found at a scene, but they did not fully comply with the existing research. Do they measure the marks accurately and apply the 'old' formula 'as if they had met the criteria', and outlining in their report that that this could be incorrect because not all of the criteria was met. Alternatively, do they not attempt any kind of calculation as the research does not directly apply to the marks, they had found in relation to the incident they were studying. I have personally seen both of these approaches appearing in reports that I have peer reviewed and been asked to critique (both as a peer review and also as a as part of criminal proceedings).

One of the key dangers with applying research to a set of marks that does not quite meet the criteria is simply, how do you know the answer you obtain is correct and therefore safe to present to the Court? Undoubtedly, you are likely to be faced with some significant questions about this when giving live evidence but leaving aside for one moment about how this may play out in a Court setting, we need to return to the question of whether or not this research can be applied. In short, the answer to this is that there are significant implications with whichever of the two approaches is taken (either nor performing any calculations or performing them 'as if' the marks meet the criteria), for reasons explained below.

Firstly, from experience and shown later with real world in vehicle experiences that I instruct, these marks are laid at high speed. Therefore, not performing any analysis on the marks means that drivers who have, in all likelihood, been travelling at high speed when they lost control may not be put before the Courts for their actions. Secondly, it is important to consider what would happen if the mathematics were applied 'as if they were' critical speed marks.

In reasonable quick succession (Brach, 1997) and (Greatrix, 2002) found that when braking was applied to a vehicle the calculated speed using existing techniques began to *overrepresent* the true speed of the vehicle, and if braking was firm enough, the true speed would fall outside of the lower tolerances. Therefore, if notable braking was being conducted at the time of the marks being made then the speed presented to the Court would be higher than the true speed of the vehicle, and significantly so (ibid).

The problem, therefore, was that calculations *were* being presented as 'fact' to a Court, when they were in fact over stating the speed of the Defendant's vehicle, or no calculations were being performed and therefore charging decisions were being made by the Crown Prosecution Service without knowing the speed of the vehicle. Considering these cases involve someone being accused of causing the death of another human being, neither of these two scenarios are particularly appealing.

But there was a solution, and my colleague Mr Stephen Cash and I managed to find it, and this is included as *Appendix 4 – Yaw Mark Analysis.* If the speed lost across the marks is considered, along with the geometry of the marks themselves, it is possible to calculate the speed of the vehicle at the commencement of the marks using the formula shown in *Figure 5*:

$$u = \sqrt{gr\left(\left(\sqrt{\mu^2 - \eta^2}\right) Cos\theta_m\right)} \Bigg/ \left(\sqrt{\left(\frac{\mu(Cos\theta_i - Cos\theta_m)}{\theta_m - \theta_i}\right)^2 + \left(\frac{\eta(Sin\theta_m - Sin\theta_i)}{\theta_m - \theta_i}\right)^2}\right) gs$$

Figure 5: *YMA Speed calculation*

Where:

- u = speed of the vehicle at the commencement of the marks, ms^{-1}
- r = radius of curved marks, *m*
- μ = road / tyre coefficient of friction, *dimensionless*
- η = longitudinal deceleration, ms^{-2}
- g = acceleration due to gravity, ms^{-2}
- θ_i = orientation of vehicle at the first discernible position, *degrees*
- θ_m = orientation of vehicle at the mid-ordinate, *degrees*
- s = length of marks, *m*

It may at first seem that this is a formula that is complex, but like all equations the numbers can easily be crunched using a spreadsheet (which we designed and distributed), the real beauty about this solution is in the input data.

To re-emphasise the Collision Investigator has limited investigatory time before there is a need to reopen the road. The analytical equipment will be limited to what they will carry with them and as a consequence it is important to develop analytical approaches

that can provide accurate data post onsite investigation. This is critical to understanding why this technique works in the practical environment.

From the beginning of solving this problem, a focus was placed upon what can reasonably be expected to be gathered from a crash scene. I had immediately discarded a number of initial ideas as a potential solution as being unworkable – too many measurements were required, or additional equipment would be required (in the face of continual budget cuts in the Police at the time). This had to be a solution that worked, in the time already available, with the equipment to hand, and something familiar to existing Collision Investigators.

In addition to measurements already taken at a scene of a collision, what my colleague and I found, was that the current onsite investigation needed to be extended to include three additional steps to be taken at the scene (in fact, with the correct surveying equipment, only one of these *has* to be done at the scene).

My addition to practices highlighted that a gradient measurement along the length of the marks, and another perpendicular, increases the accuracy of tyre mark analysis and speed calculations to be formulated. The ultimate step is to accurately survey the position of the marks.

Typically, collision scenes are measured using a Total Station, or a 3D laser scanner. A Total Station is a more traditional method (often seen on building sites) where a surveying laser is placed on a tripod and the operator walks around the scene with a prism mounted on a pole, manually plotting a series of points. A picture of a total station with operator can be seen in *Figure 6*.

Figure 6: *A Total Station*

This has now been largely superseded by deploying a 3D laser scanner at the scene of crashes, which is a laser measurement device, seen in *Figure 7,* that rotates taking several million measurements of a collision scene.

Figure 7: *A 3D laser scanner*

The Laser Scanner is often preferred over the Total Station due to the number of measurements that can be taken from a collision scene. For example, a Total Station requires each measurement to be manually inputted and, from experience, about 150 measurements would be taken at the scene of a collision.

A laser scanner on the other hand, in about the same time can capture many millions of measurements. Shown in *Figure 8* is a screen capture of a laser scan that I took at a collision locus, containing over 72 million measurements, colloquially known as a pointcloud:

Figure 8: *Pointcloud of collision locus*

Whilst discussed in more detail below, it is worthy of note that we designed a new algorithm for calculating vehicle speed based upon measurements that could be reasonably expected to be taken from the collision scene. With respect to the protocol at the scene we were able to work with existing methodologies making only slight changes to the protocols at the scene. This change in protocol was to ensure that the curvature of the marks could be accurately identified in a laser scan (or accurately measured by a Total Station). This required the placement of retroreflective studs (already routinely carried by the Police) along the edges of the marks. These should be spaced every 5*m*, meaning that a 45*m* mark would need 10 markers placed. Having done this many times, this would take in the order of about 5 minutes to do.

By comparison, taking the 'old' critical speed measurements with 'flags' took about 20 minutes and did really require two people. It was essential to ensure that the time spent at the scene was not dramatically increased, as by the very time pressures involved in keeping a road closed would make this practice unworkable. In fact, what we managed to achieve was a technique that saved time at the scene.

Of course, there is a distinction between the works conducted at the scene and back at the office, as the technique does take in the order of 15 minutes to obtain the measurements required for the calculation from the scene survey data, but this does not delay traffic.

It is worth reaffirming here that this was a conscious decision in the design. One of the main focusses here was to take a theoretic concept and design a tool/process that could be used by practitioners at the scenes of the collisions and providing results that were reliable. In essence we designed a system that required three additional steps at the scene, and about a quarter of an hour in a software drawing package. That is all that is required to get a vehicle speed. A practical solution to a practical problem.

Historically, as you will recall, the previous calculation applied a blanket tolerance of ±10% to the calculation. Leaving to one side one of my personal bug bears that there is no such thing as a 'blanket' set of input values, so why should there be a 'blanket' tolerance with the output values – this is a significant error. Take for example a vehicle travelling at exactly 70*mph* when it lost control. The calculations would present a speed range of 63*mph* to 77*mph*. What is the Court meant to think, was the car well below the speed limit, or well over it?!

What I found with our technique however was even more surprising. Because the spreadsheet was designed for use within the Court system, it was important to include upper and lower thresholds for each of the input values, the range of speeds would be outputted at the end of the calculations. For even wide-ranging input values, we have found that, the error in the output values was typically in the order of ±2% (or on occasion much lower), simply because this is only really one physical way the vehicle could have generated those marks, travel on the path it did, and reach the speed at impact that it did. It is for that reason that the calculation is extremely stable also.

This went through a number of peer review processes, not least comparing vehicle loss of control data where the speed of the vehicle at the commencement of yaw was directly measured, and the path of the vehicle accurately plotted. Running that data through the algorithm correctly calculated the speed of the vehicle at the commencement of the marks. This provided the validation for the process on data that was already in existence.

It was this test data that provided real credibility to the technique. The test data was obtained from experiments that were conducted to try and identify when and why you would want to expand the error bands in *existing* calculations. Using that data on our

algorithm showed that you could dramatically narrow the error bands using our technique.

This work was presented at the 24th Congress of the European Association for Accident Research and Analysis (EVU) 2015 to over 400 delegates from the UK and Europe and also later on that year at the Institute of Traffic Accident Investigators annual conference to a further 200 delegates. On a personal note, one of the highlights of my career was after the EVU conference when I was approached by some eminent practitioners shaking my hand and saying, "*Well done, you have solved it!".*

You would think that I am most proud of this solution because of the tight range of results it produces, and of course, that is not an insignificant element. However, what I am most pleased with here is that this was designed from the ground up, to be used 'in the field.' There are many more elegant solutions, which can be modelled with hours of testing conducted at the scene and days of post scene analysis – I consider the most important part of this research is that it was designed to work for 'the boots on the ground.'

One of the additional elements that was included within this work, was the ability to calculate the speed of the vehicle as it began to lose control, but *before* marks were generated on the road. In simple terms, if the vehicle left marks when it has already rotated, say, 5º, then what was the vehicle speed at 0º? This is the data that can be obtained from some vehicles that have been involved in significant crashes – and the contact that we had with prominent investigators in Australia and America was that that they were staggered at how well our Yaw Mark Analysis research (Cash & Crouch, 2015) calculated this speed.

Of the numerous cases I know of where this has been used (even as recently as 2022 in the matter of R v Silan KAYA (Road.cc, 2022), where one Hertfordshire Police's Collision Investigators, who we trained in 2015, used this to calculate the speed of a vehicle that had lost control leaving a series of tyre marks, this is one case that stands out more than any other, and it comes back to the point made at the very beginning – what happens if the old techniques are presented to the Court as 'fact'. Would there

be a miscarriage of justice? The example given below shows how one was very narrowly avoided.

The details of this case have been sanitised and kept to a brief narrative. In the early 2010's there was a collision where a newly qualified driver had left the road and struck a tree killing her front seat passenger[1]. Curved tyre marks were found by the Police at the scene, and the critical speed formula applied giving a speed significantly above the speed limit. She was charged with Causing Death by Dangerous Driving. She had protested her innocence all along due to the fact that she was not driving at the speed she was accused. The defence expert at the time, was deeply unhappy with the calculations performed by the Police evidence and this was argued in Crown Court at a trial. The Jury failed to reach a verdict, and preparations were made for a re-trial. Shortly after this first trial, the Yaw Mark Analysis paper was published and presented at the ITAI conference and I was contacted by the defence expert to see if I would be able to assist him with this analysis, in light of this new research being completed and something that needed to go in front of the Court.

Now, cutting an exceedingly long interim story short, I was provided with the data of this crash, and processed it and after taking very careful measurements I inputted this into our formula and spreadsheet and…it didn't work. The spreadsheet produced error after error. After spending some time looking at the data collected by the Police, it was clear that there was something odd about the rotation of the vehicle, in that the rate of yaw was not broadly constant, as you would expect for a vehicle that had sustained a loss of control. The first though was that the measurements were taken at the scene were done so incorrectly – however comparison with the photographs only revealed the most minor of discrepancies and certainly nothing to have caused the errors in the calculations. So, I asked the question, *"Did the vehicle hit anything before it lost control?"* The response came *"It is funny you should say that, but the driver did say in interview that she believed she was driven into and that is what caused her to lose control."* Furthermore, buried deep in the unused material for Court was a note from the expert vehicle examiner that there was some damage to one of the rear corners of the vehicle that was unrelated to the collision. There you have it, the answer to the

[1] R v WHITEHORN, collision date 28th October 2011

question. There is reason why the calculation mathematically collapsed because the vehicle had an external force acting on it. It rotated irregularly because it had been 'shunted' off the road. Needless to say, when the defence expert returned with all of this information, the re-trail was withdrawn.

The striking vehicle was never found (as the opportunity had been lost with time), but an innocent driver, who came awfully close to going to prison falsely for killing her friend, did not suffer an injustice.

As well as being embedded into the field of Police Collision Investigation, this has also been cited when validating and modelling straited marks which is then in turn used for the simulation (Wach & Zebala, 2021) of vehicle dynamics. They comment favourably that we:

> *"Derived a formula which accounts for a higher degree of vehicle yaw and any brake force (not only from driver input), resulting in a narrower error band than conventional CSMs* [Critical Speed Models]*. If the exact path and orientation of the collision vehicle are not readily apparent, their method allows the flexibility of considering ranges for the required values."*

This formula is included within their tyre simulation model, which allows for a computational approach to the movement of a vehicle, and specifically the tyre handling dynamics of a vehicle sustaining a high-speed loss of control.

3.5 Frame Interval Timer ('Lightboard')

The area of work that I am potentially most well-known for amongst my peers is in the field of video analysis. My works in this field will be discussed in much more detail in the next two subsections, but it is important to deal with this matter first as it forms the basis of vehicle speed calculations when dealing with video evidence. In short, in order to calculate one of the most important questions on collision investigation, vehicle speed, the distance a vehicle travelled between two points needs to be known, as well as the time taken to travel that distance. From that the average speed can be

calculated, the calculation itself is a simple one, but it is the accuracy of the input values that becomes important.

In 1999 there were an estimated 21,000 local authority operated CCTV cameras in the UK, which had increased to approximately 51,000 in 2012 (Big Brother Watch, 2012). As of 2022, it is estimated that there are as many 63,000 in London alone and over 7 million cameras in the UK (Clarion, 2022). I was based at the Metropolitan Police's Central Traffic Garage in the late 2000's, which coincided with this sudden increase of CCTV cameras, and therefore the number of collisions captured on camera. Therefore, I was actively working on casework at or around the time that CCTV analysis became part of investigations with an increasing regularity. I had a number of cases that required an analysis of CCTV, but no tangible way of accurately identifying the critical element of time required for calculations.

It is worthy of note that, CCTV cameras and dash cameras fitted to vehicles were never designed with accurate time intervals in mind. Some video timing conventions do have a reasonably accurate time interval, and some modern-day electronics afford the same luxury, but this is far from consistent across the board. Whilst the *average* number of frames per second (fps) that a camera is recorded at may be publicised (be that correctly or incorrectly) what is hardly ever known is the time interval between frames. At the time of my works in this field, there wasn't a term that I could find that related to the interval, and therefore I began using the phrase 'interframe spacing' which seems to now be in common parlance in the reports that I routinely review – although not widely used outside of the sector.

When dealing with crimes, such a burglary for example there are often no significant consequences if the time interval between images varies. Indeed, you probably wouldn't even notice it. However, this is completely the opposite when dealing with vehicle collision – the time interval needs to be known exactly. If the system is fluctuating the time between images by, say 20%, then failing to notice or account for this will result in the speed calculation being an equal proportion out.

The takeaway point here is that very small-time intervals, down to milliseconds matter. Secondary to that, with collision investigation we are attempting to use a CCTV to

calculate something it was never designed to do. The fact it wasn't designed to do something, is however, a long way from not being able to do something with the video footage. You absolutely can, but you need to test and verify the rate at which the camera is working very accurately indeed.

A digital video file will contain metadata (the 'hidden digital' signature of the file) that may include Presentation Time Stamp (PTS) data, especially with MPEG4 video files. This is not always accurate, with errors such as times being averaged, or even an offset between the actual and recorded PTS (Lee, D; Kim, N; Kim S, 2002). Not knowing the time interval exactly, as discussed above, can cause significant errors in calculations.

I spent a considerable amount of time looking to see if an existing solution to this problem existed. I found, through word of mouth, two existing techniques, both of which are still appeared to be unpublished as I am still unable to find any historical references.

The first technique was to disconnect the camera from the rest of the system and attach a calibrated video feed to the video recorder itself in an attempt to discern the rate at which images were being recorded. There is however a notable drawback to this method, in that only half of the system is being tested, because the cameras have been disconnected. With more modern-day systems a lot of the digitisation of the video occurs at the camera itself, and therefore this technique will be missing these critical processes in the testing.

The second technique I was informed that some UK police forces were using was to position a stopwatch in front of the camera and record footage. This was considered preferential by those using it because it captured the entire system (i.e., the camera was not disconnected from the system to perform the testing). There was however a significant drawback, that stopwatches only typically display times to a precision of $1/10^{th}$ second. When stopwatches were purchased with a precision of $1/100^{th}$ the digits were changing so quickly that the 100^{th} value could not be resolved as the exposure of a CCTV is longer than the increments of the digits. Indeed, if this was performed with any kind of conventional digital clock, where digits count up whilst remaining in

the same physical position, there is a problem with cameras that have an 'exposure' of longer than a single digit increment, then resolution is lost (i.e., if a camera has an exposure of 5 milliseconds, say, then all that would be seen is a blur where the millisecond unit would be recording (Cheng, et al., 2017). This of course means that precision to that level is lost.

However, the idea of positioning an optical clock in front of the camera seemed, to me at least, the most logical way of obtaining the interframe spacing, and 'all' that needed to be done was to separate the digits in some way - of course, that is quite a dramatic oversimplification, but that is the basis of the device design. If you place a device in front of the camera and record the clock 'ticking round' then looking at the video file frame by frame, and reading the time displayed on the clock in each and every image, it is possible to calculate the time interval between images, and if not a constant interval any pattern that exists within the footage. As previously indicated this needs to be performed with a precision of a millisecond.

Because this times the intervals between frames, it was called the *Frame Interval Timer* and because that is a bit of a mouthful and it is a board that contains lights, it is colloquially known as 'The Lightboard.' The Frame Interval Timer, shown in *Figure 9*:

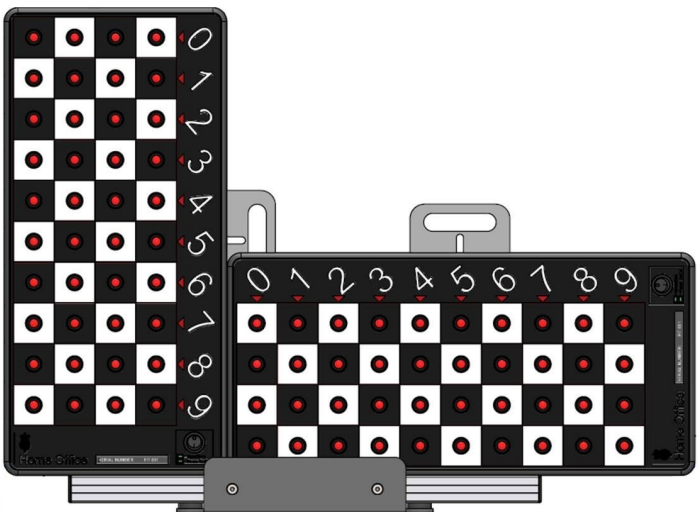

Figure 9: *The Frame Interval Timer*

The device comprises of two banks of Light Emitting Diodes (LEDs) positioned vertically and horizontally – hence the name Lightboard. The first bank consists of a grid of 10 rows of 4 LEDs where each row is numbered from 0 to 9.

The LEDs of the first column illuminate individually and sequentially from 0 to 9 for a duration of 1 second.

During each 1 second period the 10 LEDs in the second column follow the same sequence, though for a duration of 0.1 second.

During each 0.1 second period the 10 LEDs in the third column follow the same sequence, though for a duration of 0.01 second.

During each 0.01 second period the 10 LEDs in the fourth column follow the same sequence, though for a duration of 0.001 second.

Therefore, this operates as an optical clock that displays time at a precision of 0.001 second through the sequence of LEDs illuminated at any given point in time.

The second bank of LEDs that completes the Frame Interval Timer is identical to the first though oriented horizontally. When in operation an infra-red communication link between the two banks ensures that they operate in synchrony. The purpose of the two banks is to identify any effect caused by a 'rolling shutter' and where possible quantify any error that it may introduce – although the minutia of the operation and full scientific function is not needed for this thesis.

The evidential strength of the Frame Interval Timer to establish frame intervals is that it negates the need for an intimate knowledge of the manner in which the specific CCTV system records images. Its use and the subsequent analysis, tests the whole system from the camera lens right through to the recording equipment, playing software, and ultimately the analysis process.

This was an idea that was facilitated by the Metropolitan Police (who were my employer at the time) and the Centre for Applied Science and Technology at the Home Office

who secured funding to develop and finalise the design of the lightboard, and therefore the Frame Interval Timer was produced in 2016. It is perhaps salutary to note at this stage that this timing board has been heavily referenced in the analysis of the stabilisation of timing and the derivation of format that allows for the calculation of the range of uncertainty of image exposure time based on a high frame rate camera (Wach & Unarski, 2020). This paper documents a methodology for quantifying the uncertainly in the operating exposure time of any particular camera in question.

To accompany this, I published a paper detailing how the device should be deployed, and how the data could be best analysed (Crouch, 2017). This was written to go 'hand in hand' with the device and I presented it to the delegates of the 12th Annual International ITAI Conference at Hinkley, Birmingham, UK.

The initial production of the 'lightboard' was for 50 units which meant that every Police force (with the exception of a couple) had at least one FIT board as this was the purpose of the initial production run. Those Police service's that do not have one borrow those from a neighbouring force or use our device. A couple of the units were shipped internationally including as far afield as Hong Kong. Indeed, Dr Cheng who was working on a similar project at the time (Cheng, et al., 2017) at the Government Laboratory of Hong Kong changed is approach and adopted ours and uses the Frame Interval timer.

Given the number of units and the international reach of the device, it is difficult to quantify the number of investigations that this device has assisted. I would consider it a certainty that they have been used in thousands of investigations and that could be quite a conservative number.

To accompany the physical device, I have written chapters within my Video Analysis in Collision Reconstruction book discussed later, with respect to the interpretation and deployment of these techniques. Again, it is somewhat challenging to estimate to what extent this particular paper has been circulated, but I know of its use in the UK, Hong Kong, Poland and Australia, but again, this is likely to be conservative. One of the indicators I have for this, is the terminology I have seen used. As mentioned previously, the time interval between images is the element that Collision Investigators

really care about, but in all of my research reviews I had not come across a term used to define this period, just explanations as to what it was. So, I came up with term 'inter frame spacing', or 'ifs' for short. A respectable number of the documents that are now written about this element of forensics and nearly all of the expert reports that I read that are presented to Courts, have now adopted that phrase!

The key element here is that there was a need in the industry for some innovative technology to be developed to allow for the investigation into collision that previously would have gone unanswered, as there was no device that allowed for such analysis in existence previously. Not only was it the design of the physical tool but also the way in which an analysis should be performed that is a key element of embedding this into practice.

Speaking from direct experience, it is now rare to receive a case file from the police where a CCTV analysis has been performed without there being lightboard footage and a subsequent analysis.

This was a truly organic development taking a concept (the idea of a 'clock' that could be recorded) to the deployment of the timing device at fatal collision scenes that would deal with a very real issue. This issue of identifying the tiny increments of time between images being captured is essentially unique to collision investigation, so it was only right that it was a Collision Investigator that developed the solution.

It is perhaps interesting that this follows a similar thread as to the yaw mark analysis discussed earlier, whereby it was important to design something that could actually be used in the field - not a purely theoretical, something cost prohibitive or something that could not be used on CCTV cameras that capture collisions. This was designed to be used in real world scenarios, and perhaps it is a testament to that philosophy that it has been used at so many crash scenes.

I am aware that it is not immediately apparent to the reader how this will assist in the investigation of a road death, so to briefly consider a specific (and fairly common) occurrence. The methodology I have considered also means that investigators are now able to deal with CCTV cameras that have regular, but not non-constant interframe

spacings. For example, a broadly common system frame rate of 12*fps* is common and is typically recorded in a sequence of 11 frame intervals of 0.08s followed by a frame interval of 0.12s, which between them makes one complete second.

Historically an error would have been applied to calculations to cater for the possibility of the frame interval being 0.08*s* or 0.12*s*, which on a small number of images would translate to a large error margin. But now, the pattern can be identified and what my work has allowed is the precise identification of the predictable pattern of 'jumps' in the footage and therefore identifying the precise time intervals *and when they occur*.

This jump should be apparent when considering movement of a vehicle. If the time interval is materially longer than other interframe spacing, the vehicle will appear to 'jump' forwards. All that needs to be done is find those jumps and apply that pattern accordingly. The technique outlined, involves plotting a physical feature of a passing vehicle, in each and every position and identify when the vehicle moves further than usual, an example of which is shown in *Figure 10*. This example concerns a static camera, and the image shown details the analysis whereby the motorcycle's rear light has been tracked through sequential frames.

In the image the red dots represent the light's position at distance intervals that are comparable to one another (with consideration to the effects of perspective). The rear light has then been marked with a yellow dot when the distance travelled by the motorcycle appears comparatively longer than the previous intervals. This highlights exactly when the longer frame interval of 0.12*s* occurred.

Figure 10: *An example of tracking a subject to identify 'jumps' in a recording*

I have also provided the assurances to investigators that this principle can applied to a moving or static camera and have changed the way the industry has approached the analysis of collision footage - now footage is considered in its entirety and no longer is it isolated to the frames used for the speed analysis. For example, the subject vehicle may only be in camera view for 5 frames, however, in order to reliably identify a frame interval pattern a period of 20 to 30 frame intervals may require examination using vehicles not directly involved in the incident. This would not have ever been attempted prior to the development of the Lightboard.

So, in practical terms, what difference has this timing device made? The answer to that is reasonably straightforward – it is analogous to the yaw mark analysis work discussed earlier.

This means that the analysis of CCTV is possible for Collision Investigators, and where perhaps longer time intervals would have been placed on calculations, can now be specifically quantified.

Previously, where calculations were preformed, the error bounds placed on average speed calculations from CCTV footage were large in the order of ±20% - a total range of 40%! In addition, what was almost commonplace amongst the industry was to apply

and error of ±1 frame to either end of any speed calculation. Again, in the cases where a vehicle was only present in the footage for a small number of images, then this would lead to a fundamentally unhelpful speed range. These legacy practices have now all but ceased, and with careful consideration with a lightboard analysis, the tolerances applied to any calculations arising for the timing element are now negligible.

In summary, with the introduction of this single piece of equipment the errors in timing data have been reduced to zero on the majority of collisions. I cannot think of many other pieces of equipment that have been able to achieve such a seed change.

Since the introduction of the Frame Interval Timer, other manufacturers have started to produce their own versions, with slightly differing flashing patterns (to account for the effect of a 'rolling shutter' with a single bank of lights) (Input-ACE, 2021), but the original frame interval timer appears to be the favoured approach by UK Police forces with the manufacturing contract for the Forensic Collision Investigation Network (FCIN) being tendered again in 2022 (Bidstats, 2022).

It also appears to be the case that a number of other forensic providers are looking to replicate the device using a 10x10 array (to cater for even shorter inter frame spacings) (Lai & Tsui, 2019)

Furthermore, companies such as SiraView are developing machine vision software to 'automatically' read the lightboard footage, which saves time in a detailed forensic analysis. This software is currently in Beta testing and is due for release in 2023.

3.6 Video Analysis in Collision Reconstruction (First Edition)

Continuing the theme of CCTV analysis, it is probably the work around video analysis that I am perhaps best known with the industry, both in the UK and world-wide. The publication *Video Analysis in Collision Reconstruction* (Crouch & Cash, 2017) was first published in 2017 but really, it was/is the culmination of about 10 years of research and practical application. It is this book that forms the evidence contained within this subsection.

By way of a precursor, I know that the publication that is discussed in this section and the subsequent training is used internationally, in countries such as Ireland, Scotland, Germany, Hong King, Poland, Israel, Argentina and Australia to name but a few. I have trained Forensic Collision Investigators in each of those countries.

This has formed the basis for us to train private practitioners in the analysis of video footage. Basic training is provided by a single Police training provider within the UK, and it falls on me and Steve Cash to train those in the UK that require a more detailed knowledge and those international students and those that require a more detailed input into the theory.

Further to the presentation of our papers at international conferences, (Crouch, 2017) I provide weeklong courses to collision investigation students engaged in video analysis work. To date I have trained over 150 students, many of which were international students in countries such as Ireland, Scotland, Germany, Poland, Israel, Argentina, and Australia. Many of those students undertook the course in English, which is not their native language – the reason why they did this was because there was not a course that they could find that could be provided in their language. Such is the wide-reaching nature of this work, it appears that I have really struck a chord with providing a publication and a course that delivers the needs of a Collision Investigator, regardless of which country your investigations are based.

It also forms the core text for De Montfort University's programme modules for Police Collision Investigators. This is part of the core requirement for Police Collision Investigators to practice in the UK.

It is widely accepted as the text used for virtually all Police investigations in the UK where road traffic collisions are captured on video, be that from conventional CCTV cameras to dash camera footage. It is also widely cited for others researching the subject from those looking at matters such as impact speed of vehicles in test settings (Duma, et al., 2021) as well as those engaged more directly in collision investigation (Abramowski & Reński, 2022), (Ivor & Kolla, 2019), (Kolla, et al., 2022) and even those from the Institute of Physics reviewing accident reconstruction methods within national legal frameworks (Duma, et al., 2021) with comments included such as:

"Deeper knowledge can be gained from the great work of Crouch and Cash." (Wach & Unarski, 2020)

At the time I first joined the Metropolitan Police, the collision investigation prevision was provided from 5 locations, one base located in the centre of london and four others towards the outer London boroughs. The first two years of my career I worked from the central London base – meaning that most of the cases I was involved in where close to the centre of London. As may be expected, at the time (and indeed still in the case today) that this area had the greatest density of CCTV cameras anywhere in the country - as a result many of the collisions that I was initially involved with were captured to a lesser or greater extent on CCTV. However, despite this significant evidential resource only a few of those collisions captured on CCTV had the video file analysed as part of the investigation.

The main reason for this was that there were only a limited number of techniques available to Collision Investigators at the time. Only those cases where a clearly visible car drove across some clearly visible reference points could a speed be calculated. Actually, this is not quite true, as I was of the view that a speed could be calculated but they didn't know how to do it.

Entering this environment only a year or so after I had finished some of my master's modules relating to image capture, and areas of sensor technology, I found the position that only a few of the cases were analysed, odd. It simply did not sit well with me that whilst an event was captured on video, we could only perform some basic calculations, and on quite a few occasions did not use it for any scientific calculations at all.

This was plainly wrong, how could something be captured on video, yet we couldn't do an analysis with it? On a couple of high-profile cases this work would be outsourced to the Forensic Science Service based in London, however, as it may be the case this is an expensive outsourcing process and therefore only those jobs that demanded the very highest resource requirements were afforded this luxury.

I remember very clearly early on in my career while still technically a trainee I was involved in a case that was captured on CCTV. I was able to calculate in a basic way,

the average speed of the vehicle using a technique that hadn't been taught before or used before to my understanding. I had to fight with my seniors to allow me to present this as evidence, which ultimately, was uncontested at court. I have since found out that I was uncontested, as this was reviewed by a number of video experts who agreed with my findings – and therefore were not asked to give evidence.

It was from that point on that I was inspired to take some of my existing academic knowledge and apply them to the practical Police collision investigation workload. This of course was not easy; CCTV cameras never capture a collision in the same way as you might expect of a deliberately videoed event to be. However, the primary principles of photogrammetry remained the same, this is simply measuring things from video footage all be it grainy, incomplete, and/or occurring on the edges of the field of view of the camera.

Once again as with yaw mark analysis this was a case of taking the theory academic approach of photogrammetry and designing a set of tools that will be practical for a Collision Investigator working in the field to use. They had to be robust, forensically sound, and stand up to the rigours of scientific testing - ultimately these will be presented to a Court as accurate measurements from which accurate speeds have been calculated. They had to be right.

Furthermore, as no two collisions are the same, one or two tools were never going to be enough to solve the wide-ranging number of incidents that would need to be investigated. In total about eight different techniques were designed to deal with the varying different scenarios that could be faced by a Collision Investigator. They would be designed specifically for use in the field. Expensive software also was not an option at this stage, this was designed to be done with tools and equipment and software already available to the Collision Investigator. Once again this was at the very heart of the tools that were designed - a practical tool for a practical use.

In the Police environment things move very slowly and trying to affect change is difficult. These techniques were robust they'd been peer reviewed by external sources yet of course, there is some resistance to change. This may in part be the fact that the “new boy” was trying to introduce new techniques that hadn't been proven, or that

there was a degree of initial resistance as there was a distaste as implicitly this was being told that investigations 'were not being done properly' – although this was never at the forefront of my mind. Perhaps, it was a situation where the teams were either scared of the new science or felt that this was bringing a huge amount of extra work to their already overloaded diaries. Either way initial uptake could hardly be described as being fully embraced.

Then came a significant turning point in events. The Forensic Science Service closed in 2012, and the Police no longer had anyone to outsource CCTV work to. Alternative suppliers were sought, but they were either found to be cost prohibitive, or were unable to work within the timescales of a criminal investigation. This was at the same time that some of the Coroner's in London were beginning to be become a little sceptical as to the limited way in which video evidence was (or rather was not) being used. Now, this analysis *had* to be conducted in-house, and Collision Investigators *had* to get to grips with this video footage.

A few of the techniques I had developed were 'ready to go' and some of the processes and procedures were written down. A number were still in development, and it was no longer sufficient to have these available on an ad hoc basis – they needed to be used, and the techniques had to be referenced.

These techniques were peer reviewed by Professor Roy Davies, then at Royal Holloway University of London who agreed that they were scientifically sound. But this was only one part of the problem, these could be written in a research paper which would have been written with relatively high-level language, but that would have significantly limited the traction this was likely to have. I knew the techniques were scientifically robust, and that they could help assist in so many roads traffic related incidents, but all that effort could be wasted if this was not written in a way that was accessible.

This again is where my working partner at the time Steve Cash played a critical role. Together we set down to write this text, however, we never set out to author a book. In fact, the idea of the book came much later. We set out to write a user guide and/or a training manual. This was written from the ground up in a way that was designed to

train and teach. Removing as much of the technical language as was possible and including examples and step-by-step processes – avoiding the pitfalls and exploiting the data as much as possible. Little did I know it at the time, but this was perhaps the most important goal. Afterall, photogrammetry as a concept was not new, taking measurements from images has been in existence for nearly as long as taking photographs was possible. Albrecht Medenbauer is often credited with introducing the term 'Photogrammetry' (or 'Die Photometrographie') and the idea of documenting (buildings) and taking measurements from still images (Meydenbauer, 1867) (Albertz, 2001). If you can position a vehicle in two places (and measure the distance between those points) and are able to establish the time it took to travel between those points, (using techniques and equipment discussed in *Frame Interval Timer ('Lightboard')*) then a speed can be calculated. When a vehicle passed over something physical on the road surface, such as a white line or a drain cover for example, investigators were able to perform calculations as this measurement would already have been collected from the scene. This was never written down, or published, it was simply a common working practice. But when the vehicle was captured in less 'convenient positions' then little was being done.

In developing new techniques, I needed to take some existing knowledge and apply it to a subject matter in a new and novel way. For example, a number of studies had been used to establish the position from which a photograph was taken when the position of other objects were known (Ghosh, et al., 2003) and additional work had been performed to show the position of say, a road sign or other ephemeral data, (Greatrix, 2011), but nothing had been applied to positioning a vehicle.

Taking this technique as a stand-alone item, a CCTV image is essentially a photograph (save for any temporal compression issues). In most collisions the position of the camera will be known (as it will have been identified to recover the footage in the first place), so instead of using these techniques to position the *camera* they can be reverse engineered to position an object – and in the case of a collision investigation, this is a vehicle. If this is done for two positions, then a distance can be measured.

Perhaps the real art in this was to remove the technical jargon involved with photogrammetry, using co-ordinate systems and planes and use a language more commonly encountered in collision investigation, such as 'lines of sight' for example.

The book was therefore centred around two key principles, to present new techniques to the industry and also to write them in such a way that they could be easily understood by practitioners and used tools that they already had at their disposal. This turned out to be an essential step in the traction that this text has eventually had in the industry. It was accessible, with numerous worked examples from real world crashes. My focus was to make sure that when something could be done with some video footage, the opportunity was taken. I wanted the attitude of putting the disc of footage to one side with the comment 'we can't do anything with that' to stop. This was the mentality that led to the next steps that I took with this text. I gave it away!

In the UK nearly all of the Police collision investigation training is provided by one company and the awards are issued by De Montfort University. This is a longstanding arrangement and one that serves the industry well. I provided this text free of charge to this training provider to read it with the freedom to distribute this to their students as they saw fit. I envisaged that this may enhance a few sections of a couple of the courses that they offered, but what actually happened was much bigger.

The book was taken, in its entirety as the course text for all students studying the collision investigation courses. This book was the key text for anyone studying collision investigation in the UK since its release in 2017.

In real terms, this means that about 400 Police Collision Investigators have been trained in this time[2], with the total number of practicing Police Collision Investigators totally in the region of 450. To put this simply, it means that if the Police have investigated a fatal collision in the UK in the past 5 years, there is a remarkably high likelihood that they have been able to do so due to my work in this area. That means that cases where the error bounds use to be unusually wide are now in a position to

[2] At the time of authoring this thesis, the number of students was just under 400 and continues to increase with every academic year.

be useful to a Court. It stands to reason that a high number of cases where video footage would have been unable to be used instead now has been able to provide the answers to loved ones about how their family members died.

It is impossible to put an exact number of the number of cases that this work has assisted with to some degree or another, but if I were to make a reasoned estimate based on experience that on average a Collision Investigator will deal with say, 5 cases a year involving video footage (as an average, you would expect those based in cities to do more and those in more rural settings to do less), and that roughly 80 students were trained per year, that in the region of 6000 road traffic collision involving fatalities and the most serious of injuries have relied on this book.

Of course, this book has not only been the reserve of the Police, but it has also been widely used by a number of private practitioners (in the order of 100) in the UK. Meaning that this is not only used in the criminal defence cases, but also more widely in the civil forum also.

That is also before the copies that have been used abroad, for example the Police laboratories in Hong Kong (who are responsible for the investigations in that area of the world) also rely on this text, as well as many other organisations that use this around the world.

Even if the number estimated for the UK above is considered to be an overestimate, the number is likely to be surpassed when the international picture is taken into consideration. Regardless of the actual number, it would still relate to a staggering number of cases. This is something that I am proud and humbled by in equal measure.

Furthermore, this publication has be cited in the Good Practice in Forensic Collision Investigation where a number of the elements of the book have been used within the guide who purpose is listed as:

> *"To ensure that, when identifying and recoding evidence from CCTV, sufficient and accurate information and data are gathered, so that later, during the writing of the expert report, consideration and analysis can be*

given to calculating the pre-collision speeds of the participants with appropriate error bounds" (National Police Chiefs Council et al, 2021)

In summary, what set out to be a manual for the Metropolitan Police to use 'in house' has turned into a book that is used internationally for the investigation (and training of investigators) involved in the investigation of the most serious road traffic collisions.

3.7 Video Analysis in Collision Reconstruction (Second Edition)

Since the first edition of the book, in 2017, perhaps predictably, there have been a number of advancements, particularly with some of the processes that are available with inexpensive software, or software that would reasonably be expected to be already possessed by Collision Investigators. Therefore, it is entirely right that the book is updated to reflect these advancements also.

It is fair to say that I never expected the first book to have the impact that it did, perhaps still in the mindset that it was originally started life as a training manual, intended mainly for practitioners only in the field of collision investigation.

It is partly due to reflecting on the impact that the first edition has had for the purpose of this contextual piece that I have realised what a difference this text has made to the industry. Previously, when people spoke so highly of the book, I took it as a compliment as to the content (which of course it aimed at). What I didn't realise was the compliments were also about how it has helped so many people on *their* pursuit of finding the answers to the questions surrounding a collision.

There was no book that existed prior to the first edition, and there had not been anything else published by anyone else after. Therefore, it had to be us that published the second edition. There was a whole industry waiting for a second edition, even though they may not have consciously realised it. It was our responsibility to update it, it was our responsibility to action the changes to keep up with the way in which technology was changing. But I had to write it with the same mentality, it was a book to be used, not a text about conceptual ideas that could never be put into practice.

That is why the second edition has been released in February this year (Crouch & Cash, 2023). The book continues with the same core principles as the first edition, as it was important to me that the same reader friendly, easily accessible nature was maintained. Again, I have kept the science streamlined and in bite sized chunks so that those who have read the first edition can continue expanding their knowledge by reading the second.

There has also been a meaningful change in the industry with respect to how forensic science is controlled. The Forensic Science Regulator (FSR) gained statutory enforcement powers in 2022. The FSR has now determined that ISO17025 is the:

> *"Appropriate international standard for the digital forensic sciences including the processing and handling of video, related imagery and audio"*

as outlined in an appendix to their Code of Practice and Conduct (Forensic Science Regulator, FSR-C-119, 2020) issued in 2020. This therefore means that there is a regulatory requirement for any forensic practitioner including Collision Investigators, that are handling video evidence to understand the fundamental processes at play with video, both how it is recorded and stored. This means that it is no longer sufficient for a Collision Investigator to know just about positioning objects, or the intricacies of timing discussed earlier, without also understanding how such processes as transcoding, spatial and temporal compression, interpolation, and other image artifacts are generated – this is regardless of whether or not they will materially affect any calculations or conclusions reached.

But it is not simply because of the FSR directions that the additions to the second edition have been made, indeed it is my view that these changes would have been made regardless of their position. There are number of very well regarded texts (Weynand & Piccin, 2016), (Damjanovski, 2014), (Davies, 2012)[3] that deal with the theory of video analysis and understanding how an image is created, however, many of these are written from a standpoint of a 'known' (i.e. the object that is being captured by a camera is known by the examiner) and the processes involved on the machine

[3] Not intended to be an exhaustive list

vision, or video analysis is explained to the point of the resulting video file. But this is the complete opposite pathway that video forensics takes. A forensic video analysist starts with the video file and wants to identify the 'unknown' – if you like taking the established process and driving it backwards.

This is why forensic specific texts are important in this regard, ones that are industry specific, and as a lay reader, are surprisingly scarce, in my opinion anyway. Therefore, there is a need in the industry to deal with the building blocks of video analysis, from a forensic perspective are required.

It is against this backdrop that the technical areas more widely associated with the field of Forensic Video Analysis (FVA), that did not appear in the first edition of the book have now been included. Of course, staying true to my original ethos, these have been broken down into relevant sections and related back to collision investigation.

This updated document has again been provided to the Police training provider which has in turn been updated as the latest text for students to study. The feedback received to date, whilst this publication is in its relative infancy, is that again it has managed to explain some of the complex terminology and concepts in a way that is accessible to the collision investigation community.

There is one further additional section added to this second edition, which relates not only to collision investigation, but also to the whole expert community. This is a comprehensive section covering the art of giving good expert testimony. It never ceases to amaze me that, when speaking with experts from other disciplines how little they give live evidence to a Court.

Anecdotally, experts sometimes comment that giving evidence is something that they find challenging, something that they are scared of, and no-one has ever taught them how to give their evidence, nor give feedback on any evidence they have given in the past. It is perhaps concerning that there are a number of expert witnesses who are scared of giving evidence in Court, and a good number of 'experts' who have never given evidence at all. This is by no means a criticism, as ultimately, it is the Court that

decides if you are going to give evidence or not, and whether it will be contested or not.

But what if you are one of those experts that has been called to Court for the first time? Perhaps you work in a discipline where you are rarely called to Court, and therefore your peers cannot offer much assistance? How do you know what to do, even from the basics of where to stand and how to conduct yourself in a Court room, or how to refer to the Judge, or how best to convey your message? I have had the opportunity to give and observe considerable amounts of expert evidence being given to the Court and read many judgements about how their findings have been perceived. I couldn't, however, find anything written down or trained of how an *expert* thinks good evidence should be given. The emphasis in the previous sentence is important. There are a few documents in existence, and more commonly commercial training courses given by *lawyers* about how to give good evidence, but nothing that I have found written by a fellow expert. This is important for a few reasons, the scientist knows the science – that sounds obvious, but what I mean is that a scientist knows the level of detail they need to convey. They need to convey it in an accessible way, not in 'lawyer speak' or laid heavily with 'geeky language' to make them sound clever, but instead convey the message clearly and accurately. Also, by the very nature of the role, a lawyer has a particular slant to put on the evidence, but an expert must remain impartial – hence the need for something written by a peer. I often refer to giving evidence as *"the art of presenting a science."*

This was something I was passionate about, something that in my general working practise I often had musings. Why is this something people find so difficult? Afterall, I had spent quite some time thinking that this was something that the industry lacked. So, I wrote what is over 10,000 words on how to give good evidence, and the processes leading up to giving that live evidence. I then got truly fortunate again, I had discussions with Dr Nicholas Braslavsky KC about this document and how I wanted to support those experts to give better evidence, and quite fortuitously this was an area that Dr Braslavsky was also engaged with, except from the position of receiving this evidence in his position as a Deputy High Court Judge. He very kindly added elements that he commonly encountered, and peer reviewed this document. The result is an

'easy read' guide to giving scientific evidence from not only a scientist that presents similar evidence, but from a High Court Judge's perspective who is the ultimate recipient of the evidence who passes judgement on it. This chapter of the book is included in *Appendix 7 – CCTV Analysis in Collision Reconstruction – 2nd Edition Extract*. It is also discussed in more detail in *Subsection 5.4 - Giving Evidence Publication*

The main purpose of this is to assist experts who are new to giving live evidence (or perhaps those who do not do so often) with practical steps to give better evidence. As the narrative may suggest it is deliberately designed to be a practical guide. To assist with some 'myth busting' and also to provide a perspective from a Judge – after all they hear hundreds of experts giving evidence to them.

The question of course is why this is included in a book about CCTV Analysis, when the chapter does not specifically talk a lot about the presentation of CCTV evidence. Firstly, it is important to note that the fundamentals of giving live evidence are the same regardless of subject matter. Secondly, as far as I am aware, there are no texts where you can simply pick up a 'guide to giving evidence in court' and therefore to get this in front of experts that need to hear it needs a 'vehicle' and the book provides a good platform for that. Finally, this is written as a 'standalone' chapter, and I have already been asked by a number of practitioners in different disciples to provide presentations to speak to them about giving evidence. So, there is clearly a need for this to exist and I am sure that the demand to talk about this as an independent topic will grow.

3.8 Validation of developed techniques

At the very heart of this thesis, is the investigation of the death or serious injury of an individual. A criminal trial involves, at least at its culmination, a decision by a Jury as to whether someone is likely to face a lengthy prison sentence (save that the actual sentencing is reserved for the Judge), or not. Therefore, it is important the Court is provided, the very best facts (including any tolerances and limitations) upon which to best consider its decision.

The techniques I have developed form part of the administration of justice and therefore it is important that they are correct. Scientific validation is an important safeguard against a significant error – which could ultimately result in a review of hundreds of cases. It is also an essential element in the public's faith in forensic science. A flaw in the evidence of one 'forensic discipline' has a ripple effect on *all* forensic sciences – take for example the high profile 'shaken baby syndrome' cases (Crown Presecution Service, 2021) (which interestingly became partially resolved with consideration to the Child Restraint Airbag Interaction Dummy – CRABI (van Zandwijk, et al., 2019)).

The FSR outlines in its codes (The Forensic Science Regulator, 2023) that a key element of quality management is *"the validation of methods".* Scientific validation is the method by which the credibility of a method or process is verified (ILAC, 2022)

This section is intended to outline which of my research elements have been explicitly (and implicitly) validated, and which ones have not followed that route and the justification for that position.

Maximum Attainable Braking from a Pedal Cycle

This paper was peer reviewed by Dr Chris Lusher, Royal Holloway University of London. To the best of my knowledge however, this paper was not validated directly with test data, it is simply a mathematical argument.

As discussed in the narrative above, this paper was designed more to 'test the assertion' about how pedal cycles were likely to be braked. However, what is of interest is that there has been a number of additional tests that have been done with pedal cycle braking in the years that followed on from my paper, and the real world testing agrees with the mathematical model (Hittinger, 2014), (Joganich, 2018) and (Famiglietti, et al., 2020) – each of which are validated studies that produce similar results to mine. Therefore, whilst my paper itself has not been explicitly verified, the values it produces are implicitly verified by the papers that have followed. Therefore, whilst the validation of the techniques is not my work, it has been conducted by others and as a result I consider it justified to not rehearse the work of others.

However, as an extension of this work I intend to modify this mathematical approach to other areas of micro-mobility – such as e-scooters. This is made possible by the newly developed Small Vehicle Testing System SVTS, recently manufactured by ScenePro, which is the small version of the validated testing equipment used widely by the Police for the Skid to Stop/Deceleration tests discussed further below.

Given that this is another two-wheel device, I am anticipating that the mathematical model will apply also to e-scooters and would therefore be able to retrospectively validate the findings in the original paper at the same time as conducting the new research.

Quantifying the uncertainty in Skid to Stop calculations

Within the discussion earlier with respect to this publication, I document that this particular publication was relatively unique, in that it did not represent a dramatically 'new' contribution to knowledge – or at least, it was not a new technique per se. This was a discussion of how errors propagate through a mathematical calculation, regardless of the forum, or the mathematical equation (Ku, 1966). It was, in its purest form, a consideration of error propagation applied to one specific calculation used by collision investigators, and in my experience perhaps the one that is most commonly used. This error handling approach is now explicitly taught as part of the UCPD and CertHE courses (De Montfort University, 2020).

With that in mind, this is not something that, mathematically, has been explicitly verified – however given that it is not a 'new' technique, then I consider this approach to be justified, echoing earlier comments that a similar formula had been previously defined, albeit in imperial measurements (Brach & Brach, 2011). Therefore, rather than rehearse a discussion of error handling with respect to any mathematical equation here, it is perhaps salutary to discuss how this is now used in collision investigations. The work of the FCIN (Forensic Collision Investigation Network, 2020) demonstrates that whilst previously there has been considered only little variance in the rate of deceleration between similar-classed vehicles, the detailed systematic testing of a vast sample of vehicles has revealed that there is instead a small, yet significant difference.

Indeed, contained within this piece of work my mathematics were used to compare the tested results against the 'ground truth'.

Given that this mathematical model is now being taught to the Police collision investigators (as above), this has been successfully embedded into practice within the collision investigation community. Whilst I claim no credit for the measurement of the deceleration rate of vehicles, as that credit must go to ScenePro Digital Forensics who have produced a validated testing tool (Forensic Collision Investigation Network, 2020) (ScenePro, 2020) used by 41 of the 43 Police forces in England as well as many more worldwide. It is that data, combined with the mathematics used in my paper (due to the techniques being taught by De Montfort University, discussed earlier), that is now used to present these calculations in reports.

I am satisfied that the verified steps taken by the key stakeholders in this area (namely the FCIN and DMU) that this technique is suitably validated.

Yaw Mark Analysis

As discussed, this model was derived from first principles. There is difficulty in obtaining a large data set with respect to the validation of these tests, as generally speaking the methodology requires a vehicle to be driven to the point at which it loses control, and it then needs to be in collision with an object at a speed that can be approximated or broadly quantified. The safety implications of this when testing make it extremely challenging given that a vehicle out of control needs to strike a specific object.

One such test does exist (Bellion, 1997), and the validation works were conducted within the YMA publication itself. Of the 22 tests that were conducted, there were 16 tests that had sufficient data that allowed for values to be obtained. The YMA methodology predicted all of the speeds correctly. Therefore, this technique has been validated against this data, although this dataset is limited.

The works of Wach and Zebala (ibid), reference our YMA model in their paper entitled *"Striated Tyre Yaw Marks – Modelling and Validation"*, where they comment that our

works resulted *"in a narrower error band than conventional CSMs [Critical Speed Models]"* which corrected calculated the vehicle speed when compared with ground truths.

Due to recent legislative changes, namely *Regulation (EU) 2019/2144* (European Commission, 2021), data can be extracted from Airbag Control Modules (ACM's) which allow for pre-crash data to be obtained from 'real-world' high speed loss of control crashes. The regulation also stipulates that new vehicles sold from 7th July 2024 onwards must be fitted with these devices. Therefore, in my opinion, given that this will result in more data from 'real world' crashes being available, it will provide the opportunity consider more data against which the YMA formula can be validated further. Paradoxically, this increased data set will diminish the requirement for the use of the YMA formula, as the speed of the vehicle at the commencement of yaw will be identifiable in the data.

Frame Interval Timer

Whilst not a publication, the Frame Interval Timer is a device which, by its design, needs to be highly accurate with respect to displaying times. Given that its operating environment is 'out in the field' it must function in all weather conditions and also be in a position to withstand some of the impacts it is likely to endure when being carried (and on occasion dropped) when deployed by collision investigators at real world incidents. Given the impact an incorrect time can have on the calculation of speed, it is imperative that the device is able to operate accurately.

The device timing has been tested and meets the requirements of the ISO17025 as tested by the Home Office themselves. Indeed, it was found that the *accuracy* of the timing of the device was several orders of magnitude greater than the *precision* of the device meaning that it is considerably more accurate than it 'needs to be'. The device has been tested in a number of environments, and has certifications for use between -10ºC and +35ºC with a water resistance of IP54 (MacLennan-Brown, 2017)

Video Analysis in Collision Reconstruction (First and Second Editions)

As discussed earlier, these techniques were peer-reviewed by Professor Roy Davies based on photogrammetry theory. In 2017 the Forensic Collision Investigation Network conducted a series of circa 50 tests using multiple cameras and vehicles of differing but known speeds where driven through the field of view of the camera and the techniques within the text were tested.

Interestingly I was never given sight of the testing results, however, it is my understanding that the techniques were held to be valid – indeed, they then went on to be taught as the core methods for establishing vehicle speed (De Montfort University, 2020). Therefore, it follows that the techniques were indeed validated.

It is also the case that the Police collision investigation units in the UK are currently working towards the ISO17020 and ISO17025 classifications with respect to the calculation of vehicle speed. At the time of authoring this thesis, further tests are being conducted specifically for the purpose of demonstrating compliance with the Codes of Practice (Forensic Science Regulator, 2023). The results of the testing are currently embargoed and will be released as part of the documents produced for the accreditation – however, I understand there are to be no changes to the techniques employed, and therefore the methodologies defined in the texts will remain as the techniques used for the investigation of the most serious collisions.

3.9 The Institute of Traffic Accident Investigators

I am the Deputy Chairman for The Institute of Traffic Accident Investigators (ITAI) which is a world leader in the field of traffic accident investigation. Their aim is to promote *'Good Practice in Forensic Collision Investigation.'* This is for the benefit of the Membership, Emergency Services, Courts, road safety and other stakeholders. They have a unique mix of skills, expertise, experience, and collective knowledge is used to provide a foundation for the Membership to enhance Professionalism,

Impartiality, Education, Science advancement, Research, Competency Testing and to promote honesty and integrity in everything we do[4].

In this subsection I rely on the introduction of learning webinars 'ITAI Talks', the annual Crash and Research Day, the creation of the Certificate of Professional Competence, Equality and Diversity, the 'Good Practice in Forensic Collision Investigation', updating of the Code of Professional Practice and the creation of the Code of Ethics. Whilst I have been involved in a number of other membership matters, I am of the view that my impact in professionalising the industry can be best demonstrated with these elements.

Since 1990, 'Impact' the Journal of Traffic Accident Investigators has been a source of technical papers specifically designed for Collision Investigators. This route was taken rather than relying on the more traditional SAE paper route (although there is a considerable amount of 'cross publication') because it was important to provide one central location for research papers in this niche area of forensic science. This is a huge support to our membership, and for many one of the reasons why they hold membership. Papers are published from around the world, and what is interesting reading some of the back issues, is that some of the 'innovative' thinking back when an article was published has, on many occasions, now engrained itself in the core working practices of the Collision Investigator. It means, with near certainty, that the papers we are publishing today will be common working practice in the future.

In order to support out members and increase the knowledge of those practicing in the field (and those from legal or other backgrounds that take an active interest in the subject matter) we provide a series of webinars, on a wide range of topics once every other month. Due to COVID-19 restrictions preventing the annual conference (that has been running since 1993), it was important to quickly adapt to the delivery method of our training provision to ensure that our membership was supported during the times of disruption. The solution to this was to move training to a virtual platform, however, whilst we did hold 'virtual conference', attendance numbers were a little over 100, which was relatively low by conference standards. The reason for this was not unexpected however, given that the Institute represents a number of Collision

[4] As per the ITAI website

Investigators who are Police Officers, given the nature of the COVID-19 pandemic, it was difficult for Police Officers to be released from their duties to attend a full day conference. As the disruption caused by the pandemic continued, I was part of the team responsible for making the decision to continue with the remote delivery method, but to split the delivery into 1-hour webinars that occurred every 6 weeks or so. We have delivered these training sessions since 2021, with guest speakers from around the world. Topics have included, Scientific Methods to Evaluate a Driver's Response, Scientific Methods to Evaluate a Driver's Response, Investigating Highly Automated Vehicle Collisions, E-Scooters & Bicycle Impacts and Situational Awareness of Distracted Drivers to name but a few. The aim is to provide a diverse range of topics. What has been an interesting sidenote to this, is that whilst these are technical presentations aimed at the forensics specialist, there have been a number of legal professionals that have attended, who wish to gain a better understanding of these highly specialist topics.

This has allowed for our membership to easily, (free of charge) maintain their CPD throughout the COVID-19 period, but also, we have found that this delivery method is extremely popular, and we are continuing it, with no current plans to change the delivery. This is now in addition to the annual Crash and Research Day that has commenced again.

As mentioned earlier, there are a number of academic Collision Investigators who have not had the opportunity to attend a real crash scene, so every year we conduct a series of live crashes to assess a number of areas including damage profiles – this is where the annual Crash and Research Day becomes a critical provision. In addition, we also conduct a number of ‘experiences’ where people can gain real world experience of driving a vehicle with partially defective brakes, or wildly imbalanced tyre pressures. These are things that Collision Investigators regularly have to comment upon, but until we started putting these events on had never experienced it first-hand. I get to lead a high-speed loss of control experience, whereby we can talk through some of the behaviours of the vehicle, as well as the key elements of my paper, which was discussed earlier. Throughout the course of the day, about 100 students get the chance to experience what it is like to drive at a speed between 40*mph* and 50*mph*

and try to corner in such a way that the vehicle loses control. It is of course true that due to the nature of the experience, this is a bit of a 'crowd pleaser,' but it has a serious scientific meaning. Just how 'badly' do you need to drive to generate those curved tyre marks I was speaking about in detail. Now, combining these two elements, I am able to allow Collision Investigators not only to calculate the speed that the vehicle was travelling at, but also comment on what had to be done to physically lay them on the road surface also.

Figure 11: *High Speed loss of control experiences*

It is noteworthy that this goes hand-in-hand with the research that is discussed in *Section Yaw Mark Analysis (YMA)*, whereby the research developed a mathematical calculation to establish the vehicle speed. This was disseminated along with a spreadsheet that performed the calculation to establish the speed, which would, in itself be more than enough to allow an Expert to produce comprehensive findings. What this experience day allowed practitioners to do, was to be instructed by me to *feel* what it was like be in a vehicle that are leaving the marks.

Of course, one could argue, that this is not an essential requirement for giving evidence, which is of course true. It does however, strike at the very heart of being an expert witness (as discussed in the next chapter), whereby there is a duty to assist the Court in matters outside of their own understanding. I doubt that anyone (or a least I hope not) in the Court room would have ever experienced what it feels like to *drive* a

vehicle and corner so fast and firmly that the cornering forces reach the level of grip. This is precisely the experience that I am lucky enough to give to Collision Investigators in these testing days. It is an opportunity to not only discuss the science (our research) but also what it would feel like to be travelling in a vehicle at speed and to lose lateral control – or to put it another way, how badly you would need to drive for this to happen to you. This is not a simulator test, or some computer modelling of a collision, this is physically driving a vehicle, at speed along a runway, and applying a driver action to such a degree that the vehicle experiences a loss of control.

Because of the facilities that we have developed over the years with respect to the testing and physically crashing of vehicles as part of our annual Crash and Research Day we are perfectly placed to assess our members in the analysis of an actual scene. This is the only organisation, of which I am aware, that is in a position to assess whether or not an expert has acted in a manner that is considered below that of a competent Collision Investigator, and I am proud to be part of the team that created this provision. It is an essential function so that fellow Collision Investigators, the judiciary, and the public alike can have assurances that those providing expert evidence are doing so in a scrupulous manner – and it is my view that the public and judiciary can expect that a Collision Investigator's competency is tested at an actual crash scene.

Of course, it is not just a matter of setting the standards, it is also about assessing competency and in 2020 I was instrumental in the design and implementation of the Certificate of Professional Competency (CPC). This assesses the practitioner's ability to identify, record and analyse information from a crash scene. I am extremely proud of what we have managed to achieve with the CPC provision. In all assessment up to this date that I am aware of, involved assessing an individual's competence to identify marks at a *mock* crash scene, or from a series of photographs. It is clear that such an assessment can only assess part of the skill set, it can never be an end-to-end competency assessment as not all of the elements are tested. In a car crash the energy that is dissipated leaves a number of different marks and an extensive debris field. It is never possible to position two static vehicles and replicate these marks in any convincing way. Therefore, we do not take that approach.

From the outset I was extremely vocal with the need to assess students at an actual crash scene, and that as an Institute, I wanted to ensure that we could assess people's competence as an end-to-end analysis. This cornerstone principle has led to the design and implementation of an assessment that takes place at a 'proper' high speed crash. Two vehicles are physically crashed together, at speed (on an airfield) and that forms the basis for assessment. This is unique, certainly in the UK, but also for a number of our international members.

ITAI has a number of assessors, and I am an IQA tasked with ensuring that all of the assessors are providing a consistent approach to deciding on the competence of the candidates looking to have this assessment. This is currently an optional process that can be undertaken by the membership; however, this will be required for any of the membership wishing to move to the next levels within the organisation.

These assessments form a key role in public trust in the ability of our members. There are numerous studies on how differing organisational and professional approaches define their professional members. Perhaps one of the most relevant to our field of practice is the definition of practitioners who have automatism over their daily function (i.e., how they approach an investigation and are allowed to have 'discretionary judgement' based on their education, experience and vocational studies (Evetts, 2009)) – this is the heart of the function of an expert. She continues to describe that trust exists between the practitioner and the client (which indeed there must be, as the relationship of legally privileged) and that the practitioner is responsible for their own daily regulation but guided by Codes produced by professional bodies. This is where the Institute play a significant role, and where I have been instrumental in the creation and updating of the codes.

In 2019 as a Council, I was part of the team that produced the *Good Practice in Forensic Road Collision Investigation – A guide for practitioners* (ITAI, 2019). This is a collaborative piece between the National Police Chiefs Council and Accident Investigation Training Services. This document was aimed at the forensic collision investigation community with a view of setting out a minimum standard of acceptable practice and also maintain a level of consistency amongst practicing professionals.

This document was aimed at trained professionals, and rather than serving to 'teach' collision investigation, was designed to:

> *"Ensure that a practitioner collects, processes and reports on the data and evidence collected in a consistent and robust manner, such that others will have confidence in its veracity. Clearly, a practitioner can exceed the guidance; indeed, that is what is expected. Practitioners should never fall below these standards and will deviate from them only when there is a compelling reason for so doing. In such an instance, the reasons will be documented."*

This is a 72-page document which not only serves to set the standard, but also provide external parties with a guide as to what can be expected by a professionally competent examiner.

With the introduction of the competency testing as shown above and other smaller changes within the Institute and wider demographic I was part of the team that reworked the Code of Professional Practice and Conduct for Road Traffic Accident/Collision Investigators (ITAI, 2019). This lays out the 13 key principles to which we expect all of our members to strictly adhere to. The introduction of terms such as shown below are at the heart of what we do.

> *"…Honesty and integrity are paramount requirements for any person practicing or otherwise involved in road traffic accident/collision investigation."*

This updated document was designed in such a way to dovetail with the Disciplinary Code (ITAI, 2019) which sets out the standards and the process for those not conducting themselves in a manner in which aligns with the Institute's Codes. In the case where the disciplinary panel find that there has been wrongdoing, it is for us as a Council to decide the action to take, ultimately but rightly, removing a member from our register, publishing this fact, and notifying (where appropriate) the Court in which

the matter was heard – which can result in a retrial and/or further sanctions imposed on the expert by the Court.

As is normal in circumstances such as this, the Council of Management of the Institute are separate from the disciplinary panel, and therefore this is outside of the scope of this thesis.

The most recent contribution is to the introduction of a code of Ethics, Equality and Diversity which was an entirely new document in 2022 which I co-wrote with the Chairman. It states:

> *"This document sets a standard to which our members should aspire in their working habits and relationships. The values on which it is based should apply in every situation in which our members exercise their professional judgement."*

It sets out the 5 key principles to which all members are expected to comply:

> *"Integrity: To behave in accordance with ethical principles, and act in good faith, intellectual honesty and fairness*
>
> *Accountability: Take responsibility for actions, decisions and their consequences, be that as an individual or a group entity*
>
> *Independence and impartiality: To conduct forensic activities adhering to the overriding duty of an expert to the Court*
>
> *Respect: To respect the dignity, worth, equality, diversity and privacy of all persons*
>
> *Professional Commitment: To demonstrate a high level of professionalism and loyalty to the Institute, its mandate, Codes and objectives."*

This is an important document, not only for the membership to understand the expectations of them, but also to the commitment we have to the wider public and professional stakeholders. This document is still in its relative infancy, and it is difficult to measure the impact a document such as Codes has on the industry, save for when a member breaches the Codes and falls into the Disciplinary process. For that reason, there is no explicit evidence attached to this section, but it is safe to say that this contributes to the professionalism of the Forensic Collision Investigators within our membership.

Indeed, this is the point that is made by *Brough*, when she describes:

> *"An organisational culture can be thought of as a general resource that shapes and provides the means of achieving goals and aspirations. These resources may be in the form of sanctions and rewords and communicated through mission statements and expression of core values. (Brough, et al., 2017)"*

This strikes a real chord with me, as it appears that by introducing these formalised Codes, I have moved the Institute towards a more formalised 'organisational culture'. What I find most interesting about the reference above is that 'sanctions' is included as the first example. When creating an engaging and supportive network of Collision Investigators, sanctions is not one of the first things that springs to mind. However, it is a crucial step in to maintaining a high standard of credibility for the Institute. This is why all of the codes form the basis for the institutes disciplinary policy where, should a member come to notice for their conduct, this is the standard to which they will be judged. I have played an instrumental role in the recent modifications to the disciplinary policy that allows for *any* action that comes to notice being possible to trigger the policy. Previously it had to be only if referred to Council by a member or properly interested party. The reason for the change is simple, if a Judge were to make some detailed and critical comments about an expert, we as an Institute would need to be able to act. This is an important change in further increasing the professionalism of the members and the conduct of the experts.

3.10 External Examiner

As mentioned earlier, the main qualification with collision investigation is obtained from De Montfort University. For the four years prior to writing this thesis, I have been the External Examiner for the University. Now, it would of course be fair to say that an External Examiner role, whilst an interesting aside, would not normally be included in a contextual statement such as this. Save for a quick mention that there is only one External Examiner for this programme of study, and to be selected for the role, in itself, is a statement of professional standing.

In order to understand why this element is included here, requires a small amount of context. With the Forensic Science Regulator (FSR) beginning to take an interest in the activities of Collision Investigators, a body of Collision Investigators from the Police was set up to gain accreditation for this work – known as the Forensic Collision Investigation Network (FCIN). The idea was that, if all of the Police services were able to group together to define one standard of working practice, then it would be easier to fulfil the needs of the need of the Regulator in this regard.

It is perhaps worthy of note, that the accreditation which the regulator was seeking applied to organisations, but not to individual practitioners, and therefore the earlier works with relation to the CPC work with ITAI come to the fore. However, in this context, it was for the organisations to define what would be the minimum standard of academic qualification that would be for the practitioners to achieve. This is where my role as an external examiner meant I was considerably more involved that would be conventionally attributed with the role.

I was involved in a number of the formal discussions in my role as an external examiner and as a practitioner as to what I thought the minimum standard should be for someone to begin practicing in this field. It had been commonly accepted that a UCPD (Level 4) qualification would be appropriate. As far as I can gather, this was because this was the entry level qualification, and perhaps, seen as the cheapest possible way for someone to gain a certificate of competence. However, this is something that was rather frustrating professionally, as it struck me as a significant undervaluing of the work that was done. As seems logical, professionalism involves holding a qualification

that is recognised by both peers and the wider world, which forms the basis of some expertise (Mawby & Worrell, 2013). It also makes sense that these qualifications must be of a suitable level for the role to be performed. There seemed to be a lack of focus on the fact that we were investigating how somebody died. This seemed to be some kind of retrograde step, with thinking akin to 'oh, it's only an accident' rather than the fact that someone had died as a result (often) of the actions of another person. Why did we devalue the science of investigating how someone died to the lowest qualifications available? With that mentality, why don't we accept pathologists with a GCSE in biology or firearms expert that had never fired a gun?! Of course, this is said slightly flippantly, but it is a frustration that seems to particularly animate me – why would collision investigation be treated any differently to any other forensic science. This divide between the disciplines is something that I have been trying to bridge, and this is just another mismatch that didn't make sense.

With much wrangling and discussion (and to be honest some pretty feisty decisions, particularly with those holding the purse strings) the minimum standard to practice was lifted to the CertHE level. Of course, my own personal views are that this is still too low, but at least now there are specific modules covering key areas of the field of expertise that a Collision Investigator is likely to come across, rather than a superficial look at some of the elements at play. I am sure that this level will, in the fullness of time be raised further, but for now this is where it stands.

So, what is the difference and why was it so important to make this change? Well, the CertHE level includes modules such as accelerometers – which are used in nearly every test conducted by a Collision Investigator at the scene of a collision. Previously, whilst an investigator may have understood how to conduct a test, they would not have understood the fundamentals of the science at play. Secondly, collision investigation technologies (some of the modern devices fitted to vehicles to assist the driver, or to take steps towards semi-autonomism) must now be considered, as it is an important distinction between decisions that the driver took, and those that the vehicle themselves chose. Additional assessed input is now required with respect to environmental factors, along with applied mathematics for collision investigation. A vehicle examination module and also a compulsory CCTV element are now required.

It is however, not until foundation degree level that modules including pedestrian and pedal cycle collisions, motorcycle collision and dynamics, vehicle dynamics and tyre technologies, and advanced damage analysis are added. In my mind, which must be the minimum standard to practice in this field, but it may be argued that this will take too long to implement, certainly in the short term. My personal view is that this will eventually be the required standard, but it did not (nor was it ever likely to) happen during my (first) tenure.

The change of course was a positive one, as was the move to a more distance-based learning method of delivery, but these steps away from the narrative contained within this piece. Due to some tenacious work, both with my recommendations to the University and also to the industry partners, the minimum standard was raised, even though I do not feel it was raised high enough.

4 The Wider Demographic

4.1 Introduction

My professional works in this field are not restricted to the improving understanding or increasing support for the specialist Forensic Collision Investigators who are already working within the field. I have spent a lot of time working with the legal profession and also students increasing their knowledge into this specialism. In this section I rely on two elements of this work, specifically the Collision Investigation chapter of the Fifth Edition of the publication *Crime Scene to Court* which is included at *Appendix 6 – Crime Scene to Court – Fifth Edition – Collision Investigation Chapter*. This is a text aimed at students studying Forensic Sciences and forms one of the key university texts in that regard. The second element relied upon is a series of 'bitesize' webinars produced for *LexisNexis*, a 'go-to' source for legal professionals wishing to gain information and knowledge on a specific subject.

Further to this, I have provided expert insights into various matters, directly to increase the public understanding of the subject. These include expert explanations into two road traffic murders covered by the Netflix documentary series *Meet, Marry, Murder* and BBC News television appearances into the M25 coach crash that occurred in 2018.

This section is intended to be an overview of some of the ways in which I have been able to share my knowledge to further the understanding of collision investigation with the wider demographic.

4.2 Crime Scene to Court – Fifth Edition – Collision Investigation Chapter

I have just finished my most recent publication; The Royal Society of Chemistry (RSC) has produced four editions of *Crime Scene to Court* (The Royal Society of Chemsitry, 2016), a substantial book with an international readership, not least being one of the core texts for many of the degree students on any forensic programme in the UK.

The book was originally intended to provide a textbook for under- and post-graduate forensic science students in UK Universities. However, it has now been additionally used in Police training, CSI training, law schools, by lawyers, barristers, and also

actually used in court - and not just in this country. This is a well-established book, with the first edition being completed in 1998, that is very well respected in the forensic industry, and I have been asked to contribute to the Fifth edition, writing the new chapter on collision investigation. This is currently in its draft format, but so far will be contributing thirty pages (over 10,000 words) for new students embarking on their career in the whole field of forensics.

This book itself, is subtitled *The Essentials of Forensic Science* and it caters for many areas of forensic science from entomology to blood pattern analysis. It is written for those within initially limited scientific knowledge and covers the journey of an investigation from the scene of a crime to a laboratory and the culmination of the evidence in Court.

Within my chapter I have covered a number of fundamental topics such as human factors, single and multiple car collision, incidents involving pedestrians, motorcycles, and large goods vehicles. Outlined are how Collision Investigators approach the task of analysing the collision scene, what is looked for and how the evidence is recorded. It discusses why distinct types of marks are important, and what they mean with respect to the events of the collision. I have included discussions of the ephemeral data that is found at a collision scene, the way in which a scene is marked up and measured, as well as the testing that is conducted at a scene of a collision and the evidential value of conducting these experiments.

Time is spent discussing how information is obtained from a vehicle, from the digital data that appears to be more and more prevalent in modern vehicles, to the way in which the profile of the damage can be used to assist with the speed and direction of any impacts. Of course, as you may have guessed, a section on video evidence is also included and how accurate speed profiles from vehicles can be obtained with limited information.

I consider it an achievement to be the person selected by the editors and publishers to write this section. Out of all of the Collision Investigators in the UK (or indeed further afield) I have been selected to contribute to this book, due to both my knowledge of the topic and also with the clarity in which I can explain the subject matter. It was these

key elements that were identified with my CCTV book and also the LexisNexis webinars (discussed in *Section 4.3 - LexisNexis Webinar Series*) and also the Netflix documentary series (discussed in the *Section 4.4 - The wider public – inspiring an interest subsection*) that lead the publishers to approach me.

This is a nice accolade, and it is one thing being held in high esteem by your own peers, but to also be recognised for the contribution made to the wider forensic sphere to such and extent of being asked to contribute in this way is a mark of the impact that I have had within the industry as a whole.

Clearly, with this only just released, it is not going to be possible to specifically quantify the impact it will have in professionalising the forensic community. I consider it unlikely to have the impact on the collision investigation sphere as some of my other publications as it is not a granular analysis of forensic analysis. It may, however, assist the wider forensic community to understand what our area of forensic discipline is about and perhaps inspire some individuals to enter the industry.

4.3 LexisNexis Webinar Series

In 2019 I was asked along with my colleague to produce a series of 6 short webinars on the topic of Collision Investigation for LexisNexis. The series was entitled "Obtaining best evidence in Collision Reconstruction", within their Personal Injury (and Clinical Negligence) provision.

LexisNexis define themselves as a leading global provider and legal and regulatory intelligence. Amongst many of their other services (such as business development software) they are often considered in professional circles as one of the 'go to' places for technical resources and information relating to a number of topics across the legal spectrum.

LexisNexis were missing information relating to how and what an expert is likely to be working on with respect to an analysis of the collision, and we were approached to prepare this content from scratch. The aim of these talks was to make them a practical guide for the legal professional, not only covering the details of what they could expect

of their expert, but also how they could assist them by recovering the correct evidence and correctly instructing the expert. This was about defining the standard that could be expected of an expert, and how taking a collaborative approach with the legal team will produce the best results, which is why the series is entitled 'Obtaining best evidence…'

The six webinars produced covered the following topics:

- Collision Data Recorders (LexisNexis, 2019)
- Video Analysis (LexisNexis, 2019)
- 3D scanning and Modelling (LexisNexis, 2019)
- Locus Visits and Testing (LexisNexis, 2019)
- Analysis of Physical Evidence (LexisNexis, 2019)
- Picking your Expert (LexisNexis, 2019)

The collision data recorders webinar was predominately aimed at covering some of the recent developments with obtaining vehicle borne data. Discussions were centred around how this data is used including how it can be used to calculate the speed of the striking vehicle and not just the host vehicle for the data.

Figure 12: *LexisNexis Webinar Series*

The video analysis and 3D scanning and modelling cover many of the topics already discussed in this thesis, with a little more focus on the recovery and handling of a forensic video exhibit. The locus visit and testing was to discuss the merits of attending

the locus of a collision even if the crash occurred several months (or even years ago) as well as some 'jargon busting' with respect to some of the tests conducted by the police (such as the skid testing discussion that appears earlier in this thesis in *Subsection 3.3 - Quantifying the Uncertainty in Skid to Stop Calculations*).

The Analysis of Physical Evidence was to try and remind the viewer that a collision analysis is not simply about the technological analysis, every scratch, scuff, and gouge mark tell and important story about how the collision occurred. Often, I get approached on new cases, where the precursor to any discussions is 'We don't have much information on this…", but there are lots of marks recorded on the road. What they actually mean is "this isn't captured on CCTV…", so it is a reminder that the forensic discipline of collision investigation includes the analysis of marks, and lots can be told.

The 'picking your expert' was designed to round off the series and give a number of practical ways that a legal professional can find out, in a non-aggressive way, how to assess the suitability of their intended expert.

Together these form a body of work that is designed to educate the legal profession about the forensic discipline, a view from the 'inside out' if you will. I often get contacted by the legal professionals that have seen the webinars and complimented on how they have given a real insight into what can be done, and how the relationship between the expert and the legal team is so important in securing the best evidence possible.

4.4 The wider public – inspiring an interest

I am a firm believer that when professionalising any industry, it is the duty of the professional to inspire the next generation. In my field that means making the forensic discipline more accessible to the lay person. For the avoidance of any doubt, there are a number of ways this can be done, by practitioners engaged in the early years recruitment of forensic specialists, however my approach has been slightly different.

I cast my mind back and realise that the only reason why I studied Physics at university was because my Physics teacher during my A-Level made the subject relatable (perhaps a similar story can be recounted by a number of professionals in their chosen

field), but this is a principle that I hold close to my heart. In order to inspire the next generation, it is the professionals in this generation to make the field accessible. To put it simply, I am of the view that it is *this* generations responsibility to inspire the *next*. For that reason, I am of the view that is salutary and worthy of a short section in this thesis dedicated to how, on a public platform, media appearances can make the forensic science of car crashes the aspirational destination for people starting out on their careers or considering a change. Encompassed in this, is 'managing the expectations' of the public with respect to what collision investigation is all about – this is one of the cornerstones of science communication.

There are of course a number of different areas where the science communication has been used in a more public way. One of the big problems that any forensic scientist comes across is what is colloquially known as the 'CSI Effect.' The popularity of forensic science has grown as a result of a number of television dramas, such as 'CSI' and 'Silent Witness' to name but a few. It is a huge benefit to the industry as these kinds of programmes increase public interest in the roles, and as a result increased people are flooding into the industry. It does, however, have a downside to the wider world in that the forensic science shown in these programmes is not always a true reflection of what is possible. Furthermore, when combined with a Hollywood angle, the further from the limitations of the science you go. How many Hollywood films have you seen where the piece of video footage is enhanced and enlarged 20 times so that you could read the tattoo on somebody's arm or that a DNA profile was obtained from the tiniest fragment of dust from the corner of a room? In reality these are not possible, but it does heavily skew the public's opinion of what they believe is possible. This is known as the 'CSI Effect' and is something that the forensic scientist has to regularly combat, to manage the expectations of the public, if you will.

The expert's role is to teach and educate the reader (or the recipient of live evidence) which adds an additional level of difficulty because you need to realign what the public *think* is possible, to what is *actually* possible. If this is not done it leads to a situation where the reader feels that more could have been done with a particular piece of evidence and for whatever reason it was chosen not to be done.

This goes even further when you deal with the science of a car crash because lots of people drive and, in many respects, consider themselves to be an excellent driver, and secondly the situation where dramatized car crashes appear commonplace. But the way in which cars are shown to flip in a Bond movie, or suddenly burst into flames in an America action movie is a long way from the truth. Therefore, in order to combat this, there are a small handful of additional works that I have conducted that work in a way to try and better explain the science and challenge some of the misconceptions – this is separate to the court appointed function of an expert witness which is discussed in the next section.

The main principle behind these works is dealing with the 'general public' who would not normally have an interaction with these professions. It is about bring the bringing the forensic science to people's doorsteps and explaining it in a way that is simple to understand.

On some of the Crime and Investigation channels many high-profile murders are covered, with subject matter experts discussing the cases, and the scientific detail. On occasion these documentaries cover cases where a vehicle has been involved in a murder and there is motor vehicle involved. These documentaries cover all of the detail and need an input to camera, from an expert to explain the complex detail in a digestible way to those who regularly tune into these programmes. So far, I have taken part in two such documentaries, which are a new part of the Netflix Series *Meet, Marry, Murder,* with a potential audience in excess of 200 million people worldwide. There is no authentic way of telling how many have viewed this programme (save to say that prior to being on the Netflix platform there must have been sufficient numbers for Netflix to put it on their platform, which perhaps gives an anecdotal idea of its reach).

It is perhaps not the exact viewing figures that are the most important, it is more do with the need to explain the intricacies of a forensic science to a lay audience. In essence educating them in the science that underpins the professions. Again, challenging the CSI Effect discussed previously, and making the science accessible to all.

There is a real skill involved in presenting these findings for a documentary, as you know it will be heavily edited and the narrative will be broken into a series of chunks. This is unlike giving evidence to a court, where you have a longer time to speak, and a continued narrative of the evidence. The distilling of the science is paramount.

The delivery style must also be different in such and environment. The message needs to be communicated very quickly indeed, without being able to gauge any feedback from those being spoken to. The formal information is delivered in an informal manner – but in the same way as going evidence in court, it is important that the authority of the science is maintained whilst at the same time maintaining an engaging delivery.

Figure 13: **"***Meet, Marry, Murder" Recording*

I am of course asked to do more reactive works such as a newspaper article into the crash that Prince Philip in January 2019 (Daily Mail, 2019) was involved in and an interview of BBC news with respect to the M25 Swanley Coach Crash in 2018.

Figure 14: *BBC News Interview M25 Coach Crash*

These are reactive educational pieces, whereby there is a public desire to find more information relating to a particularly hot-topic, and it falls upon subject matter experts to explain complex processes in the simplest terms (after all, and as explained at length above, the role of an expert is to explain the most complicated matters in a way that the lay public will understand). They need to be reactive because within a few days there will be another news item that tops the list, and very quickly the forensic road traffic element falls from the public eye and the opportunity is lost. It is worthy of note, that the public impact here is not of great detail, it is impossible to write or present a piece to camera that is going to widen the understanding of the public dramatically, but I strongly feel that parts of educating the wider public is about timing. When people are talking about a topic is by far the best time to get content in front of them.

It would perhaps be remis of me, at this late stage within this thesis to not consider that fact that my works have taken me around the world. I am in the extremely fortuitous position to have had my expertise called upon in countries such as Australia, Singapore, Cayman Islands, America, Greece, Germany and Belgium to name but a few.

It is fair to say that I always feel a little uncomfortable when called upon as a world leading expert, because at a conceptual level, I am not sure what a world leading expert actually looks like. I feel privileged to be asked to assist courts around the world in matters outside of their own understanding. Similarly, I feel slightly concerned that

there do not appear to be experts in their own country who can assist at the level required of me. Of course, from a scientific standpoint, it does not matter which country in which my services are requested, as the science is the science.

That being said, when I reflect on my position within the industry internationally, it must mean that I have been chosen to represent the science in a foreign country. Clearly my name has not been identified 'at random' as if drawn out of hat but has instead been selected specifically to assist with those matters. This means, by implication that they require me to educate and enhance the understanding of forensic collision investigation matters in their country.

In many of these cases, I have been latterly invited to speak and train Collision Investigators in the country that I gave evidence, in order that the knowledge and experience can be shared with their practitioners. A good example of this is with the analysis of CCTV evidence in Hong Kong, where as recently as last year, the entirety of the Government Laboratory was trained by me into the analysis of video evidence.

Science is an evolving discipline, and the advancement of knowledge is the only common pursuit, therefore the sharing of understanding is paramount to developments in field being the forensics or otherwise.

In summary, this outlines that it is incumbent on me and my current peers to make sure this strand of forensic science remains interesting and accessible to the wider demographic, with the aim to inspire the next generation of forensic specialists.

5 The Expert Witness

5.1 Introduction

We have discussed previously the requirements of an expert, but it would be remis to not include within this thesis the reasons why the very act of being an expert witness advances knowledge and understanding – after all that is the whole purpose of an expert witness to teach and guide the Judge and Jury through complex matters that are outside of their own understanding.

From the outset is important to mention that you can be an Expert in a field, but very few are called to be Expert Witnesses, as they have been identified as being at the pinnacle of their understanding (although I personally have some conceptual difficulty with this term, as I do not think an Expert should reach the pinnacle of their understanding until the day they retire, but this is perhaps beside the point).

Courts, by their very nature, have to make life changing decisions and need my help to make them.

I have come to realise by writing this piece that by its very nature, the way in which this evidence is presented and the way that an expert conducts themselves at all times in the process directly impact on how the professions is viewed. Is this some sham, a pseudo-science, or is this a forensic discipline properly routed in science? The very act of being accepted as an expert witness *is* in itself a significant act of Public Works.

How evidence is present directly impacts on the way the profession is viewed and how it influences the profession. It would be tempting to conflate being an expert and an expert witness, but that would be erroneous. The *first* requirement of being a forensic expert is being accomplished in my own scientific professional, but I must also be in my '*second* profession', of being an expert witness. This is a discipline in its own right, one that requires great skill and sensitivity.

This section discusses my work fulfilling this important public work, but also how I have been able to publish a text that assists others to give a higher standard of evidence than was possible previously.

5.2 Ethics of the Expert Witness

Ethics is focussed on doing what is fair, right and moral. Whilst there are a number of definitions, all centre around this principle. It therefore follows that these ethical principles translate also into professional ethics, with many professions having a code of conduct and ethics that define the ethical principles that their members are expected to conform to, such as the Institute of Traffic Accident Investigators *Codes of Conduct.*

To briefly rehearse the duty of an expert witness from the Criminal Procedure Rules (*ibid*).

> *"CrimPR 19.2:*
>
> *(1) an expert must help the court to achieve the overriding objective*
>
> *(a) By giving opinion which is:*
>
> *(i) Objective and unbiassed*
>
> (ii) Within the experts area of expertise…
>
> *(2) the duty overrides any obligation to the person from whom the expert receives instructions or by whom the expert is paid…"*

This is at the centre of the work of an expert witness. In summary, they must assist the Court (in matters outside of their own understanding), they must be impartial (the duty to the Court and not 'their' client) and finally that they must only comment on matters within their expertise (often referred colloquially as making sure that they 'stay in their lane'). Furthermore, whilst it sounds obvious, if it is likely that a judge or jury can reach their own conclusions without any help, then the opinion of an expert is

unnecessary [1 [1975] QB 834]. Furthermore, this judgement known as the stated case of 'Turner' (a murder case that went to appeal) which has become an authority on the admissibility of expert evidence, the judgement makes clear that an expert can offer a properly reasoned opinion based on their experience/expertise (an exception to the Common Law principle that witnesses are not allowed to normally give opinion evidence) i.e., experts are different to other witnesses, in that they are allowed to give evidence based on their opinion.

"We do not have trial by expert in this country: we have trial by judge [or jury]*"* [[2020] EWHC 2115 (QB)]. This is an important underscoring to this section, that it is not the expert that is the 'finder of fact'. The Court can choose to disregard expert evidence should they wish, and indeed this is a direction often given by a judge at the end of a criminal trial – however, whenever expert evidence is called, from personal experience, there is a tangible change within a Court room, a heightened level of focus and attention, perhaps only paralleled by the evidence given by the defendant and/or victim.

Therefore, this generates an interesting jeux du position – expert witnesses are just another witness, and within the law (save for the unique position of being able to give evidence based on their 'opinion') their evidence does not carry any additional weight by default. It is for the finder of fact to attribute whichever weight to the evidence as it finds appropriate. Yet, as discussed above, it feels that in practice there is a great expectation placed on the expert evidence. Indeed, it is documented that *"Similarly, the London Criminal Court Solicitors' Association accepted that expert evidence "has an effect on the fact-finding tribunal … like no other type of evidence";* and *"the Association of Forensic Science Providers accepted that scientific expert evidence can have a disproportionate effect on juries"* (The Law Comission, 2011)

Of course, great care needs to be taken when using the word 'expectation' and for the avoidance of any doubt, the expectation on the *expert witness* is to be impartial as defined by the directions above. The 'expectations' discussed here are to do with the expectations from the finders of fact on the *expert evidence* and the often subliminal pressures that places on the *expert witness.* We must draw a very clear distinction

between how an expert may feel about the pressures placed upon them and the pressures placed upon the science.

What follows is a personal reflection on how this places ‘pressures’ on an expert witness and how these can be mitigated. It is deliberately written as a personal piece, as when giving evidence you are alone in the witness box, and there the burden of expectation is a personal one.

An expert needs to be strong and resist pressures placed upon them by those that instruct them to reach ‘favourable’ findings (to be clear, not all instructing parties place pressures on the expert, but it is certainly not uncommon to encounter those that do). This is discussed in more detail at the end of this subsection. It is far more common, driven in part by the CSI Effect discussed earlier, that there is an expectation from the finder of fact that the science will unlock all of the ‘secrets’ in the case, after all, the whole reason the expert witness is allowed to give evidence in a particular matter is to assist the Court in matters outside of its own expertise i.e., you are there precisely to help them with the ‘secrets’ of the case (House of Lords, 2019). Therefore, it often feels as though the expert is expected to have some kind of ‘golden key’ to unlock all of the evidence for the jury – this is quite some way from reality.

An expert therefore, needs to be disciplined in that, they need to be explicit in their approach detailing both what the science can answer, and those areas that it cannot. Both elements are equally important – it is important that the expert ‘manages the expectation’ of the finder of fact and does not allow any of the findings to be over-represented. Indeed, if the expert is not explicit in this in their initial findings, or evidence-in-chief, they will quickly find that this a focus of the cross-examination.

It is clear, that throughout the history of criminal justice, certainly in the UK, there is a common theme that runs through some of the ‘infamous’ miscarriages of justice - the jury have placed ‘too much faith in the wrong kinds of science’, and the scientist has not placed the appropriate safeguards in place when discussing the limits of the science (Roberts, 2022)

But experts are humans too. They will be acutely aware that there is a victim in the case and can, on occasion have sight of information that the jury have not seen (as it has been ruled inadmissible by the trial judge for example). It is essential that an expert is solely focussed on their duty to the Court. This can place a pressure on the expert that no-one else sees and can lead to an unconscious bias (touched upon a little later in this subsection).

On a personal level, I do not really feel this pressure when giving evidence. I think this is perhaps because I have always been interested in understanding fully what the science can and cannot say. To put it in the words of Einstein *"an unwavering pursuit of the truth",* however I would add an important extension to this that is *'whilst at the same time not overstating the findings'*. Maybe this is easier for me, because in many of the deaths and serious injury cases that I am involved with, both of the drivers are 'good people'. They kissed their loved ones goodbye that morning and got into a car to drive to work in the same way they have done every weekday for the past 20 years – they never set out to hurt anyone that day, and in most cases are remorseful beyond words that the worst outcome has happened.

From a personal perspective, perhaps this mitigates any potentially perceived feelings of the need to get justice, that being said, I have also dealt with a number of murder cases involving motor vehicles and I do not have those feelings on those cases either. Maybe this is because my 'normal' case load puts me in a focussed mindset, but I am not sure I will ever be able to answer that question. I keep at the forefront of my mind that I cannot change the outcome of the incident, and what is done is done, but if I do not approach my work with care, I can compound the 'injustice' of someone's death with another injustice…a potential miscarriage of justice. It is not my job to convict or acquit, that is exclusively the function of the Court (an essential principle of UK law is that anyone accused of a crime has a right to be tried in front of their peers – a right dating back to Clause 39 of the Magna Carta in 1215!). Whether or not this is the same thought process that other collision investigators go through (or any forensic scientist for that matter), is not something that I would ever be able to answer – save for anecdotally from discussion there appears to be a common focus amongst practitioners to have an overriding pursuit for the truth i.e., the 'pleasure' derived from

our challenging work exists in ‘solving the puzzle’ rather ‘getting a conviction’. That is perhaps why this brief discussion can only, truly, be written from a personal perspective. I am unable to comment on the thought processes of others, how they cope with the pressures or the expectation that will undoubtedly sit on their shoulders much like mine.

It is paramount for the expert to ‘stay in their lane’ and remain true to the obligations of providing objective (and where appropriate subjective) evidence to the Court.

There is another important step in this process – and that is to attempt at all stages to safeguard both against bias and against an *allegation* of bias. It is important to draw a distinction between these two points, which is perhaps not immediately apparent. Briefly touching on the first point, bias (usually unconscious) is something that every scientist needs to guard themselves against, and an expert witness is no different (Forensic Science Regulator, 2020). Confirmation bias is, arguably, the most obvious trap for expert witnesses to fall into, whereby a person is more likely to favour those findings that agree with a preconceived theory (and/or disregard those that do not support the pre-existing idea). Many texts exist on this, such as the excellent summary paper dealing with forensic science specifically (Kassin, et al., 2013), but it is not the area that I want to focus on in this particular area of discussion.

What is worth unpacking a little more is the idea of guarding against *allegations* of bias. In nearly every trial I have been involved in, either by giving evidence and watching and mentoring other experts giving evidence there is nearly always, at some point, an allegation of bias. Certainly, in criminal cross-examinations, it seems to me to be a ‘go to’ line of questioning to make an explicit or implicit inference that the expert has been biased in some way – only favouring evidence that would support their ‘side’, thereby undermining the credibility of the expert. It happens with such frequency that you can predict its occurrence, and it is possible to prepare yourself for a rebuttal to the questioning. For example, throughout the written report you can include side notes, small paragraphs or sections, deliberately tailored to explicitly deal with impartiality. This can be something as little as a brief discussion of why a particular factor has been actively discounted (rather than just not mentioning it) or it could be an entire appendix

dealing with rational between a particular forensic approach. There are no hard and fast rules, indeed this is an experience-based response, knowing that when faced with a question like *"why is it the case that you only seem to favour the higher end of the speed range?"* you can cut the line of questioning dead in its tracks by responding *"Indeed, I agree that this seems counter intuitive on first glance, however, the rationale is contained in detail in Appendix X"*

That is of course, slightly tactical, in the sense that you are preparing yourself for cross examination, but the consequences are very severe if the expert is assessed as being biased by the Court. In a recent matter [2023] EWHC 931 (KB) HHL Sephton KC (sitting as a High Court Judge) stated that *"A second reason why I do not feel able to rely upon Mr X is that he did not appear to me to understand the obligation of an expert; fairly to deal with all the evidence and not simply to address the points that support his hypothesis. Mr Hunter's criticism is fair that Mr X was happy to emphasise the witness evidence that supported his theory whilst remaining silent about those witnesses whose evidence did not."* (sanitised). Such a published judgment is likely to be used to cross examine this expert time and time again and may ultimately result in the expert withdrawing from being an expert witness in the future. However, the consequences are not exclusively limited to the career, with the personal life of the expert also compromised such as in the case where a jail sentence is imposed on an expert that has such a high degree of bias/manipulation of evidence [[2019] EWCA Civ 392, [2019] 1 WLR 3833]. This should, in itself, help focus the mind of any expert that found themselves in a situation to be 'tempted' to not accurately and transparently report the facts.

In my view, the ethical requirements of an expert witness can be briefly and neatly summarised with this quote *"If the Law has made you a witness, remain a man of science. You have no victim to avenge, no guilty or innocent person to convict or save. You must bear testimony within the bounds of science"* (Brouardel, 1900)

5.3 Expert Witness

I am routinely called to give evidence at The Royal Courts of Justice and the Old Bailey. Given the nature of the setting and the casework (such are murders where a motor vehicle has been involved) attract a considerable amount of attention. Of course, the Court rooms are full of the people that need to be there in the usual course of a trial, Judge, Jury, Counsels etc, who are perhaps already well versed with the role of an expert. However, family members, friends and often a suitable number of journalists are also present in the court room, hanging on virtually every work that gets spoken. By the very nature of expert evidence, this is often some of the most critical evidence in a matter being heard, and therefore it is my experience that when I enter the witness box, it is clear that there is a real focus on the words I am about to speak.

This is a unique position, where under immense pressure, I have to teach! I am there to assist the Court in matters they did not understand prior to the trial, it is therefore, in a large part, my responsibility to teach them about the science. If I teach badly not only does this not assist in the matters at hand, but also reflects badly on the entire profession.

An expert will give the same Oath as any other witness *"I swear by almighty God that the evidence I should give shall be the truth, the whole truth, and nothing but the truth"*[5]*.* So, you are legally bound to tell the truth…but there is nothing that says you have to tell the truth in a competent manner. You can truthfully give terrible evidence!

Giving evidence is all about conveying the overly complex intricacies of a collision in the simplest way possible but keeping the essential detail. I try to find a way in which the science can relate to people. Afterall, we all use the same physics every day, to open doors, or to not fall through our seats when we sit down – but, fortunately, not many are involved in very serious car crashes. So, I must explain this in a way that makes sense and is relatable. A comment often attributed to Einstein (Einstein, 1897 - 1955) is *"If you can't explain it simply, you don't understand it well enough"*. This is true – and indeed is the whole purpose of giving live evidence.

[5] Other affirmations and deity variations also are given

When I am giving live evidence, I know that what I am going to say is going to get quoted in newspapers and in some of the high-profile cases, in the national news on a nightly basis. It is also true to say that the number of times I have been mis-quoted is numerous, so that is another thing to be aware of whilst giving evidence, that even if I am slightly misquoted, will it fundamentally change the evidence?

I have been told that I am an engaging evidence giver, which can explain the science in a digestible way. I have spent hours teaching others how to give evidence and observing them doing so. Some people handle the pressure well, others really do not. You can be the most technically gifted expert in the world, but if you cannot communicate it in the box, you are a terrible expert. The role is to communicate, and to communicate well.

On top of the several days I will spend in Court throughout a trial listening to all of the evidence, I will spend hours (if not days) in the witness box giving evidence, and then then hours again listening to another expert give evidence. There is no let up, and experts are held to some of the highest standards. This is pressure cooker stuff, you are the centre of attention, and there is nowhere to hide. You cannot take a few hours off to go and do some more testing, or put your feet up, it is question after question about your subject matter.

This is included as one of the final chapters in this thesis. I was wondering how it would be possible to articulate the public impact that an expert has when then are giving evidence, is it a wide-ranging impact when the world is watching a particular high-profile murder? Is it your peers that have come along to watch because they have heard they can learn a lot from you? After much thought and reflection, I think it is considerably more obvious than that. The public work is being called to give expert evidence in itself.

Throughout this thesis I have discussed about what being an expert is all about, and how my works have assisted other people understand about the science of collision investigation and also to help them be better experts – but the public work *is* the giving of expert evidence.

As stated at the very beginning it is an honour to investigate the death of another human being. It is humbling to be in a position where you can give answers to loved ones about how their family members died, but it is the actual giving of that evidence that is the public work.

Taking a step back, save for a few other peers, who else could do it? What would the court do if they didn't have an expert to assist them? To be an expert is, perhaps, one of the most privileged positions that can be taken. Regardless of the discipline, the Court has looked at your qualifications and experience, looked at the difficulties in a case that they are required to consider and have chosen me.

If I had not completed the works up until this point, I would not be the expert they were calling. If the case was straightforward, they wouldn't need the help of an expert, and I wouldn't be called. To be specially selected for this role, and to assist a public Court with information they desperately need is, in itself, an accolade that only a tiny proportion of people ever get the opportunity to do. I have had this opportunity numerous times.

Looking at it more widely, the *Expert Witness Institute* in early 2022 provided a pictographic detailing what they consider to be the core competencies of an expert as seen in *Figure 15*.

Figure 15: *The Expert Witness Institute Core Competencies* (Expert Witness Institute, 2022)

Unsurprisingly, at the very centre of these competencies is *'Ethics, Values and Personal Attributes'* features. It is one of the reasons why, as explained earlier, I have developed a number of the Codes for the Institute of Traffic Accident Investigators. It is entirely right that this is at the heart of everything that an expert does and is encompassed by the *'Area of Expertise'* as this is, to put it simply, what an expert is limited to within the legal system. That is of course, not to say that Ethics, Values and Personal Attributes should not be part of the everyday life, of the expert, it is simply a reminder as to the remit of an expert.

With respect to the centre 5 segments, dealing first with 'Understanding the law, regulation and guidance regarding Expert Evidence'. Another segment is *'Delivering Compliant, impartial, well-constructed, comprehensible Expert Witness Reports'.* For me, these two elements are combined, in the sense that in order to deliver a compliant

report, there must be an understanding of the law, regulation and guidance. That is not to play down these elements by any means, they are after all a cornerstone of being an expert. It is important to know the role and the remit of the expert – this is in essence the 'rule book' to which experts must adhere. This is what I practice on a daily basis, with every report I write and every matter that I peer review.

It is the elements contained within the next 3 segments that interest me greatly, namely, *'Participating constructively in Discussions of Experts'*, *'Creating quality Joint Statement'* and *'Giving effective oral evidence in a tribunal or court'.* This is usually what all of the works that have been done by the expert comes down to. Remember, as stated at the very beginning of this thesis 'Forensic' means 'for the Court' and an Expert Witness, is only ever a witness when they are called by the Court to assist them in matters outside of their own understanding. There is a general expectation that an expert will give a higher standard of evidence than other witnesses, for example, how they conduct themselves and how they present evidence is expected to be superior to lay witnesses. I consider these three steps as 'The art of presenting a science'. This is because there is a skill in presenting complex terms and concepts in an easy and digestible way. It is a skill that can be learned and honed with practice. Rather than discussing these elements fully here, I will save this discussion for *Section 5.4 - Giving Evidence Publication*, where I talk in detail about how I have produced a publication to raise the standard, specifically of these three core competencies.

Moving on to *'Commitment to CPD'* which is, diagrammatically, an element that wraps around the authentic expert, in that it is important that an expert remain current. This is the sole purpose behind the development of the 'ITAI Talks' webinar series to provide a clear avenue for those practicing in the field to have access to CPD sessions from leading experts. This is on top of the annual Crash and Research Day mentioned previously and also the Journal articles that I have written.

Finally, *'Commitment to* [the] *Expert Witness Profession'* can be interpreted in many ways. It could be interpreted as being the best expert I can possibly be, in an insular sense of the wording. Personally however, I consider it to be a calling to give back to the profession as a whole, and that is something that I have aimed to do throughout. I

have tried to raise the profile of collision investigation in the wider demographic. I have tried to increase the professionalism of the members of the Institute of Traffic Accident Investigators by the introduction of 'hands-on' competency testing and Codes of Conduct and Ethics. I have endeavoured to further the technical knowledge of Forensic Collision Investigators around the world by the development of CCTV analysis techniques and tools, identifying the ways in which a speed of a modern-day vehicle can be calculated when it loses control, not to mention mathematical models of correctly propagating errors in a fundamental calculation as well as demonstrating why a pedal cyclist is likely to 'go over the handlebars' before they skid. I have been fortunate enough to train numerous international Forensic Collision Investigators in the techniques I have developed, and I consider this to be my interpretation of what *'Commitment to Expert Witness Profession'* means.

5.4 Giving Evidence Publication

As is often the case with giving live expert evidence at a trial I sit through an 'opposing' expert's evidence. I have observed dozens if not hundreds of expert's giving evidence, and from a position within the well of the Court (as experts are nearly always granted permission to sit behind the legal teams in judicial trials), I have a viewpoint that allows me to see how the evidence is delivered and how it is received by those in the Court room such as the Judge and the other legal professionals, as well as the Jury – although it would be fair to say that it is not possible to know exactly how it is received by the Jury as their discussions and deliberations are private, however it is possible to see from their body language, and their general engagement (such as taking notes etc) whether or not they are receiving the evidence well, or poorly.

It is my general observation that the quality of the evidence given by collision investigation experts is degrading. There seems to be a lack of understanding of some of the basics, such as when to speak and when not to, and how to physically hold up exhibits so that the entire Court room follow the evidence that is being talked about. I am not sure whether this is a lack of training and/or experience or whether it is not accepted that giving evidence is not as important as it was once considered. Either way, the route of the cause is not important, it is something that needed to be addressed.

During the early stages of my career, formal training was offered in giving live evidence with a 'mock trial' set in a court room setting. This was helpful to experience with feedback to give more effective evidence, but as I understand it, this is no longer offered. Also, whilst this was helpful, I am of the view that this tries to get all experts to conform to a certain model of witness, as viewed by the legal profession. Of course, there is nothing wrong with a view directly from the legal profession in this, quite the contrary, it is helpful - but there is no input from an expert talking about their experience of giving evidence or how they effectively get their evidence across. I have always thought that this was missing a key element.

Such training is still available, but again this is led by legal experts (Bond Solon, 2022), but what I have been unable to find is any advice on giving evidence from the perspective of the expert. This seemed like a principal element that expert's both new and experienced could benefit from. Given the second edition of the CCTV book, discussed in *Section 3.7 - Video Analysis in Collision Reconstruction (Second Edition)* included a number of updates with respect to the wider forensic video analysis content, it seemed to me that this would be a good opportunity to include a small section on how to give effective evidence and the book would be a good vehicle, to get this into the marketplace.

By a coincidence, that at the time of identifying this need and putting a concept together I was giving evidence at the Royal Courts of Justice in front Dr Nicholas Braslavsky KC who was sitting as a Deputy Judge [(2019) EWHC 2049 (QB)]. Dr Braslavsky KC, as well as sitting as a judge also still practices as council, and since giving evidence in front of him has recommended me for a number of subsequent matters. I approached him with my drafted version of the document, and it transpires that he shares my passion for increasing the standard of expert evidence also. He very kindly agreed to peer review my document (and, indeed has added elements from his viewpoint as a Judge), and the resultant document is included as *Appendix 7 – CCTV Analysis in Collision Reconstruction – 2nd Edition Extract*

Within the documentation, there are 18 subheadings covering the following topics:

- Court Types

- The Golden Rule
- Written Work
- Pt. 35 Questions
- Discussions with other experts
- Preparations for Trial
- The Courtroom
- Meet with your instructing party
- Be a teacher
- Exhibit Presentation
- Answering Questions
- Be clear on the question
- The role of an expert and the limits of expertise
- Consistency of Language
- Know when to talk…and when not to
- When and how to concede a point
- The DO NOTS
- Enjoy giving evidence

This document describes all areas from the preparation of exhibits, to preparing a joint expert report to the enjoying giving live evidence. It has been written in an accessible and engaging style.

For example, when considering the preparation of a Joint Statement between experts, contained within the 'Discussions with other experts' section, it sets out in detail how best to prepare for a conference between experts, the importance of the discussions being privileged and the primary aim of producing a concise document that ultimately helps the Court understand the extent of the agreements and differences between the experts. When this is followed it is possible to produce a document that is of significant use to the Court. For example, in a recent Judgement [(2019) EWHC 2049 (QB)] when I had produced a joint statement, His Honour Judge Bird commented:

> *"There is a commendably clear and succinct joint expert report from* [the experts] *which sets out an agreed position."*

This illustrates that when done correctly, the overriding duty that the experts owe to the Court, is executed well. It greatly assists the Court in dealing with matters in an efficient and clear manner. In a criminal matter, it is reasonably rare that the reports of the experts will be put in front of the Jury. There may be snapshots, perhaps diagrams or key findings, but it is highly unusual that a full report would be put into the Trial bundle. The Joint Statement, however, is nearly always included in the Trial bundle and therefore it is important that this is written in a way that it will be received by the target audience.

Whilst the inclusion of this chapter is within my book written about CCTV analysis, it only makes light reference to collision investigation. This is deliberate as this text is designed to be agnostic, in the sense that it should be applicable to any forensic expert giving evidence, or indeed any expert from any discipline giving evidence.

Due to its recent release, it is not possible to measure the response that this chapter will have, but it is certainly my aim that it will add to the existing training for expert witnesses, but from the unique position of being written by an expert who gives live evidence regularly.

6 The (not so) Final Chapter

6.1 What is next?

Prior to completing this piece of work, I knew that I had made a significant difference to the industry – due in part to the fact that my peers continually comment on my works as having done such, but I had never really considered the enormity of the changes that have been made. This is of course the beauty and importance of performing reflective views on a career that I am passionate about and endeavour to make stronger.

But as the last chapter, I think it would be a good opportunity to look forwards, to the things that are in the near future that I think are likely to have a significant positive impact on the industry and public perception going forwards. There are two notable events that are on the immediate horizon that are likely to be worth a brief discussion here.

6.2 Chair of the Institute of Traffic Accident Investigators – Summer 2023

I have been elected the next Chair of The Institute of Traffic Accident Investigators, a position that I will take up in the summer of 2023. As I am sure that the reader may have gathered by now, there are a few things in my career I find truly humbling. As mentioned, being in a position to investigate the death of another human is humbling – but it is further humbling still to be selected by your peers to not only be a person they hold in the highest regard in terms of technical ability, but to also be the person they chose to being their mouthpiece on the international state. It is hard to consolidate that, especially because I will be the youngest Chair (by some 20 years) ever to be elected. As with many organisations, the role of Chair, along with the day-to-day functions, is chosen to the figurehead of the organisation. The role is taken by someone who commands the respect of his peers and also within the wider forensic community, being able to engage with the key stakeholders, such as the Police, policy makers and other forensic organisations.

Being selected for this role, particularly at my age, means that I have reached what is considered to be the very highest level of expertise within the field. Perhaps more importantly, not simply in terms of technical ability, but in the way that the profession is represented to the wider demographic. Of course, I haven't officially been handed the reins yet, so it will be interesting to see what further changes I will be able to affect, but simply being chosen for this role is a measure of how I am viewed by the industry in which I work.

I am heavily involved with the Institute pursuing becoming a Chartered Institute. We are ever closer to being able to call ourselves as a Chartered Institute, and I would anticipate this to become a reality whilst I am Chair. In order to be awarded a Royal Charter the organisation has to demonstrate a collaborative approach in setting the highest of standards across the board, both within the organisational structure and also to the wider membership. My works with setting the Codes and Certificate of Professional Competence are key markers in the achieving such status. Receiving a Royal Charter will be, in all likelihood, the most significant step in the history if the Institute.

6.3 United Kingdom Accreditation Service (UKAS)

I have recently been approached by the United Kingdom Accreditation Service as a Technical Assessor. As mentioned previously, the FSR has indicated that collision investigation units will need to meet International Organisation for Standardization (ISO) standards (specifically ISO17020 and ISO17025, depending on the in-field vs office-based analysis).

It is apparent that a regulator within the industry leads to an increase in the professionalisation of the role, I am serving an important function in the assessing of the technical practitioners to ensure that they are competent to be presented as experts within the industry. This is similar to the assessment work I fulfil with the Institute of Traffic Accident Investigators, but this time against a framework set out by the new FSR.

I am considered a subject matter specialist that enters an organisation as part of a formal assessment to see if the processes are being adhered to and, perhaps most critically the processes are fit for purpose. It is the role of a technical assessor to determine if the methodology is being conducted in a robust way, and that the way in which processes are being implements are scientifically robust.

This means that I am asked to attended collision investigation units and assess if their work meets the required standards. It is perhaps no surprise that I am asked to perform this function more often than not against the video analysis section of the functions. This is mainly because it is the CCTV Book that has been discussed at length within this thesis that forms the basis of the techniques and processes that the assessed organisation is presented for accreditation. On a personal note, it is interesting as it appears that this video analysis work has gone 'full circle' in that, as you may recall, I met a degree of resistance when introducing new techniques within the Police. But now, by contrast, I am now invited in by the Police to assess if they are correctly applying these.

The impact of these works is yet to be fully understood, but it is fair to say that being an assessor for the regulator will have a significant impact on the professional standards within the in industry. As a technical assessor, it will be one of my key responsibilities to identify whether an organisations practices are forensically sound. Ultimately making the decision whether or not their processes (and therefore findings) are safe to be put in front of a Court.

6.4 Parliamentary Advisory Council for Transport Safety (PACTS)

The Parliamentary Advisory Council for Transport Safety (PACTS) is the secretariat to the All-Party Parliamentary Group for Transport Safety. Its charitable objective is:

> *"To protect human life through the promotion of transport safety for the public benefit." (The Parliamentary Advisory Council for Transport Safety, 2022)*

I sit on this council as an advisor along with a number of distinguished colleagues from other disciplines, from road engineering to driver behaviour. As the name suggests the purpose of this group is to provide an avenue for detailed subject matter expertise to be put before Parliament.

This is, by its very nature a wide-ranging brief, with discussions on everything from road design, speed limits and vulnerable road users. We discuss all topics that are necessary to maintain road safety from a multi-disciplinary approach, this is what makes this such a powerful organisation.

One of the recent pieces of work that the council were engaged in was the consultation piece with respect to the recent changes to The Highway Code. In the latest edition there has been a bit of a shift in the implied order of priorities within the road network, and to summarise, the vulnerable road users (pedestrians, cyclists, and horse riders etc) have been given implicitly more protection on the roads.

This is the guide that all new drivers are tested on in their driving theory test and all existing drivers (should) re-read. Therefore, the impact of this document is far reaching, potentially to every driver in the UK. But of course, it is not just a document, The Highway Code is designed to be an ethos and description of behaviours that are common with the best driving behaviours, with a view to ultimately reduce the casualties on the road. Whilst I had only limited input in this document, there are a number of imminent pressing matters that I am taking an active role in, such as the use of e-scooters. New electronic two wheeled scooters have been around for a few years now, but there is limited specific legislation surrounding them. Currently pilots have been run with official hire schemes which is a modification to the Road Traffic Act which details these e-scooters as mechanically propelled vehicles. There were over 900 recorded cases of fatalities, and injury collision to both their riders and to pedestrians in 2021. There were 12 fatalities, and approximately 40% of the number of collisions were deemed as causing serious injury. The case is simply put that, in 2021 it is estimate that 500,000 e-scooters were legally purchased in the UK but are being illegally ridden.

Also, on the horizon is the role that autonomous vehicles are likely to have in society going forwards and how both the infrastructure and the operation of those vehicles can be done safely. It is an exciting time to be part of this Parliamentary Advisory committee and I expect to be playing a key role in the new legislation guidance being put before Parliament, and then ultimately the country.

6.5 On reflection

At the end of this thesis, I find myself reflecting on the journey to this point. I find myself working in an industry where I have the privilege to investigate how another human being dies. In preparing this thesis, I found myself opening my slightly dog-eared first year physics textbook from university, which on one of the opening pages contained the statement.

> *"You don't know physics, unless you can do physics…the study of physics is an adventure. You will find it challenging, sometimes frustrating, occasionally painful, and often richly rewarding and satisfying. It will appeal to your sense of beauty as well as to your rational intelligence." (Young & Freedman, 2004)*

Substituting the words Collision Investigation in the place of physics in the sentence above perfectly surmises my thoughts on my journey in the field.

It is important for context here to note that when I first began working for the Police the word Forensic did not appear in the job title, or in the specialist unit names (i.e., Collision Investigators working within a Collision Investigation Unit). At that time, the word 'forensic' was seen as if it was sort of a dirty word. It is of course rather odd as the term forensic (in our context) means quite simply 'for the court' – which I am not sure what people took issue with.

However, I am not sure that was their interpretation, as I think they were more concerned with the difference between our role and some of the more 'conventional' forensic sciences such as fingerprints or DNA. The fact that a few though that the role wasn't scientific was also slightly concerning! It was my position from the outset that

collision investigation was where physics met forensics, but this was often met with ridicule. It would not be an understatement to describe the views held by those around me with respect to the two disciples as being 'like oil and water'. In many respects, although not consciously, this made me far more determined that these two disciples were not fighting each other, indeed they were complimentary when looked at in the right way. The conscious element of this has been trying to demonstrate that these two subjects do indeed belong together, something that I have held a firm belief for since starting my work. Now I cannot claim credit for the rebranding of collision investigation units to forensic units, in fact I am not sure exactly where or why this decision was made, but it was the right one. What I can however proudly say is that my work in this field has been recognised by both the Institute of Physics and the Chartered Society of Forensic Sciences. I have been fortunate enough to be able to reach chartered status with both of this institutes due to works in this field, but the fact that I have also been awarded fellowships of both of these organisations is something I would describe as one of my proudest moments.

I am not normally one for titles (note here that the post nominals that I hold are more for the Court benefit than any other reason, as they do need to see, explicitly the qualifications and accreditations of the expert). I am certainly pleased that my works are being used and having an impact, and I see these as being tools for doing some good.

It is impossible to predict what the further is going to hold for me in this industry that I feel strongly about. Indeed, the research that I have conducted and the influence I have made has been as a result of me stumbling across something that didn't make sense or didn't feel right. I am therefore pretty certain that the next thing that I get involved in will also be unexpected and unpredictable – it will find me, in the same way all of the other topics have. For me, that is simply part of the excitement in an industry that is so rapidly developing with the introduction of autonomous vehicles and the data that's available for capture from vehicles it would not surprise me in the slightest if the next avenue of study and exploration comes from that domain.

The duty of an Expert, as outlined at the very beginning, is to impartially and thoroughly investigate the matters in which I am instructed. In my case, it is investigating how somebody died. It is a duty that I take very seriously indeed, and I am pleased to be able to say that I have been able to contribute to the understanding and application of 'new' science to the field of Forensic Collision Investigation. There are loved ones who now have the answers to how their family members died, and there are people who are now bought to justice as a direct result of my research and dissemination of techniques that have advanced the field.

This process has taught to me that my analytical thinking and my passion for the subject means that whatever lands on my desk next, will be treated with the same critical thinking and enthusiasm as all of the other areas that I've been involved in. This is of course what makes a highly emotive subject fun and exciting.

I don't know what changes I will be able to make to the industry next, who my professional works are likely to support in the future, nor the next case that causes me to start digging into the next area of 'unknowns', but I am sure the next topic that catches my attention will 'find me', as most of the areas discussed in this thesis have previously.

To finish with one more quote from my scientific hero (Feynman, 1981) *"The prize is in the pleasure of finding the thing out, the kick in the discovery, the observation that other people use it* [my work] - *those are the real things…"*

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