Impact of Forensic Science on Criminal Justice System Outcomes: How Does Chemical Trace Contribute?

by

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Statements and Declarations

Declaration of Originality

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The research associated with this thesis abides by the international and Australian codes on human and animal experimentation, the guidelines by the Australian Government's Office of the Gene Technology Regulator and the rulings of the Safety, Ethics and Institutional Biosafety Committees of the University. The research was approved by the Tasmanian Social Sciences Human Research Ethics Committee (Ethics Reference Number: H0016013).

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Abstract

The criminal justice system is expected to be fair and effective. Decades of research point to the critical role that forensic evidence may play in meeting this expectation. Yet this evidence base has focused almost exclusively on biometric evidence, and little is known about the efficacy or otherwise of smaller disciplines. The aim of this research was to explore the contribution that chemical trace evidence in particular may make in supporting police investigations and court processes in Victoria, Australia.

Quantitative and qualitative data relating to the use and impact of chemical trace and other forensic evidence were collected in a series of three studies based on criminal justice system data and surveys of investigators. A quantitative analysis of criminal justice system outcomes revealed new insights into the role played by forensic science. In particular, it was discovered that the impact of forensic evidence varied between disciplines and that there are potential interactive effects of using multiple forms of evidence, which may enhance fair and just outcomes.

This research has provided insight into the diverse and nuanced ways that chemical trace evidence is used in criminal investigations and pre-trial processes that lie beneath the observable impact on the judicial steps measurable using quantitative methods. Capturing qualitative data has proven essential for revealing the less tangible modes of benefit provided, which need to be recognised to appreciate the full value provided by this form of evidence. Chemical trace evidence in particular was found to influence the decision-making of investigators in a number of ways. This finding contradicts prevailing forensic community perceptions that the benefits of trace evidence are largely confined to its application in court.

Knowledge of the use and impact of forensic evidence could be used by service providers to guide the strategic deployment of services and to optimise the support provided to police investigations and court processes. The findings in this research have implications for the effective use of chemical

trace and other forensic evidence. The limited availability of empirical research on the value provided by many forensic evidence types is a current weakness in the effective utilisation of forensic science in the criminal justice system.

CHAPTER 1

Introduction

Background

Forensic science plays a role in the criminal justice system through the support it provides to policing and the courts. Forensic resources are finite and the demand for forensic services generally exceeds the capacity of forensic service providers. Therefore, it is important that forensic science is utilised strategically so that the services provided to policing and the courts deliver maximum benefits and ultimately flow on to serve the public, such as through the rapid resolution of criminal investigations, achieving high clearance rates of criminal offences and reducing crime rates in general. Consequently, it is essential to understand how effectively forensic science is fulfilling its role in the criminal justice system. However, forensic science is not a single homogenous product and the large array of forensic disciplines, along with the associated diversity of evidence characteristics, adds a high degree of complexity to the task of evaluating the effectiveness of forensic science.

The term forensic science is routinely used to cover a large and diverse range of disciplines or services (ANZPAA - NIFS 2019). The National Association of Testing Authorities (NATA), the body responsible for accreditation of scientific laboratories in Australia, defines ten classes of forensic testing within which thirty-five subclasses are listed (National Association of Testing Authorities (NATA) 2013). The classes and sub-classes have been established according to the scientific basis of these disciplines and the materials or sample forms to which they are applied. However, there are other forensic science disciplines that sit outside of the realm of forensic science testing laboratories, which include pathology, odontology, forensic medicine, forensic psychiatry and forensic anthropology as examples.

There are also noteworthy aspects of variation across the spectrum of forensic disciplines which relate to the characteristics of the forensic evidence and how the services are applied. These points of variation include:

(i) Whether the services are applied at crime scenes, are conducted at the laboratory or are a combination of both;

(ii) The degree to which the evidence that is produced is based on expert, but subjective, assessment or based on the results of analytical testing;

(iii) The type of information that the evidence provides (i.e. determine that an incident that has occurred was in fact a criminal offence; identify persons that are involved in a criminal offence; draw a connection between items that relate to a criminal offence; or a combination of the previous);

(iv) The timeliness typically associated with the disciplines (i.e. timeliness of service deployment and timeliness of the provision of results);

(v) The crime types that the disciplines are typically applied to.

As a consequence of the diversity of the disciplines, the characteristics of the evidence and how the services are applied, there is scope for forensic science to impact on criminal justice processes in different ways. The diverse nature of forensic science, and the broad scope for how and when forensic evidence can impact on criminal justice processes, must therefore be taken into account when undertaking an assessment of the effectiveness of forensic science in the criminal justice system.

In this research, the effectiveness of forensic science is evaluated by studying a selection of forensic evidence types. For each discipline, the impact of the forensic evidence on the outcomes of criminal investigations and court processes is examined, as these actions can be considered primary functions of forensic science (Strom & Hickman 2014). Chemical trace evidence is the forensic discipline of primary focus in this research but the impact of other disciplines, and potential synergies that may exist between the disciplines, are also examined. The disciplines of forensic science that are covered in this research have been selected to provide diversity in terms of the

scene and laboratory-based services, the information provided by the forensic evidence and the crime types that the disciplines are typically applied to.

Focus of this research

The overarching objective of this research was to examine how effectively forensic science is fulfilling its role in the criminal justice system (Julian et al. 2011). This research has been conducted as one component of a larger project which comprehensively examined the role of forensic science in the criminal justice system and which included studies which examined the forensic processes relating to the crime scene, the forensic laboratory, police investigations and the courts (Julian 2016; Julian et al. 2011). The research presented in this thesis is particularly focused on examining whether the benefits of forensic science to criminal investigations and court processes are broad and widespread. The potential of forensic science to make a valuable contribution to the detection of suspects and the prosecution of offenders has often been evident in individual cases that have gained public prominence ("Azaria - the trial begins", Murdoch & Lahey 1982; "Daytona Beach Serial Killer Suspect Is Arrested", Victor 2019). On some occasions, this prominence has come about because the forensic evidence has been particularly noteworthy ("Serial killer Ted Bundy's DNA used in cold cases", CBS News 2011; "Doubt over DNA test in Falconio case", Murdoch 2007). However, it is the systematic contribution of forensic science that is of most relevance to evaluating the effectiveness of forensic science in the criminal justice system (Ludwig & Fraser 2014). A number of reviews and research studies have been conducted that have been directed at evaluating the effectiveness of forensic science (Blakey 2000; Briody 2004; Home Office 2007; Peterson et al. 2010; Roman et al. 2009). The literature relating to these studies, and the conflicting findings on the impact of forensic evidence that have emerged, is discussed in Chapter 2.

When assessing how effectively forensic science provides support to criminal investigations, it is also important to understand how the stakeholders in these processes seek to use forensic evidence. Since this has been identified as a gap in previous research (Julian et al. 2011), a component of this

research is focused on how police investigators utilise forensic evidence and what benefits they had expected the forensic evidence would provide to their investigations, and to the prosecution of the cases in court.

Aim and scope of this research

One aim of this research was to quantitatively assess the impact of a selection of different forensic disciplines. This was achieved by tracking the outcomes of the criminal investigations and court processes in a sample of cases, building a database of such case data and then statistically analysing the relationships between the forensic results and outcomes of specific judicial steps (i.e. charges laid against suspects and the determination of guilt (or otherwise) in court). Forensic disciplines were selected which differed in certain characteristics, including the type of information that they can provide, so that the use and impact of these disciplines could be compared. It was also an aim of this research to build on the findings of the quantitative studies by using alternative methods to address research questions that could not be fully answered using the quantitative database approach. This was achieved by surveying a sub-sample of lead investigators from the database study to capture information about what benefits they expected the forensic services to provide to their investigations, how they utilised the forensic evidence and what their perceptions were of the value of forensic science in general. Another aim of this research was to explore the decision-making process that is followed by forensic scientists when conducting cases that span across a combination of scene and laboratory examinations. In such circumstances the forensic scientists can encounter a variety of forms of evidence which must be considered collectively to reach their final conclusion of their examinations.

This research has been conducted using a limited selection of forensic disciplines. Chemical trace evidence, which actually covers the examination of a collection of materials types often present in trace quantities, has been the forensic discipline of primary focus. At the forensic laboratory where this research was based, chemical trace evidence includes, but is not limited to, the examination of

paints (and other surface coatings and polymers), glass, fibres and gunshot residues (inorganic primer residues). Forensic fire examination, biology (DNA) examinations and ballistics / tool marks examinations were also examined in this research. Although some findings from this research may be limited to the specific disciplines that were studied, it is expected that the results from this research will have broader implications for forensic science. This research has focused on the application of forensic science to criminal investigations and the courts. It is acknowledged that forensic science can make valuable contributions in other ways (e.g. support to intelligence-based policing, disaster victim identification, coronial processes) however such applications of forensic science are not within the scope of this research.

Significance of this research

This research provides an in-depth evaluation of the impact of a selection of forensic disciplines and adds to the existing published literature that is based on empirical studies of the contribution of forensic evidence to the criminal justice system (see Chapter 2). The task of evaluating the effectiveness of forensic science has been approached from the perspective of the forensic service provider. Case datasets were developed on the basis that the cases contained forensic evidence types that had been selected for this research. This differs to some other pieces of research which have developed datasets according to offence types and as a result have presented a view that is more in line with crime type (e.g. homicide, volume crime). Some weaknesses of other published research have also been addressed, including incorporating the results of forensic examinations into the statistical testing of quantitative data. To capture the dual value of forensic evidence, to either implicate or exculpate suspects, it is essential that the results of the forensic examinations are considered. Additionally, some of the disciplines of forensic science that have been examined in this research have not been well represented in previous studies (e.g. chemical trace evidence, forensic fire examination) (Williams & Weetman 2013) and the findings from this research will add diversity to the existing published literature.

This research presents a detailed examination of chemical trace evidence. For what is believed to be the first time, a mixed methods approach has been employed in this research, consisting of a quantitative case processing study and a survey of police investigators. This approach has produced quantitative and qualitative data which describes the utilisation and impact of chemical trace evidence to a level of detail that has not previously been reported. The study of forensic fire examination increases the diversity of the forensic disciplines that have been studied in regard to their contribution to police investigations and court processes. The study of how forensic fire examiners incorporate a variety of evidence forms into the decision-making process that they follow to reach a conclusion of the cause and origin of structural fires is also believed to be a piece of research that has not been previously reported.

Presentation of this thesis

This thesis consists of a combination of articles that have been submitted for publication in peer-reviewed journals (Chapters 4, 5 and 6) and other conventional chapters.

Chapter 2 presents a review of the published literature which has been directed at evaluating the effectiveness of forensic science. A collection of publications which report the findings of reviews of forensic service providers that were conducted by government agencies in the United Kingdom and the United States are presented. A body of empirical research that has resulted in mixed findings regarding the impact of a variety of forensic evidence forms is also presented and evaluated. The chapter finishes with a review of publications which are generally more recent and have proposed different approaches to how the effectiveness of forensic science should be evaluated.

A key component of the rationale of this research is that the impact of forensic evidence on judicial outcomes can provide an indication of the effectiveness of forensic science. The rationale of this approach is presented in the first section of Chapter 3 and justification is provided for the methodology applied in each of the studies. A mixed methods approach has been used for the

examination of chemical trace evidence which has produced a combination of quantitative and qualitative data. The research design for the study of chemical trace evidence has also enabled capture of data relating to the impact of other forensic evidence forms and the rationale behind this approach is also presented. In the second section of Chapter 3, important components of the methodologies applied in the quantitative database studies, the survey of police investigators and the decision-making study of the forensic fire examiners are presented. Chapter 3 finishes with discussion about my status as an insider researcher and the implications for the research findings that are associated with the position that I held within the Victoria Police Forensic Services Department preceding and during the conduct of this research.

In Chapter 4 the case processing quantitative study of chemical trace evidence is presented. This chapter is an article that has been submitted for publication and is the first part of the study of chemical trace evidence. The impact of chemical trace evidence on judicial outcomes has not been well studied, yet the future viability of this discipline has come under critical attention (Roux et al. 2015). Empirical data was produced in this study which describes the relationships between the results of chemical trace, as well as some other forms of forensic evidence, and the outcomes of police investigations and court processes. Descriptive statistics were produced which provide a detailed picture of the cases that include chemical trace evidence. Profiles of the criminal offences, the investigating policing types and the timeliness characteristics of these cases are presented.

The second part of the study of chemical trace evidence is presented in Chapter 5. This chapter is also an article that has been submitted for publication. In this study, a sub-set of cases from the quantitative study was used to source police investigators who had experience in applying chemical trace evidence in the investigation of potentially criminal incidents. The survey of the police investigators was directed at exploring what their expectations were when they applied chemical trace evidence services and how they used the forensic evidence in their investigation. The survey

produced quantitative and qualitative information that built on the findings from the case processing quantitative study.

Chapter 6 is the third article that has been submitted for publication. This chapter reports the findings of a case processing quantitative study of forensic fire examination. Forensic fire examination is intrinsically connected to the investigation of arson, a crime that is considered difficult to investigate and prosecute. Often for structural fires, fire examination services produce the only form of forensic evidence that is available to support the investigation and prosecution of the arson case. Forensic fire examination contrasts in multiple ways with the other forensic disciplines included in this research and notably can provide evidence that can be crucial in establishing whether a fire that occurred was a criminal act (i.e. arson). This chapter also presents the findings from a study of the frequency of a variety of evidence forms that are utilised by forensic fire examiners to reach their finding on the cause and origin of structural fires.

In closing, Chapter 7 summarises the research that has been conducted. The findings that have emerged from each study are presented and their implications for the delivery of forensic services are discussed. This chapter includes discussion of the role of forensic service providers and the numerous points within routine case processing steps that can influence the value of forensic evidence. It is concluded that a deficiency in empirical data that describes the use and impact of forensic services is a critical impediment to optimising the contribution of forensic science to the criminal justice system.

CHAPTER 2

Literature Review

Introduction

The following review will summarise previous attempts that have been made to assess the effectiveness of forensic science. The chapter will initially cover forensic service reviews initiated and conducted by government agencies, firstly in the United Kingdom and secondly in the United States. Literature relating to studies which have used quantitative methodology to examine the impact of forensic evidence on judicial outcomes as a means of evaluating the effectiveness of forensic science will be presented. This body of work will be critically reviewed and weaknesses in these publications regarding factors such as the methodology applied, and the criteria used for assessing effectiveness, will be discussed. To this point there has been greater attention paid to some of the more prominent forensic disciplines, such as DNA and fingerprinting, and a number of other forensic disciplines have not yet been well examined. Consequently, there is a gap in the knowledge of how different forensic disciplines and different types of forensic evidence can impact on processes within the criminal justice system. The reasons why it is important to address this gap will also be covered in this chapter. A third section of this chapter will present literature published in the last ten years which has provided a broader view of the value of forensic science and how its effectiveness should be evaluated. In closing, the anticipated contribution of this research to the existing literature will be discussed.

Forensic Science in the spotlight

Significant growth in forensic science occurred through the seventies and eighties with expansion of the resources allocated to forensic laboratories (Johns & Kahn 2004). Surveys of forensic laboratories in the United States in the 2000s indicated growth was continuing in both the number of laboratories operating and the demand for forensic services (Peterson 2014). Policing services and the courts have become more reliant on forensic evidence (Wilson et al. 2010) and jurors now hold

high expectations for the inclusion of forensic evidence in criminal cases (Dioso-Villa 2014). It has followed that forensic science has come under greater scrutiny with regard to factors such as the value that forensic science laboratories were providing to policing (Bitzer et al. 2015; Bitzer et al. 2017; Julian et al. 2011; Ludwig 2016; Ludwig & Fraser 2014; Ribaux et al. 2016), the validity of forensic evidence presented in court (Edmond & Martire 2016; National Research Council 2009; President's Council of Advisors on Science and Technology (PCAST) 2016) and the cost effectiveness of utilising forensic science in general (Speaker 2015).

Reviews of forensic services in the United Kingdom

A number of reviews of UK forensic laboratories were initiated by the government and conducted by government departments in the 1990s. In 1994 a study was conducted on the use of forensic services by eleven police forces in the United Kingdom (McCulloch 1996). The aim of this study was to identify the most effective ways to use forensic services. Database records were sourced which recorded assessments of forensic services that had been made by members of the "Scientific Support Unit" and Officers in Charge. This study covered a large range of forensic evidence types (e.g. biological samples, chemical trace evidence, firearms, fingerprints, etc.) as applied to a large range of offence types (i.e. major crime and volume crime). The methodology in this study utilised subjective ratings of the "usefulness of the forensic submission" for individual cases according to a simplistic four-point scoring scale ranging from "very useful" to "no value". The author recognised that there were issues with this methodology and noted that there was variation in the ratings completed by the Scientific Support Managers and the Officers in Charge. Some of the important differences that were noted included: (i) the fact that the Officers in Charge evaluated only the usefulness of the forensic submission to the case, whereas the Scientific Support Managers additionally evaluated the scientific value of individual tests; and (ii) that the frequency which the

Officers in Charge completed the evaluations was much lower than for Scientific Support Managers, with an apparent tendency to complete the evaluations more often when the forensic submissions were deemed to be useful. The authors also noted that the use of the scoring scale in conjunction with the associated definitions left room for individual interpretations. However, the fact that the data obtained in this study showed that the evaluation of forensic submissions by the Officers in Charge varied across offence categories and that the evaluations by the Scientific Support Managers varied across different forensic tests, indicates at the very least that the perception of the value of forensic evidence can be variable.

In 1995 a report of a joint study, "Using forensic science effectively", commissioned by the Association of Chief Police Officers (ACPO) and the Forensic Science Service (FSS) was published (ACPO/FSS 1995). The overall objective of this study was to improve the use of forensic resources in police investigative processes. The study was directed at: (i) police forces and how they utilise available forensic services; and (ii) suppliers of forensic services and how they may be able to tailor the services that they provide to better meet police investigative needs. An additional aim was to "stimulate police forces to analyse their own arrangements for forensic science support provided in the investigative process" (ACPO/FSS 1995, p. 9). The research team consisted of representatives from the FSS (a forensic science provider and a government agency at the time of this study), UK policing and the Home Office (the UK government department responsible for policing). Twelve of the forty-one police forces operating in England and Wales were the subject of this research. The methodology was based on semi-structured interviews with personnel that included scientific support managers, crime scene officers and police investigators. Forensic service providers were also interviewed but in a lesser number. Data was gathered from these interviews regarding the existing modes by which forensic support was being utilised, with the aim of identify anomalies and elucidating good practice. A major theme in the findings of this study centred on the disconnection of the scientific support to the investigation process. The awareness of forensic science amongst the

police using these services was found to be inadequate. Once again, this study was largely based on subjective assessments of forensic services, predominantly from the police user perspective.

Government reviews of forensic services in the UK continued through 2000s. Blakey, Her Majesty's Inspector of Constabulary, released the first of two reports in 2000 titled "Under the microscope" (Blakey 2000). In this report, Blakey stated that the recommendations of the previously released document "Using forensic science effectively" (ACPO/FSS 1995) remained valid but had not been acted upon and sought to provide a status up-date regarding how effectively forensic science was being used by UK police forces. The two most prominent forensic identification services, DNA and fingerprints, were part of the focus of this review. This study found that there was little relevant data available and questioned the quality of the limited data that was available for comparing the use and effectiveness of forensic science. Blakey reported that there was poor monitoring of some aspects of the DNA service, such as sampling practices. More generally, a lack of meaningful performance indicators was "a real concern" (Blakey 2000, p. 83). Blakey referenced the importance of monitoring the value and cost of investigative processes and proposed that rigour should be applied to the resourcing of scientific and technical support. Notably Blakey commented on the importance of developing monitoring systems to assess the effectiveness of forensic services. The second document in this series "Under the microscope: refocused" (Blakey 2002) was an assessment by Her Majesty's Inspector of Constabulary of how a sample of UK police forces had responded to the previous report (Blakey 2000). It was found that there had been a mixed take up of the recommendations.

In 2003 a report was released titled "Improving service delivery: The Forensic Science Service" (Bourn 2003). This was a review conducted by the UK National Audit Office, which specifically examined the services delivered by the Forensic Science Service (FSS). The FSS at the time of that review was the major provider of forensic services to police forces in England and Wales. Although this was largely an audit of service delivery, with a strong focus on factors such as timeliness and

cost effectiveness, the review did direct some attention to “the impact of forensic analysis in furthering criminal investigations” (Bourn 2003, p. 31). The review utilised data that the FSS maintained, which consisted of assessments of the effectiveness of their analyses. For individual cases FSS scientists would score the conclusiveness of their results using a seven-point scale whereby: a score of 1 equated to “conclusive evidence to eliminate a suspect...”; a score of 7 equated to “conclusive evidence to associate a suspect...”; and a score of 4 equated to “inconclusive to either associate or disassociate a suspect...”. It was found that in 2001-02 the FSS scientists rated their results as providing conclusive evidence to either associate or disassociate suspects in 47% of their cases. In reference to cases without suspects, 72% of their cases were deemed by the FSS scientists to “be of some intelligence value” (Bourn 2003, p. 31). These results were presented as a favourable assessment of the forensic services provided by this agency. However, it is questionable as to whether this study has measured the impact of the forensic services in the criminal justice system in a meaningful way. The methodology is weakened by the fact that it is based on subjective self-assessments that were made by FSS scientists who were responsible for the work that was performed. The review also found that the assessments were not performed for significant proportions of cases (49% of non-drug cases in 2001-02) which introduces the possibility of the results being skewed along lines relating to the case results (i.e. were the assessments completed more often depending upon whether the results were deemed to be valuable?). Additionally, these assessments relate to “furthering the investigation” and court outcomes are not considered. The review recognised that the FSS were unaware of whether charges were brought against suspects or whether prosecutions led to convictions or acquittals and suggested that the introduction of a mechanism to inform the FSS of these outcomes would help the agency to better understand its impact in the criminal justice system. Despite the fact that there was emphasis on whether forensic results led to “furthering the investigation”, the methodology used in the examination of the impact of forensic evidence did take into account evidence which eliminated suspects, which indicates that

there was some recognition that the value provided by forensic evidence is not confined to implicating suspects.

In 2005 the Home Office released a report that reviewed the research that had been conducted on the application of forensic science to volume crime investigations (Bradbury & Feist 2005). The objectives of this report were to identify: (1) the mechanisms by which forensic science is applied; (2) the strengths and weaknesses of the use of forensic science; and (3) the way in which forensic science contributes to "the detection (and conviction) of crime". This was a broad and comprehensive review which covered scene attendance, evidence collection, the conversion of forensic identifications into the detection of offenders and the contribution of forensic science to the court process. Like previous UK studies of forensic science, this review applied a degree of emphasis on forensic identification disciplines, notably fingerprints and DNA. With regard to the forensic identification sciences, the conversion of forensic identifications into the detection of offenders was a process that was found to be often incomplete. For example, a study conducted in England and Wales found that approximately seventy percent of successful forensic identifications using DNA evidence ultimately led the police investigation process to reach a conclusion that was considered to have "cleared up" a "detected crime". A lack of supporting evidence was found to be the cause of why many investigations in which identifications were made, did not proceed to completion. This review found that relatively few studies up to the time of this report had attempted to evaluate the impact of forensic science on guilty pleas, convictions and the length of sentences. The absence of comprehensive case tracking databases and difficulties in marrying discrete databases together were major impediments in conducting examinations covering the whole of the criminal justice process.

In 2007 the findings of another study on the use of forensic science by police forces in the UK were released (Home Office 2007). This study was initiated by the Home Office and the report was widely known as the "SWIM report". The report's findings and recommendations were used to form a

package titled the “Scientific Work Improvement Model” (i.e. “SWIM”). As per some previous reviews of forensic science in the UK, the “SWIM report” once again noted difficulties in accessing data that could be used for measuring and monitoring the performance of forensic services and attributed part of the difficulty to the fact that relevant data was held in separate systems. Two important facets in the application of fingerprint and DNA services were identified in this study as having significant variability. The first was nominated as “attrition” and referred to the various points after a crime is reported that the process ends before an offender is prosecuted. There is a lengthy sequence of steps in the chain of events between the reporting of a crime and an offender being prosecuted. These steps include the police investigators calling for the application of forensic services, the collection of exhibits by crime scene officers, the laboratory-based analysis of exhibits for forensic evidence and the use of the forensic evidence by police to seize offenders. “Attrition” refers to the breakdown of this process at any point, with particular emphasis on factors that do not relate to the limitations of the evidence but rather are failures within the policing and forensic processes. The second facet was “lead time” which referred to the length of time between the reporting of the crime and the eventual prosecution. The “SWIM report” proposed that “Attrition” and “Lead time” were two key overall performance measures of forensic services. This study was largely based on fingerprints and DNA, and “lead time” effectively equates to timeliness, a criterion previously used as a performance measure when evaluating forensic science. However, identification of the fact that there are numerous points where failures can occur in processing a potentially criminal incident through the police investigation, forensic examination and court processing systems is important and has the potential to be applicable to other types of forensic examinations.

Recent reviews in the UK

Through the current decade, and notably following the closure of the Forensic Science Service in 2012, there was a shift in the provision of forensic services in the UK to a model where services are

provided through a combination of commercial organisations and some in-house provision by the 43 police forces in England and Wales. Issues developed with this change in service provision which were examined in some recent government reviews of the status of forensic science in the UK.

A review of forensic services in England and Wales titled “Review of the provision of forensic science to the criminal justice system in England and Wales” was reported in 2018 (Home Office 2018). At the request of the Minister for Policing and the Fire Service, the collaborative review was conducted by the chair of the National Police Chiefs’ Council (NPCC), chair of the Association of Police and Crime Commissioners (APCC) and the Home Office. The review was prompted by persistent stakeholder concerns regarding quality and perceived instability in the provision of forensic services, which had been highlighted by one significant provider entering into administration and another being investigated for alleged manipulation of results. The review was based on interviews with stakeholders (i.e. from the criminal justice system, the Forensic Science Regulator and commercial services providers), visits to police forces and review of reports and other documents. Themes that were addressed in the review included the risks associated with fragmented administration of forensic science, the apparent insufficient regulation of quality (including a lack of enforced standards) and the fragmented state of research and development. It was noted in the report that without “a more formal role for the criminal justice system in evaluating the frameworks that guide decision making, there is a risk that the needs of the criminal justice system will not be met” (Home Office 2018, p. 30). This comment reflects that it is important that forensic science is providing value to the criminal justice system and there is a need to monitor how well that goal is being achieved. Recommendations from the review related to the need for sustainable funding and service provision models, and a more coherent system to ensure that the benefits of advances in science and technology were realised by policing and the criminal justice system. It was also recommended that an implementation plan be developed that ensured that practitioners and policy makers have stronger evidence and data to support decision making and facilitate working with partners more effectively.

More recently, an inquiry was conducted by the Science and Technology Select Committee of the House of Lords which considered the contribution of forensic science to the criminal justice system, the scientific basis for certain techniques, the regulatory framework that underpins standards and the instability of the forensic science market and related research. The report from this inquiry "Forensic science and the criminal justice system: a blueprint for change" was published in 2019 (Science and Technology Select Committee 2019). The inquiry was conducted via twenty-one oral evidence sessions involving fifty witnesses, the assessment of one hundred and three written submissions and a visit to the Metropolitan Police Service's Directorate of Forensic Services. Witnesses included stakeholders from police organisations, academic institutions, criminal bar associations, private forensic companies and the Judiciary. The report cited concerns that had been raised in previous reports regarding the provision of forensic services being under threat and reliant on unregulated experts, challenges relating to digital forensics, reduction in budget and the limited scientific basis for some evidence types. The recommendations in the blueprint for change were that there was a need to develop a new forensic science strategy whereby the provision of services would be regulated, the quality of services monitored, and standards enforced. Fair pricing for services needed to be achieved to address problems that had developed regarding fair access to forensic science and justice. Priorities in research and development needed to be established which as a priority should include research to develop capabilities that would meet the increasing demands on forensic science that are imposed by the rapid growth in digital evidence. To achieve these outcomes, recommendations were also made about reforming the Forensic Science Regulator and creating a Forensic Science Board (to perform an overarching strategic role) and a National Institute of Forensic Science (to perform a strategic role with research and development). The report touched on the efficiency of services suggesting that "levels of funding and the value for money in the forensic science market" needed to be considered (Science and Technology Select Committee 2019, p. 470). Support for the proposals relating to the regulation of the forensic science market, strengthening quality standards through accreditation of service providers, improving access to

forensic services and bolstering research and development was outlined in the recommendations presented in the UK governments response to the “blueprint for change” report (*Government response to the Lords Science and Technology Select Committee report: Forensic science and the criminal justice system: a blueprint for change* 2019).

The main issues that these reviews sought to address were service delivery, the fundamentals of forensic science and the challenge of keeping pace with advancing technology, particularly in regard to digital evidence. The effectiveness of forensic science was not stated to be a focus of either review, however the importance of the contribution of forensic science to the criminal justice system was apparent in both reports, and reference was made to either the relevance of efficiency or the need for measures of impact to guide decision making.

Reviews of forensic services in the United States

Studies have also been conducted in the US that were of a similar nature to the UK research, in that: (1) they were initiated and/or were conducted by government funded organisations; and (2) they were directed at assessing the delivery of forensic services.

The findings of an audit of the Forensic Services Division, Michigan Department of State Police were reported in 2003 (McTavish 2003). This review was conducted by the Auditor General for the purpose of assessing the effectiveness and efficiency in providing forensic serves to the criminal justice agencies. In this report effectiveness was defined as “program success in achieving mission and goals” and efficiency as “achieving the most outputs and outcomes practical with the minimum amount of resources” (McTavish 2003, p. 15). In performing this audit official records and procedures were examined, personnel from the forensic service provider and the courts were interviewed and conviction data was examined. This audit reached a broad sweeping conclusion that this laboratory was generally effective and efficient in providing forensic services, but detailed

information and data that supported the finding were not presented. The report did however present data that illustrated the organisation's inability to process the DNA profiles of offenders, which supported the finding that the DNA database that was in use was incomplete and not fully effective (i.e. the Combined DNA Index System known as "CODIS").

In 2004 the American Society of Crime Laboratory Directors (ASCLD) conducted a study of the status and needs of US forensic laboratories (Johns & Kahn 2004). ASCLD is a professional society of senior managers of forensic laboratories in the US and it plays a role with regard to maintaining appropriate standards of practice. This study was conducted from the perspective of managing forensic laboratories and addressed issues such as resourcing, education and training, accreditation standards and collaboration between laboratories across the federal, state and local levels that exist in the US forensic environment. This study found that the funding allocated to forensic laboratories had not kept pace with the increasing demands for services. The primary need across the forensic laboratories was for additional personnel who would be required to achieve the delivery of more timely services. The findings in this report built on those presented in the previous National Institute of Justice "Status and needs" report which also identified resourcing, practitioner training and transfer of technology between laboratories as critical issues (National Institute of Justice 1999).

In 2004 the National Institute of Justice (NIJ), the research, development and evaluation agency of the U.S. Department of Justice, submitted a report to the US Congress titled "The status and needs of forensic science services providers" (National Institute of Justice 2004). This report was prepared by the NIJ through collaboration with US organisations active in the field of forensic science (including ASCLD and the American Academy of Forensic Sciences). The impetus for this study was based on a government Act which specified that the NIJ should submit a report addressing the needs of forensic service providers. As defined by the terms in the Act, the report addressed: (1) resources; (2) education; (3) professionalism and accreditation; and (4) collaboration between laboratories. Several needs were identified, and recommendations were made which included:

examiners to be required to meet training and proficiency standards; additional personnel and equipment was required to address backlogs; accreditation of service providers and certification of practitioners was desirable; and service providers needed improved research and development programmes to keep pace with technology.

In 2005 a report was released regarding a census that was conducted of publicly funded crime laboratories operating in the US in 2002 (Peterson & Hickman 2005). The census was conducted by the Bureau of Justice Statistics in conjunction with the American Society of Crime Laboratory Directors (ASCLD). This census found that there were 351 laboratories that met the criteria covering the scope of this census (i.e. publicly funded laboratories which employed scientists to examine physical evidence, prepare reports and present evidence to the courts of law). The census was based on survey responses received from 87% of the eligible laboratories in the US. This census collated detailed information in regard to staffing, budget, case workloads and accreditation status. The report presented findings that related to problems in service delivery and personnel shortfalls that were common across the surveyed laboratories. However, similarly to the ASCLD review (Johns & Kahn 2004) and the NIJ report (National Institute of Justice 2004), the role of the forensic laboratories in supporting the criminal justice system was not the focus of this study. Consequently, although this report covers issues that are important for the management of forensic services, the fact that it does not explore the ultimate function of forensic science (i.e. to support criminal investigations and court processes) means that it cannot be considered to be a full assessment of the effectiveness of forensic science in the criminal justice system.

In 2009 a report from a major study of forensic science in the United States was released. This study was authorised by US Congress and conducted by the National Academy of Sciences, and was titled "Strengthening forensic science in the United States: a path forward" and is commonly referred to as the "NAS report" (National Research Council 2009). The scope of this study was broad and covered a range of issues. It examined forensic science from a technical perspective and challenged the

scientific basis of some disciplines, notably those based on pattern recognition, which are heavily reliant on the interpretation performed by the forensic practitioners. It addressed quality control systems within the forensic community and made recommendations regarding accreditation, practitioner certification and monitoring systems for detecting erroneous findings. And from a managerial point of view it noted the great disparities across federal, state and local forensic science laboratories regarding their funding, scientific infrastructure, skilled personnel and quality control systems. However, despite the broad ranging and in-depth nature of this research, this study did not examine the performance of forensic science in the criminal justice system to any great depth. Aspects of the report failed to reflect the varied means by which forensic evidence can assist criminal investigations and court processes. The report recognised that forensic science consists of a diverse range of forensic disciplines which utilise different technologies and methodologies, but still at times applied emphasis on using forensic science for the identification of perpetrators. Mention of other forensic capabilities, such as determination of whether a reported incident is or is not a criminal offence, was omitted and in this regard the report fails to present the full value of the support provided by forensic science to the criminal justice system. The report also viewed providing strong evidence for prosecutions as a major role of forensic laboratories. Forensic science examinations should be targeted at testing relevant hypotheses (e.g. does the blood left at a crime scene come from a certain suspect?) and can equally be of value whether it produces evidence that supports the prosecution case or the defence case. Again, failing to acknowledge that forensic evidence can dis-associate suspects with crimes understates the value of forensic evidence. Further, to draw an alignment with the prosecution puts at risk the impartiality of forensic science, which must be maintained in the interest of achieving just outcomes.

Continuing the scrutiny of the fundamentals of forensic science, a report to the President of the United States of America from the Council of Advisors on Science and Technology (PCAST) was published in September 2016 titled “Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods” (commonly referred to as the PCAST Report) (President’s Council of Advisors

on Science and Technology (PCAST) 2016). This report presented the findings from a working group of the PCAST which had conducted evaluations of the scientific validity of seven forensic feature-comparison methods. Full evaluations were conducted of DNA analysis (single source/simple mixtures and complex-mixtures assessed separately), bitemarks, latent fingerprints, firearms identification and footwear analysis. An evaluation of hair analysis was based on supporting documentation for hair analysis from the Department of Justice. The criteria that were used to assess scientific validity included that the method had been subject to empirical testing and was shown to be repeatable and reproducible. For objective methods, the working group examined whether accuracy, reproducibility and consistency had been measured. And for subjective feature-comparison methods, they examined whether error rates had been determined based on "black-box studies" (independent tests typically involving "questioned" samples and one or more "known" sample"). The report was critical of most of the methods and reached findings that the majority did not meet scientific standards for validity. The PCAST Report made four recommendations directed at the forensic science community. It recommended that scientific evaluations of validity should be conducted by an independent agency on an on-going basis. For latent fingerprints, firearms analysis and DNA analysis of complex mixtures, it recommended that method development should be undertaken to convert these currently subjective methods to objective methods. The development of a national research and development strategy and reforms to the interagency committees responsible for standards within classes of forensic science, were also recommended.

Scrutiny of the scientific foundations of a number of forensic disciplines, particularly those based on pattern recognition, has continued. As an example, the American Association for the Advancement of Science (AAAS) conducted evaluations of the scientific and technical foundations of latent fingerprint examination and fire investigation with the aim of identifying aspects of these disciplines which are well founded in science and aspects which are not (Almirall et al. 2017; Thompson et al. 2017). For both disciplines, recommendations were made for trials and research to be conducted to determine the reliability of the conclusions reached.

Critical evaluation of UK and US forensic services reviews

The government funded reviews of forensic services conducted in the UK and US from the mid-1990s through to the current decade have not fully assessed the value that forensic science is adding to the criminal justice system. On some occasions these reviews have tended to adopt a business or management perspective and have included a focus on service delivery. A common theme through these reviews, particularly with the US work, is that of workloads, backlogs and resources (both personnel and equipment). These factors do influence the effectiveness of forensic services in terms such as timeliness, and they also impact on the success of offender profiling systems such as DNA databases. The UK studies within this group of research explore the forensic processes and the related aspects of police investigations in greater depth. They seek to identify areas of weakness and to find the opportunities to improve the provision of forensic services. Some important areas that are covered include: (i) conversion of forensic identifications via fingerprint or DNA evidence into the apprehension of offenders (and the attrition that occurs between evidence collection and the final court processes); (ii) the roles of personnel across policing and forensic services, their understanding of forensic capabilities and better means to achieve the full potential benefits of the available forensic evidence; and (iii) improved utilisation of the finite forensic resources (i.e. when to deploy forensic services and strategies that are based on targeting crimes types, etc.). But still the scope of this group of UK research, similarly to the US studies, generally stays within the police investigation and forensic services phases of the criminal justice process (i.e. the research does not extend into the final court phase). These reviews tended to concentrate on DNA and fingerprints, and the identification of suspects/offenders in general. The contribution of many other forensic disciplines, which can provide different forms of valuable information in addition to identifications (e.g. assist with meeting a legal requirement to establish that an incident was in fact a crime) have not been

well examined. Overall this research does not explore the impact of forensic evidence in the court phase of the criminal justice process as a means of assessing the effectiveness of forensic services.

Empirical research on the effectiveness of forensic science

To date there has only been a small number of studies that have attempted to provide an empirical evaluation of the impact of forensic science on the criminal justice system. Wilson et al. (2011) highlighted this gap in 2011 when they reported their findings following an extensive search of existing literature for evidence that DNA testing was effective in supporting police investigations. Only five studies were found in this systematic review that met the set criteria: the studies must include a control group and provide an estimate of the effect of DNA analysis on increasing offender identification, arrest, conviction and case clearance. The five eligible studies were as follows: (1) Roman et al (2009); (2) Dunsmuir et al (2008); (3) Briody (2004); (4) Schroeder (2007); and (5) Tully (1998).

Briody (2004) examined the effects of DNA evidence on homicide cases in court. This study utilised official forensic and police records pertaining to 150 homicide cases in Queensland, Australia between 1996 and 1999. This was a controlled study that investigated defined hypotheses and applied statistical testing. DNA evidence was a component of the evidence presented by the prosecution in half of the 150 cases. The other half, which did not include DNA evidence, acted as a control group. This study analysed the relationship between the inclusion of DNA evidence in the prosecution case, along with other predictor variables (victim variables, offence variables and defendant variables) with the following stages of the court process: (1) cases reaching court; (2) guilty pleas that are entered; (3) the conviction of the defendants; and (4) the length of custodial sentences. Four hypotheses were tested which were based on each of the four court stages

outlined. The hypothesis that a higher proportion of homicide cases would reach court when DNA evidence was presented by the prosecutors was validated using statistical correlation methodology. Odds ratios were calculated and the likelihood of a case reaching court were found to be more than 14 times higher with DNA evidence than without. A significant relationship between DNA evidence that implicated the accused and the likelihood of conviction was also established, with the calculated odds ratio indicating conviction was more than 23 times more likely for cases with DNA than for those without. The hypothesis that longer custodial penalties would be imposed when incriminating DNA evidence was presented could only be tested in manslaughter cases because in Queensland life sentences are mandatory for murder convictions. However, there was found to be a correlation between DNA evidence and longer custodial sentences in manslaughter cases. DNA evidence, however, was not found to have a significant association with guilty pleas.

A randomised trial was conducted in the US that was aimed at testing whether collecting and analysing biological evidence in property crimes led to better case outcomes (Roman et al. 2009). The trial was applied to 500 cases of property crime that had occurred in 5 US cities between the period of 2005 and 2007, and for which biological evidence had been collected from the crime scene. At the time of this study, DNA analysis was only utilised routinely for the most serious violent crimes in these jurisdictions. However in this trial, half of the cases were randomly assigned as the treatment group and DNA testing was added to the traditional investigation process. The study estimated the impact of DNA evidence on key case outcomes: (1) whether a suspect is identified; (2) whether a suspect is arrested; and (3) whether the case is subsequently accepted for prosecution. Differences in the results between the treatment and control groups were statistically tested using t-tests. In each of the three categories the results for the treatment group were significantly higher ($p<0.001$). That is, in this study the application of DNA testing resulted in more suspects being identified, more suspects being arrested and more cases being accepted for prosecution. This study also compared the impact of DNA and fingerprints on the case outcomes and reported that DNA was

more effective than fingerprints in identifying suspects and also resulted in more suspects being charged.

There have been a series of related US studies that have been reported in recent years that are best reviewed as a group as they have all utilised the same source of data, employed similar methodology and have been performed by a related combination of researchers. The results of these studies have been variable and they have produced conflicting findings in regard to the impact of forensic evidence on criminal justice processes. Each of the studies used the same case record data from five US jurisdictions for the year 2003. These studies tracked the outcomes of reported crimes by collecting data from police, forensic and prosecution case files. The complete data pool consisted of 4205 randomly selected cases covering the following offence types: aggravated assaults; burglaries; homicides; rapes; and robberies. The data pool included cases which did, and which did not, include forensic evidence. For the cases that did include forensic evidence, the disciplines of forensic science that had been applied were varied and covered combinations of most evidence types (e.g. biological samples, fingerprints, firearms, trace evidence, etc.). The initial and core research was a project funded by the National Institute of Justice (NIJ) and conducted by Peterson, Sommers et al (2010). This was a large and detailed piece of work that examined the entire pool of 4205 cases but addressed each of the offence types separately. The study explored the effect of crime scene and laboratory examined evidence on the outcomes of criminal justice processes including: (1) arrest; (2) referral for prosecution; (3) charges laid; and (4) convictions. The effects of other non-forensic variables (such as victim and witness reports and suspect/victim relationships) were also examined. Logistic regression methodology was applied in the analysis of the data. Peterson, Sommers et al (2010) found that crime scene and laboratory examined evidence did impact on the processes of arrest, referral for prosecution and laying of charges, although “the predictive power of forensic evidence varied by crime type and criminal justice outcome” (p. 123). Notably forensic evidence was found to not have significant effect on case conviction for any of the offence types.

Baskin & Sommers (2010; 2011) performed additional research that resulted in the publishing of two further reports. These studies drew upon the same pool of data but utilised only the homicide and burglary cases. As per the original work by Peterson, Sommers et al, Baskin & Sommers also applied logistic regression methodology to analyse the data. These studies focused on the same criminal justice processes, but the effect of forensic evidence was assessed according to the following variables: (1) presence of evidence at crime scenes; (2) laboratory submitted and examined evidence; and (3) evidence that linked a suspect to a crime scene and/or victim. Once again, the effects of non-forensic variables (relating to the incident reported, the people involved and the investigation that followed) were also assessed. For the study on homicide cases, Baskin & Sommers considered the most noteworthy finding to be that "none of the forensic evidence variables had any significant influence on any stage of criminal case processing" (2010, p. 8). Eye witness reports and suspect/victim relationships were found to be the most powerful predicators of criminal case processing. In the study of burglary cases the presence of crime scene evidence was found to be a significant predictor of arrest and referral for prosecution (Baskin & Sommers 2011). Regarding the effect on arrest it should be noted that forensic evidence was analysed prior to arrest in less than one third of cases in which it was collected. The authors proposed that the collection of "tangible evidence", that is physical items that do not require scientific analyses (e.g. stolen property) and which are not actually forensic evidence, could contribute to the observed effect of "crime scene evidence" on arrests. Witness reports were found to be the main predictor of case processing outcomes with statistically significant impact on arrest, referral and charges. Baskin & Sommers concluded that overall, "forensic evidence was non-determinative in residential burglary cases" (2011, p. 82).

A common finding across these three publications (Baskin & Sommers 2010; Baskin & Sommers 2011; Peterson et al. 2010) was that forensic evidence did not significantly impact on convictions. However, despite the fact that these studies were based on the same pool of data and that they

applied similar analytical strategies, Peterson, Sommers et al and Baskin & Sommers reached opposing conclusions on the effect of forensic evidence on arrest, referral and charges.

Most recently Peterson, Hickman et al (2013) undertook further studies with the aim of clarifying the discrepant findings in the three previously published reports. For this work the same data obtained from the five US jurisdictions that was used in the previously discussed studies was again utilised, but on this occasion it was analysed in aggregate (i.e. cases of all offence types were pooled). The methodology was also varied with a combination of basic descriptive statistics, bivariate analysis and multivariate analysis (using logistic regression) being applied. In contrast to the previous studies, the analyses conducted by Peterson, Hickman et al did not include correction factors for selection bias. The study yet again examined the impact of forensic variables (collection of crime scene evidence, laboratory examination of evidence and evidence that linked suspects with the victim and/or crime scene) and other non-forensic variables on the outcomes of the following criminal justice processes: (1) arrest, (2) referral for prosecution; (3) charges; (4) plea entered; and (5) conviction. The findings in this work were similar to those of Peterson, Sommers et al in 2010 in that the collection of evidence and the examination of evidence were found to be (although with some variation) predictors across the processes of arrest, referral and charges. Additionally, and in contrast to all three previously published reports, convictions were found to be significantly influenced by collection of evidence (bivariate analysis), laboratory examination of evidence (bivariate and multivariate analyses) and evidence that linked a suspect to the crime scene and/or victim (bivariate analysis). Peterson, Hickman et al found that collectively "forensic evidence is statistically related to several case processing outcomes" (2013, p. 84) on the basis of the bivariate analysis and concluded overall that "forensic evidence played a consistently strong role in criminal justice case processing" (2013, p. 89).

Forensic examinations can produce valuable evidence that can assist with achieving just outcomes. Forensic evidence can establish important associations between criminal offences and persons of

interest, direct investigations towards implicated suspects and can be a critical component in the prosecution's case. However, an equally important capability is that forensic evidence can eliminate persons of interest, re-direct police investigations away from innocent suspects and assist with clearing wrongly accused parties in criminal trials. It is essential that evaluations of the contribution of forensic evidence take into account both the association and elimination of persons of interest. This group of studies (which is based on the analysis of data derived from five US jurisdictions for 2003) ultimately amounts to a somewhat confusing body of work with conflicting findings, even though similar methodology has been applied to the same pool of data in each of four studies. It is difficult to draw clear conclusions regarding the impact of forensic science on criminal justice processes from these four publications given the inconsistency of the reported results. But most critically, there are weaknesses that are common to the methodologies of each of the four publications. These studies essentially are restricted to assessing the impact of forensic evidence that supports the prosecution case. The effectiveness of forensic evidence is only considered from the point of view of furthering the criminal justice processes to ultimately convict suspects. The value that forensic evidence can provide in clearing suspects and redirecting police investigations, and also achieving just outcomes in court hearings, is completely omitted. The results of forensic examinations must be taken into account when assessing the impact of the evidence, as whether the results implicate or clear a suspect determines the direction of the impact on the investigation and court outcomes. Despite the fact that Peterson, Sommers et al (2010) highlight that there are different reasons for utilising forensic science in police investigations (including "establishing an element of the crime", "identification of a suspect or victim", "reconstruction", etc.), these studies either confine their assessments to the contribution of forensic evidence in establishing a link between a suspect and the crime scene and/or victim or do not take into account the results of the forensic examinations at all (i.e. the forensic variables assessed were simply whether evidence was collected or whether evidence was examined in a laboratory).

It is also important to recognise that forensic science is made up of a range of disciplines, which are applied in different ways (e.g. at the crime scene and in the laboratory), provide different evidential information (e.g. directly identify suspects, develop a nexus between items and a crime, determine whether an incident was a criminal offence) and have potential to impact on investigations and court trials in different ways. Another limitation across all four publications is that in the analysis of data, forensic evidence is dealt with as one entity although the forensic evidence that was collected in these cases is actually applicable to a broad range of diverse disciplines (Peterson et al. 2010). Consequently, this body of work does not provide any insight into the potential differential impact of various forensic disciplines on different stages of the criminal justice process. The value of performing such a study (i.e. which examines whether differential impact of the evidence produced by different forensic disciplines) is however acknowledged by Peterson, Hickman et al.

Australian literature on the impact of forensic evidence and the effectiveness of forensic science

Research conducted by Briody (2004), which used a controlled study to examine the effect of DNA evidence on homicide cases in Queensland, Australia, has already been discussed. There is literature for further research conducted in Australia, which has examined the impact of forensic evidence or has been related the effectiveness of forensic science.

Studies have been conducted in Australia that were designed to benchmark forensic processes and identify best performance in the application of fingerprint and DNA services to support the investigation of volume crime. The first study, known as the Australian End to End Forensic Identification Process Project ("E2E1" for short), was conducted in 2011 and involved the

investigation of burglary cases in eight jurisdictions across Australia (Brown et al. 2014). The project used methodology based on the United Kingdom Scientific Work Improvement Model (SWIM) (Home Office 2007) to examine the progression of forensic support in cases through five stages: 1. crime scene attendance; 2. evidence submission; 3. analysis of evidence; 4. identification; and 5. arrest. Data was collected regarding lead-time, the time taken to progress from one stage to another, and overall success was defined as the arrest or charging of a suspect. This study produced a variety of findings including that there were some notable differences between the results obtained for fingerprints and DNA evidence (e.g. fingerprint evidence was submitted in twice as many cases; lead times were shorter for fingerprint evidence; arrests were made based on fingerprint evidence more often than DNA) and that the longest lead-time was from identification to arrest. From this study, a number of recommendations were made to the jurisdictions, which were aimed at developing consistency in the collection, submission and analysis of evidence for both fingerprints and DNA. The project was repeated in 2015, End to End Phase 2 ("E2E2" for short), to measure whether recommendations drawn from the best performers in the first project had produced any impact (Bruenisholz et al. 2019). The results obtained indicated that a number of improvements had been achieved including increases in crime scene attendance, identifications and arrests, which the authors attributed to the improved use of forensic evidence. However, the overall lead times were similar in both phases of the project and wide variation in results were obtained across the jurisdictions. Advances in technology (digital imaging of fingerprints and robotics for DNA analysis), greater emphasis on service delivery models, and changes implemented for scene attendance practices, were additional factors which were considered to have contributed to the improved performance.

Further research conducted in Australia was "The Effectiveness of Forensic Science in the Criminal Justice System" project (Julian 2016; Julian et al. 2011). This was a major five-year Australian Research Council (ARC) Linkage Project (LP0882797) that brought together a multidisciplinary team of academic researchers, forensic scientists and representatives of state and federal police, from

multiple agencies and from universities in Australia and Switzerland. The project, which was divided into multiple sub-projects listed below, aimed to conduct a comprehensive examination of the role of forensic science in the criminal justice system, with focus on the forensic processes and outcomes relating to the crime scene, the forensic laboratory, police investigations and the courts.

1. What is meant by the "effectiveness" of forensic science?
2. What are the critical points in the forensic process (i.e. in a forensic-led investigation and prosecution)?
3. Crime Scene - What makes a good crime scene examiner?
4. **Forensic laboratory - What is the impact of forensic evidence on police investigations and court outcomes?**
5. Police - How can police use forensic evidence for investigative and intelligence purposes?
6. Courts - How do lawyers understand and use DNA evidence?
7. What are the "pros" and "cons" of information sharing between criminal justice agencies?
8. How can the 'economic' effectiveness of forensic science be measured?

The research presented in this thesis, the sub-project highlighted in the list above, is particularly focused on examining whether the benefits of forensic science to criminal investigations and court processes are broad and widespread. The number and variety of the sub-projects reflects recognition of the multi-dimensional contribution of forensic science to the criminal justice system. This ARC project produced a collection of empirical data on critical aspects of the forensic processes, and information about the forensic processes pertaining to scene examination, laboratory analyses, police investigations and court trials have been published and disseminated to relevant industry and researchers.

A randomised field trial was conducted in Australia which sought to evaluate the potential to enhance the police response to residential burglaries (Antrobus & Pilotto 2016). This study found that forensic evidence, either fingerprints or DNA, was used to support investigations and to assist in

solving cases (measured in terms of charges being laid). Furthermore, increasing the capabilities of crime scene examiners in terms of a combination of forensic technical capabilities and also their approach to interacting with victims in a more procedurally just way, resulted in a higher proportion of cases being solved. It was found that there was scope to improve the collection of fingerprints, which in turn contributed to a higher rate of solving cases. However, the results obtained in relation to the collection of DNA samples did not follow a similar trend (that is greater training in collecting DNA samples, along with capability to collect more DNA samples, did not significantly increase the rate of identifications and cases solved).

A chapter titled “Forensic Science Effectiveness”, that was composed by a group of Australian and Swiss authors, is presented in the “Encyclopedia of Criminology and Criminal Justice” (Roux et al. 2014). This chapter reviews the status of the existing knowledge of the effectiveness of forensic science through the stages of forensic process from crime scene to court. A range of limitations and weaknesses applicable to each of the forensic processes are described including: the limited availability of empirical data relating to some processes (e.g. crime scene); collective findings that are conflicting and unclear for some processes, in part due to methodological weaknesses in the studies conducted; a need to extend the research on some processes to other forensic disciplines; and knowledge that is largely based on anecdote. The authors propose that a better understanding of the broad contribution of forensic science is required to enable a true evaluation of its effectiveness and they conclude that effectiveness can only be assessed by contrasting outcomes and impact against what the forensic science community itself claims to be able to achieve. It is also highlighted that the contribution of forensic science to intelligence-led policing and investigations must be accounted for in a full assessment of the effectiveness of forensic science.

Different views of the effectiveness of forensic science

Through the last decade a body of literature has emerged that has challenged aspects of the preceding research that utilised quantitative case processing methods to measure the impact of forensic evidence on judicial outcomes. This body of literature proposes that a full evaluation of forensic science requires a broader view of value, and that because forensic science contributes to the criminal justice system through varied modes, multiple forms of impact must be considered in assessing the effectiveness of forensic science.

Many authors have noted that it is difficult to assess the effectiveness of forensic science. Williams and Weetman (2013) stated that it has been difficult to establish the contribution of forensic science to the criminal justice system and to do so via an empirical study it is necessary to deal with the messy complexity of the investigation of major crimes. Ludwig and Fraser (2014) have also recognised the complexity of the relationship between forensic science and the criminal justice system. From a systematic review of published reports relating to the use of forensic science in the investigation of volume crimes, they found that forensic science appeared to be misunderstood and "not used effectively or efficiently in the investigation of volume crime" (p. 86). They also found that that the processes required to use forensic science effectively in investigations are more complex than had been recognised.

Some authors have assigned importance to defining key terms such effectiveness, efficiency, value and even forensic science itself, when examining the effectiveness of forensic science (Bitzer et al. 2015; Bruenisholz et al. 2019; Ludwig 2016). Without intending to add to this discussion, effectiveness can be considered to relate to having impact and achieving an intended outcome. Efficiency adds an element of productivity or the degree to which a desired outcome is achieved and may also include consideration of cost and waste. However, when these terms are used interchangeably or with other intended meaning it can add confusion to discussions of the

effectiveness of forensic science. Ludwig (2016) contends that effectiveness, efficiency and value are concepts that vary depending upon the organisation within which they are defined. Bitzer (2017) considers the definition that is used for forensic science itself, and the perception of particular aspects such as its objective and role, as a factor that causes the assessment of the contribution of forensic science to be not straightforward.

There has been criticism that the published quantitative research has centred on a narrow aspect of the value provided by forensic science. Ludwig (2016) suggested that a narrow notion of value has been applicable in a proportion of the literature that has examined the effectiveness of investigations and the use of forensic science, and that the definition of value has been dependant on the organisation associated with the research (e.g. police force, forensic service provider). Bitzer et al (2017) have stated that the published research that has sought to measure the contribution of forensic science via its predictive power for the outcome of judicial steps (e.g. charging, conviction) or its throughput regarding technical procedures (e.g. number of yielded profiles) have produced results that are “close to disastrous”, depicting an overall negative image of the utility of forensic science (p. 16). They have suggested that this research has only covered court-orientated outcomes and that to measure the utility of forensic science, multiple potential dimensions of contribution must be taken into account. In an assessment of relevant research in the UK, Williams and Weetman (2013) described three underlying weaknesses: (i) a narrow focus on the identification sciences (i.e. DNA, fingerprints and shoe impressions); (ii) a concentration on quantifying throughput (e.g. measuring attrition, detections aided); and (iii) a focus on volume crime to the neglect of major crime, and that as a result of these weaknesses, gaps exist in the knowledge of the utility of forensic science to support homicide investigations.

Bitzer et al (2015) introduced the concept of “utility of the clue” for evaluating the contribution of traces to supporting investigations, which was defined as the added value of information attained via the trace. As opposed to quantitative methodology in which the impact of forensic evidence is

statistically tested across a sample set of cases, the proposed use of utility of the clue is to be applied via a case-based approach with a detailed study of the decision-making processes impacted by the use of the traces in specific cases. Bitzer et al (2017) also detailed multiple important decision-making steps and proposed that there are seven embedded milestones relating to the use of forensic science in cases. The steps begin with the decision to attend a crime scene, move through to the decision to analyse collected traces and finish with the use of the traces in investigations, intelligence and in court, all of which are decisions that can influence the value that forensic science provides to a case. On a similar theme regarding an important association between forensic science and decision making, Williams and Weetman (2013) have asserted that an evaluation of the use of forensic science in homicide investigations must include exploration of the decision-making related to when and how forensic resources were utilised.

Another theme that has emerged regarding the assessment of the effectiveness of forensic science in individual cases is the suggestion that the status of the case and the specific contribution of the forensic evidence should be considered. In exploring the use of DNA in homicide investigations, Schroeder and White (2009) specified that the solvability of cases should be taken into account when considering the contribution of forensic science to the investigation. They draw a distinction between “dunkers”, cases requiring little investigative effort because there is no doubt about the identity of the offender, and “whodunits”, cases requiring a more demanding investigation that can be reliant on and benefit most from supportive forensic evidence. Bitzer et al (2017) add support to this view and considered the utility of forensic evidence to be primary in cases in which suspects are yet to be identified, but only of secondary utility in cases where suspects have already been identified. This concept was also considered by Amankwaa & McCartney (2019) in their evaluation of the effectiveness of the UK national DNA database in that they also assigned lesser value to contribution of DNA when it is simply used to confirm the identification of an offender (referred to as “warm hits”) and to construct the prosecution case. Williams and Weetman (2013) also recognised these two aforementioned categories of investigation based on solvability and proposed

that the investigation status influences the utilisation of forensic science in the cases. For “self-solvers” (cases in which a suspect has been unambiguously identified and admissions have precluded the involvement of a third party) the crime scene work is processed quickly, and analytical work is commissioned to support prosecution. In contrast, for “whodunit” cases (identification and confirmation of suspects have not been accomplished) more scene examinations will be commissioned, and the results of examination are of greater interest.

There is growing potential for forensic science to support intelligence initiatives and the contribution of forensic science to public security is another mode of impact to be considered in evaluating its effectiveness. The introduction and development of DNA and fingerprint intelligence databases in recent decades has been a major development that has revolutionised how forensic science is utilised and perceived (Ludwig 2016; Ludwig & Fraser 2014). However, Amankwaa & McCartney (2019), while acknowledging that the value of the UK National DNA Database has been demonstrated in individual cases, contest that the aggregate value of the database is yet to be ascertained. These authors note a lack of meaningful evidence for assessing the effectiveness of the database but state that “what evidence exists shows that while DNA databases may offer slightly improved detection or conviction rates, the overall contribution of DNA databases to public security may be negligible” (Amankwaa & McCartney 2019, p. 53). Roux et al (2012) have described the potential of forensic science to play a role in supporting the move towards policing models where intelligence and crime analysis are central to developing strategies to disrupt crime, and they have suggested that DNA, ballistics, drug profiling and document examination are examples of disciplines that have valuable case linking capacity via their forensic case data . The potential to develop greater capabilities in forenic science based intelligence to support arson investigation has been presented by Bruenisholz et al (2017) who have proposed a methodology for the detection of repetitive deliberate fires that is supported by a systematic approach to the collection of forensic traces at fire scenes.

Recent government reviews of the provision of forensic services in the UK have previously been discussed (Home Office 2018; Science and Technology Select Committee 2019). In England and Wales, the provision of forensic services has shifted to a mixed model where services are provided through a combination of commercial organisations and some in-house provision by the police forces. This development, and the associated impacts on quality standards, research and development and cost effectiveness, demonstrate how structural organisation can influence the effectiveness of forensic science. Koppl (2005) has proposed that when there is competition for the provision of forensic services and independence from policing, it can lead to increases in the quality of results and cost effectiveness. In an examination of the marketisation of forensic science in England and Wales, Lawless (2010) has described associated efficiency gains but also presented an assessment of various impacts on the science-police relationship. Another relevant development is the trend for forensic service providers to introduce the role of forensic case coordinators into their organisational structure. Bitzer (2019) has used five European laboratories as examples to describe the role of forensic case coordinators and how they serve as mediators facilitating effective decision making relating to the analysis of samples and the communication of results to stakeholders.

Houck et al (2009) identified that managers of forensic laboratories are often forensic scientists who have moved into managerial positions without receiving training in forensic laboratory management. They considered the absence of laboratory management training, along with a lack of standardised metrics for efficiency, quality and service, to be a hinderance to improving forensic laboratory performance. Further still, Houck has stated that “a lack of strategic leadership and systems management threaten the forensic industry” (2019, p. 349). Forensic laboratory managers require an evidence-based means for assessing how much good the organisation is doing with the resources they are provided. However, Houck also states that legal or judicial outcomes “cannot logically be used as a metric of success for a forensic agency” (2019, p. 350). Houck et al have developed a performance evaluation model known as FORESIGHT which uses standardised metrics to evaluate and benchmark laboratory processes. Metrics with links to financial information provide measures of

efficiency (Speaker 2015). FORESIGHT, which has now been adopted in over one hundred forensic organisations internationally, enables the managers of forensic laboratories to compare performance against benchmarks and to reduce or eliminate performance deficits. Although FORESIGHT is directed at providing a means to monitor the value provided by forensic laboratories, and with financial considerations measure how efficiently that is being achieved, the system is largely based on comparing performance between forensic organisations. It is not an explicit aim of FORESIGHT to measure the effectiveness of forensic science in the criminal justice system and a mechanism for assessing the contribution of forensic laboratories to the processing of cases through the criminal investigations and court trials has not been presented. Judicial outcomes alone, measured crudely as the frequency of guilt or innocence findings, do not provide a measure of effectiveness. However, omitting the impact of forensic evidence on police investigations and court processes from methodology that is used to examine the effectiveness of the provision of forensic services, does fail to encompass the core function of forensic science to provide support to the criminal justice system.

A recent article by Casey et al (2019) articulates an increasing trend to shift forensic science capabilities out of the laboratory and in to the field, and proposes that this decentralisation of forensic capabilities triggers the need for significant change in the role of forensic service providers in the future. Central to this discussion is the point that, accompanying the uptake of field deployable analytical capabilities, these increasingly user-friendly portable tools are used by non-specialists. The field deployable analytical capabilities are applicable to both physical and digital traces and examples include: rapid DNA technology, drug and alcohol testing; fingerprint “livescan technology” and tools used to interrogate computers and mobile devices. Case studies are presented that illustrate by example how working practices, policies and laws have been changed to accommodate new forensic capabilities which result in the demand for forensic laboratory services being reduced. It is suggested that these developments, along with increasing demand for forensic science to support intelligence and security initiatives, change how forensic science should serve the

needs of the criminal justice system and society more generally. Such changes in the utilisation of forensic capabilities have direct implications for what the effectiveness of forensic science may look like in the future and how effectiveness would be achieved.

Conclusion

The existing work that has examined the effectiveness of forensic science can be broken down into three groups. The first group accounting for the larger proportion of work consists of reviews conducted by government agencies, which have had a general focus on the delivery of forensic services. The UK proportion of this group has tended to concentrate on improving the provision of forensic services specifically to policing. Through this work there has however been reference to some important issues. Some reports have recognised the importance of knowing the outcomes of police investigations and court processes when evaluating forensic science. The difficulty that is posed by the fact that there is disconnection of relevant data that can be used in the evaluation process has also been noted. The two most recent reviews were focused on addressing issues which have arisen as a result of a shift in the provision of services to a mixed model of in-houses services (i.e. within police forces) and commercial providers, but the reviews also scrutinise the fundamentals of forensic science and the quality of the services being provided. The US work has similarly been directed more at the delivery of forensic services rather than at the impact of the evidence that they produce. Many of these reviews simply have not intended to address the effectiveness of forensic science in the criminal justice system but rather provide a status report regarding a range of metrics relevant to the management of crime laboratories (e.g. case workloads, resourcing, accreditation, etc.). The fundamentals of forensic science were at the forefront of the significant “NAS” (National Research Council 2009) and “PCAST” (President’s Council of Advisors on Science and Technology (PCAST) 2016) reports with particular attention directed to challenging the validity of disciplines based on subjective methods.

The second group consists of a collection of studies that have been conducted in association with academic institutions or other research organisations. These studies have taken the evaluation of the effectiveness of forensic science to a greater depth. They have applied more robust approaches which have been directed at examining the impact of forensic evidence on investigative and judicial

processes. They have aimed to address stated hypotheses and followed methodologies with structured design, often involving the collection and analysis of case data and the application of statistical testing. They have produced empirical data of the impact of forensic evidence on investigative and judicial processes. However, the results arising from these studies have been mixed and have left room for further work to be conducted. Some of the studies have been flawed by the fact that they have failed to consider the results of the forensic examinations. More attention has been given to the disciplines of DNA and fingerprints. Given that these are disciplines that are highly utilised and of high public profile it is appropriate that they are subject to such research. However, all forensic disciplines cannot be considered to be alike and this therefore leaves a gap in the knowledge of the impact of a number of categories or classes of forensic evidence.

The third group of literature presents a broader view of the value of forensic science, which has implications for what constitutes effectiveness and how it should be assessed. In this more recent literature the value provided by forensic disciplines is taken deeper within criminal investigations to the nuanced utilisation of evidence by police investigators. It also extends the value of forensic evidence beyond the boundary of judicial outcomes to the role of forensic science to support intelligence-led policing and security more broadly.

The research conducted in this project was aimed at building on previous studies and aimed at addressing some of the limitations that have been identified in previous work. This study approaches the assessment of the effectiveness of forensic science from a forensic science perspective, differing from previous work that has frequently viewed the impact of forensic evidence according to offence types. The data sets used in this study were created on the basis that they consist of cases to which specified forensic science services have been applied (i.e. as compared to selecting cases of specified offence types for which the frequency that forensic science services have been applied is unknown at the time of sampling). The dataset for chemical trace evidence cases covered a range of offence types. However, the dataset for forensic fire examination was closely associated with property

damage by fire (arson) offences. This approach was adopted to overcome the problem encountered with some previous studies that have selected cases according to offence types and subsequently found that the frequency that some forms of forensic evidence have been applied is too low to achieve a meaningful analysis of its impact on case outcomes (Peterson et al. 2013). Selecting cases according to the criteria that they have been subject to specified forensic services provides better opportunity to ensure that the data set is of adequate size to statistically assess the impact of those disciplines on criminal justice processes.

The results of the forensic examinations were critical variables in this study. The forensic reports that were issued in the selected cases were interpreted using discipline specific criteria as to whether they "connect a person to a crime", "do not connect a person to a crime" or are "inconclusive". These interpretations correspond to, and can equally be considered as, being evidence that "supports the prosecution case", "does not support the prosecution case" or is "inconclusive". Sorting forensic evidence according to these classes and aligning them with the outcomes of police investigations (whether charges were and laid) and court processes (whether guilt/innocence was determined) meant that this study was not subject to a limitation applicable to some previous work which failed to consider the results of forensic examinations (i.e. studies which have simply considered whether forensic science was applied).

Recent literature has articulated how the value of forensic science extends beyond its contribution to judicial outcomes. However, the need for performance indicators which describe the impact of forensic evidence and which can guide decision making by providers and users of forensic science has been repeatedly called for throughout the relevant literature. As stated by Julian (2011) "the policing and forensic services community has been 'flying blind' in terms of the true impact of its work" (p. 220). In this research, quantitative case processing methodology has been used to examine a core function of forensic science, the provision of support to criminal investigations and court processes. The data used in the quantitative case processing methodology resides in systems

accessible to police and the applicable forensic service provider, and this research trials methodology with potential as a model for producing empirical data to guide the optimal provision of forensic services. However, mixed methodology has been applied in this research and qualitative information has been captured to explore more deeply the utilisation of forensic evidence by police investigators.

CHAPTER 3

Research Design and Methods

Part 1: Research rationale, research questions and hypotheses

In general, forensic laboratories are committed to providing the highest level of forensic services. In pursuit of this target they typically have well established systems for monitoring and developing their services. Quality programs are embedded in accredited forensic laboratories which involve a range of processes that are aimed at ensuring that examination results are technically correct. Research and development programs assist laboratories with keeping pace with advancing technology. And service delivery is closely managed by monitoring a range of business statistics, such as the volume of cases completed and the timeliness of the service. This investment in quality programmes, research and development, and monitoring service delivery, reflect that within the forensic science community there is a focus on managing the business of forensic services. However, there is also scope for forensic laboratories, and the forensic science community more widely, to benefit by measuring the impact of their services and assessing how well forensic science is fulfilling its role in the criminal justice system. Gaining a clearer understanding of the mode of impact of the full range of forensic disciplines, with respect to how they can guide police investigations and assist the courts to reach just outcomes, should increase the ability of forensic laboratories to strategically utilise their resources such that they provide maximum value to the criminal justice system.

The first question that arises is how to assess the effectiveness of forensic science in the criminal justice system? Consideration of the basic principles of forensic science provides a useful starting point for answering this question. A role of forensic science is to apply science to physical evidence and produce findings that will assist police investigations and the courts. That is, forensic science should be contributing to achieving appropriate justice outcomes by influencing the outcomes of police investigations and court trials. It is critical to recognise that the value of forensic science is not limited to detecting offenders and producing evidence that implicates suspects. The role of directing police investigations away from innocent suspects and protecting accused parties against wrongful

convictions is equally important. As a result, forensic science should be having an impact on criminal investigations and trials, but the nature of the impact in individual cases will be dependent on the results of the forensic examinations (i.e. whether they support the prosecution case, the defence case or are inconclusive).

It follows that, if forensic science is having an impact on criminal investigations and trials, it would be expected that there will be an alignment of the results of forensic examinations with the outcomes of police investigations and court trials.

Exploring the relationship between the results of forensic examinations, the laying of criminal charges and the determination of guilt could therefore provide a mechanism for assessing the influence of forensic science on the criminal justice system. If these three variables do not align (i.e. the frequency of suspects being charged and defendants being found guilty is not higher when there is forensic evidence that supports the prosecution case), the impact of the forensic evidence and the value that forensic science has added to these criminal justice processes would be in doubt.

Modes of impact of forensic evidence on criminal justice processes

Forensic science consists of a diverse range of disciplines (ANZPAA - NIFS 2019). The traditional services provided are based on biological, chemical and physical examinations. With the rapidly expanding use of technology in the community, forensic science has also needed to extend into the realm of digital evidence and computer-based examinations. Forensic services not only vary in their scientific basis and methodology, but they can also vary in how they are applied. Some forensic services are applied “in the field” at the scenes of crime, while others are more typically applied “at the bench” within the laboratory. Using forensic science as a tool for intelligence presents yet another mode of application that is developing (Ludwig 2016; Roux et al. 2012). Despite the described diversity, many different forms of forensic evidence are used by police investigators and the courts to establish the facts regarding the same questions: “was the person of interest involved

in an incident or were they not?" and "was the incident a criminal offence?". However, forensic disciplines can produce different information and consequently there is variation in how forensic evidence can assist in answering that question, and in turn variation in how forensic evidence can impact on how cases are processed through the criminal justice system. Some of the modes of impact that forensic evidence can have are as follows.

- Determining whether an incident that was investigated **was, or was not, a criminal offence**.

  This includes forensic fire examination (both scene examinations and laboratory-based analyses of fire debris samples) for the purpose of determining whether the incident (i.e. a fire) was a criminal offence (i.e. an act of arson).

- Establishing a **direct connection** between an individual and any combination of crime scene, victim, suspect or other person of interest.

  DNA science and fingerprinting are personal identification disciplines and their evidence is routinely used to draw a connection between persons of interest and a criminal offence.

- Establishing **an indirect connection** between an individual associated with an item and any combination of crime scene, victim, suspect or other person of interest.

  Chemical trace evidence such as paint, glass and fibres can be used to establish a nexus between items such as motor vehicles, tools and clothing and the scene of a crime and/or a victim. This provides an indirect connection of persons associated with the items to the criminal offence.

Disciplines of forensic science could be categorised according to the modes of impact described above. The evidence of some disciplines however may provide information that can lead to impact via more than one of the categories. For example, the identification of residues of an illegal lachrymatory substance on clothing (e.g. residues of capsicum spray) could both establish an indirect

connection between the owner of the clothing and an assault, but also establish that an illegal weapon was used in the assault. Although the three evidence categories described are different, they are each used by police investigators and the courts to assist with answering the questions of whether or not persons of interest are connected with an incident and whether the incident is a criminal offence.

The various roles and agencies operating within the criminal justice system have different objectives. Consequently, they will have differing perspectives of how to assess their effectiveness and they will use different metrics to evaluate themselves (refer Table 3.1). For some roles and agencies, the evaluation of their performance can be based directly on case outcomes because they have a clear direction in their role. Police are responsible for the investigation of crime and on occasions will refer to case clearance as a measure of success (i.e. investigations which result in suspects being charged). Similarly, prosecutors may measure convictions and defenders may measure acquittals. However, the evaluation of the effectiveness of forensic science must encompass the contribution of forensic evidence to both implicate offenders and exculpate innocent suspects. Consequently, using case outcomes in a generalised way, such as whether suspects are charged and defendants found guilty, will not provide a true measure of effectiveness, but rather it is whether forensic science is impacting on these outcomes (and other criminal justice processes) and contributing to the achievement of just outcomes. The aim of this research is to examine how a selection of forensic disciplines impact on police investigations and court processes, rather than to use generalised outcomes as a measure of effectiveness. An additional measure that is sometimes considered in evaluating efficiency in the criminal justice system is the timeliness of the outcomes that are achieved. Timeliness is an additional factor that can be overlayed across the outcomes presented in Table 3.1 to produce further metrics relevant to efficiency. The timeliness of the provision of forensic results and how that may influence the impact of forensic evidence is also examined in this research.

Table 3. 1 Phases of the criminal justice system, the associated outcomes for each phase and potential metrics for evaluating effectiveness.

Phase in the CJ process	**Roles/Agencies**	**Outcomes**	**Metrics**
Crime scene examination	- Police - Forensic scientists - Specialists in forensic disciplines (e.g. fire examination, blood stain pattern analysis, clandestine laboratory examination)	- Reconstruction of events (Who? What? Where? How? When?)	- Quality of crime scene records (notes, photographs, video) that support investigative and court processes. - Collection of relevant physical evidence. - The relevance and quality of samples collected for laboratory-based analyses. - Quality and clarity of information provided in specialist written reports.
Laboratory analysis	Forensic science service providers	- Provision of results of forensic analyses which support criminal investigations (including intelligence). - Provision of results of forensic analyses which supports court processes (e.g. prosecution brief; defence case). - Provision of information and data which support intelligence-based initiatives.	- Results of forensic analyses including: - Determination of criminal offences (e.g. prohibited substances, forgery, arson, etc.); - Identifications (DNA, fingerprints, etc.); - Eliminations (DNA, fingerprints, etc.); - Comparison of samples for common origin (e.g. ballistics, paint, glass, fibres, etc.).
Criminal investigation (including intelligence)	Police	- Determination of whether an incident was a crime. - Hypotheses of events. - Preparation of evidence to present in court (brief of evidence). - Crime prevention and crime disruption.	- Clearance of non-criminal incidents. - The arrest of offenders. - Charges laid and referral to prosecution. - Crime resolutions (e.g. convictions, crime clearance). - Crime rates (e.g. crime reduction). - Identification of crime patterns (e.g. hot spots).
Court	- Prosecutors - Defenders - Juries - Judges	- Acquittal or no finding of guilty. - Conviction or other finding of guilt.	- Guilty pleas entered and plea bargaining. - Convictions and acquittals. - No reversal of court findings on appeal. - Sentences. - Wrongful convictions and exonerations.

Research questions

The overarching question that is the basis of this research is "What impact does forensic science have on criminal justice system processes and outcomes?". The role of forensic science in the criminal justice system has already been discussed, but a core function of forensic science is to influence criminal investigations and court processes in order to achieve just outcomes. This leads to more specific questions that this study seeks to answer.

RQ1 Is forensic science impacting on police investigations and influencing whether suspects are charged with criminal offences?

RQ2 Is forensic science impacting on court processes and the determination of the guilt or innocence of those who are charged with criminal offences?

RQ3 Do multiple pieces of forensic evidence in a case increase the probable impact of forensic science on police investigations and court trials?

RQ4 Does the type of information provided by different forensic disciplines, influence how the evidence impacts police investigations and court processes?

RQ5 In what ways, if at all, does forensic evidence influence the decision-making of investigators?

On face value, it is logical to assume that if forensic science is being effective, it will be having an impact on the decision to charge suspects and the determination of guilt or innocence. However, this research aims to move beyond a crude measure of association between forensic science and criminal justice outcomes and to generate a more nuanced understanding of this relationship and what variables may moderate this relationship. As a starting point, it is proposed that differences that exist between forensic disciplines, such as the type of information that they provide, will cause there to be differences in how the evidence that they produce impacts on criminal justice outcomes (i.e. impact with different strength, impact at different stages of the criminal justice process). This

research will seek to explore whether there are differences in the impact of different forensic disciplines on charges being laid and guilt or innocence being determined, and whether these differences relate to the categories of evidence types that have been defined.

This research will also examine case variables, which may influence the relationship between forensic evidence and the outcomes of criminal investigations and court processes. Relevant case variables include timeliness of the provision of the results of forensic examinations, type of offence and type of police investigating unit.

Hypotheses

Drawing together the previously discussed relationship between forensic results, police investigations and court process, the following hypotheses are drawn.

Hypothesis 1

- If forensic science is adding value to police investigations, either by establishing that an incident is a crime or by linking suspects to a crime, then it is predicted that ***during police investigations of potentially criminal incidents it is more likely that suspects will be charged if the case includes forensic evidence which connects the suspect to the offence***.

Hypothesis 2

- If forensic science is adding value to court outcomes, either by establishing that an incident is a crime or by linking suspects to a crime, then it is predicted that ***defendants in criminal trials will be more likely to be found guilty if the case includes forensic evidence which connects the accused to that offence***.

There are three variables within these two hypotheses: (i) forensic results; (ii) charging of suspects; and (iii) determination of guilt. The result or outcome for each of these variables, for any given

potentially criminal incident that was subject to receiving forensic services, can be measured. Consequently, it is possible to apply a quantitative empirical approach to investigating both hypotheses.

For some crimes, particularly major crimes such as homicide, rape and other crimes against the person, a multidisciplinary approach can be applied in the provision of forensic services. With consideration for the fact that multiple disciplines of forensic services are sometimes applied to major crime cases, a third hypothesis is proposed.

Hypothesis 3

- If forensic science is adding value to police investigations and criminal trials, then it is predicted that ***the probable impact on the outcomes of police investigations and criminal trials will be increased when cases include multiple pieces of forensic evidence*** that align in terms of implicating or exculpating suspects.

The potential additive or synergistic effects of combinations of forensic evidence within this hypothesis could also be investigated using a quantitative empirical approach.

As previously discussed, forensic disciplines can produce different information or categories of forensic evidence. How the forensic evidence is used in the processes relating to investigations and court trials, and the mode of impact of the evidence, may be influenced by the information that the evidence provides. A fourth hypothesis is proposed.

Hypothesis 4

- The ***use and impact of forensic evidence*** *during police investigation and criminal trial processes* ***will vary between disciplines*** *and will* ***depend on the information that the evidence provides***.

Quantitative methodology could be used to capture data which describes the impact of forensic disciplines at different stages of case processing through the criminal justice system. However, the utility of forensic evidence and its mode of impact could also be explored in greater detail by using methodology that enables the capture of qualitative information.

A mixed methods design involving three separate studies will be applied to explore the four hypotheses. Chemical trace evidence will be the forensic discipline of primary focus. A selection of other forensic disciplines will also be included in the research to enable the comparison of forensic evidence which differs in the type of information provided.

As illustrated in Table 3.2, Study 1 will be a quantitative case processing study of chemical trace evidence along with biology (DNA) and ballistics / tool marks, which will assess the support for Hypotheses 1, 2, 3 and 4. The impact of each discipline of forensic evidence on the police investigation (Hypothesis 1) and the court process (Hypothesis 2) will be examined. The inclusion of three disciplines of forensic science enables the comparison of their impact (Hypothesis 4) and methodology will be applied in the quantitative analysis to test for interactions between the disciplines that may impact case outcomes (Hypothesis 3).

The examination of chemical trace evidence will continue in Study 2 via a survey of police investigators which will address Hypotheses 1, 2 and 4 (refer Table 3.2). The data collected from the survey, which will include quantitative and qualitative information on the use and impact of forensic evidence, will also be used to explore Research Question 5, how forensic evidence impacts the decision-making processes during police investigations.

The first part of Study 3 involves a quantitative case processing study of forensic fire examination, which will assess the support for Hypotheses 1 and 2 (refer Table 3.2). Forensic fire examination provides a different category of forensic evidence to those examined in Study 1 (i.e. the results of forensic fire examinations can assist with establishing whether a crime has been committed).

Hypothesis 4 will also be addressed as the impact of forensic fire examination evidence can be compared with the impact of the disciplines in Study 1. The second Part of Study 3 consists of a study of the fire examination process which will explore Research Question 5 and how forensic evidence impacts the decision-making processes during the forensic examinations. The study will examine the range of evidence forms that are utilised in the decision-making process that the forensic scientists follow to reach their conclusions of the cause and origin of the fires.

		S1 Chemical trace evidence quantitative study	S2 Chemical trace evidence survey study	S3 Forensic fire examination quantitative study	S3 Forensic fire examination process study
RQ1	**Impact on investigation outcomes**				
H1					
RQ2	**Impact on Court outcomes**				
H2					
RQ3	**Multiple forensic evidence enhances impact**				
H3					
RQ4	**Forensic impact varies between disciplines**				
H4					
RQ5	**How does FS impact on decision making processes?**				

Table 3. 2: Colour-coded matrix of the research questions, hypotheses and the connected studies.

Key:

FS = forensic science; H = hypothesis; RQ = research question; S = study.

Coloured fill indicates the research questions and hypotheses that are addressed in the specified studies:

Impact on investigation outcomes; Impact on Court outcomes; Multiple pieces of forensic evidence enhances impact; Forensic impact varies between disciplines; and How does FS impact on decision making processes?

Part 2: Mixed methods research design

A mixed methods research design is well suited for exploring the relationship between forensic science results and criminal justice system outcomes. Mixed methods research has been increasingly utilised in recent decades (McKim 2017). The existing body of research on the impact of forensic science has relied extensively on quantitative methods based on administrative data collected by criminal justice system agencies but there are benefits in using mixed methods to explore this relationship. Mixed methods are especially suited to this research as it provides a means to gain a more nuanced understanding of the relationship between forensic science and criminal justice outcomes. Johnson et al have suggested that the growth in mixed methods research is such that it has been "recognised as the third major research approach or *research paradigm*, along with qualitative research and quantitative research" (2007, p. 112). Mixed methods is a research approach for "collecting, analysing and mixing both quantitative and qualitative data in a single study or a series of studies" (Creswell & Creswell 2005, p. 317) and "is appropriate for answering research questions that neither quantitative nor qualitative methods could answer alone" (Shorten & Smith 2017, p. 75). It has also been argued that the use of mixed methods overcomes the limitations of relying on any single method and capitalises on the unique advantages offered by qualitative and quantitative methods (Maruna 2010; Walter 2013).

To explore the overarching questions driving the present research, a combination of quantitative analyses of retrospectively collected administrative data as well as quantitative and qualitative analysis of survey data will be used. Retrospectively collected administrative data from police and courts will be analysed to test the proposed hypotheses and to explore more broadly the relationship between forensic science results and criminal justice system processes and outcomes as well as case variables (e.g. timelines of reports, offence type and police investigation unit type), which may influence this relationship. A quantitative case processing study (i.e. based on the quantitative analysis of administrative data) will be followed up with a survey study of a police

investigators from a subset of cases within the case processing database to further explore the relationship between forensic science and criminal justice system outcomes.

There are multiple purposes and benefits in using the proposed combination of quantitative case processing data as well as quantitative and qualitative survey data. One purpose of using mixed-methods in this research is to facilitate the assessment of different dimensions of the phenomena being studied (Collins & O'Cathain 2009) and enable a more complete and comprehensive understanding of the relationship between forensic evidence and criminal justice outcomes.

Quantitative case processing methodology will be used to examine support for the hypothesised relationship between forensic science results and criminal justice system outcomes at different points of the criminal justice system process (i.e. investigations and court proceedings) and to explore the potential influence of pertinent case variables on this relationship. Two data sets will be developed for these studies. One dataset will be based on cases which include chemical trace evidence but will also include biology (DNA) and ballistics / tool marks evidence, and consequently will enable both comparison of the impact of the different disciplines and analysis of additive or synergistic effects between the disciplines. Development of a second dataset based on forensic fire examination cases broadens the investigation of the impact of forensic evidence to a different category of forensic evidence (i.e. evidence which can establish whether an incident is a crime).

The surveys of police investigators will explore the utilisation, expectation and impact of forensic evidence as perceived by police investigators and will incorporate both close-ended questions to generate quantitative data and open-ended questions to yield qualitative data. The survey questions will be finalised after the quantitative analysis of administrative data is complete so that questions arising from the analysis of administrative data may be further explored through questions posed to police investigators. The findings from the surveys will be used to not only gain a richer understanding of the relationship between forensic science results and criminal justice system outcomes but will also explore how investigators utilise forensic science to facilitate investigations.

Hence, this research will explore not only what impact forensic science may have but also how it is utilised (i.e. an evaluation of outcomes as well as processes).

An additional benefit of using mixed methods in this research is that mixed methods allows for a triangulation of results (Maruna 2010). A convergence in findings from the separate analyses of administrative data and surveys of police investigators would suggest that the findings of this research are relatively robust and generalisable to the broader population (Walter, 2013).

Part 3: Detailed outline of each method

This thesis comprises three separate studies of a selection of forensic disciplines, with chemical trace evidence as the discipline of primary focus. The overarching question of this research is "What impact does forensic science have on criminal justice system processes and outcomes?". The three studies incorporate different methodologies in the examination of the selected forensic disciplines. Together the three studies constitute a mixed methods approach for exploring a set of research questions and hypotheses that have been drawn from the overarching question. The three studies are presented in this thesis as articles that have been submitted for publication in peer-reviewed journals (Chapters 4, 5 and 6). The methods applicable to each study are presented in detail in the relevant chapters. This section provides a summary of the methods for the three studies.

Study 1: Quantitative case processing study of chemical trace evidence with other disciplines

For this study, a database was developed that consisted of criminal investigation cases which included chemical trace evidence, and in some cases also included evidence pertaining to biology (DNA) and ballistics / tool marks examinations. The database contained key variables for the

statistical analysis of the relationship between forensic evidence and the outcomes of police investigations and court trials: (i) the results of the examinations relating to the selected forensic discipline; (ii) whether the police investigations resulted in suspects being charged; and (iii) whether court processes resulted in the determination of guilt or otherwise. The database was constructed as an SPSS file (Statistical Package for the Social Sciences) from retrospectively collected criminal justice agency administrative data.

Information relating to the forensic cases was obtained from a combination of sources, consisting of:

- the computer-based case management system known as FCM (Forensic Case Manager) that was utilised by the Victoria Police Forensic Services Department at the time of the study;
- forensic hard copy case files and official reports (on-line or hard copy) that were issued by the laboratory and which detailed the examinations conducted, the results of the examinations and the interpretation of the results.

The results of the forensic examinations were obtained from the official reports that had been issued by the forensic laboratory. The reported results of the examinations were classified according to the following three categories: (i) the results provided support to the prosecution case; (ii) the results provided no support to the prosecution case; and (iii) the results were inconclusive. For the statistical analyses the interpretations were collapsed to the binary categories of the results provided “support to the prosecution case” or the results provided “no support to the prosecution case”. The results of forensic examinations can be presented in written reports in various formats and likelihood values, scales and descriptive text may be used to convey evidential strength and significance. It is recognised that the presentation of the evidence may influence the readers understanding of the results and in turn influence the impact of the evidence (de Keijsera & Elffers 2012; Howes 2017; Howes & Kemp 2017). However, the influence of reporting formats is not within the scope of these studies.

The criminal justice outcomes for each case were obtained from records in the Victoria Police on-line incident database, commonly known as LEAP (the Law Enforcement Assistance Program). Case identifying information was collected from the forensic records and used in searches of the Victoria Police LEAP database to locate the police investigation record which corresponded to the forensic case (refer Figure 3.1). The case identifying information included details of the incident investigated (e.g. names of people involved, date that the incident occurred and the type of offence) and details of the investigating police (e.g. details of the lead investigator and their policing unit). Some forensic case records also included unique codes used by Victoria Police to identify incidents that have been investigated (i.e. LEAP incident and sub-incident numbers) and to identify persons of interest in criminal investigations (Master Name Index or MNI). These codes could also be searched in the Victoria Police LEAP database and used to locate the corresponding incident record. Information additional to the primary variables that were required for the quantitative analysis (i.e. forensic examination results, charges laid, determination of guilt) was also collected (refer Figure 3.1). This information was used to develop a profile of the cases associated with the selected forensic disciplines regarding factors such as the associated crime types, the types of policing responsible for the investigations and the timeliness of the forensic service delivery.

Once completed, the constructed database was used for a combination of statistical analyses. A variety of descriptive statistics were used to develop a profile of the qualities of the constructed database, the forensic evidence in the cases and the associated criminal investigations. To test Hypotheses 1 and 2, the relationships between chemical trace evidence and criminal justice outcomes of charges laid and guilt determined were initially examined using bivariate analyses. To test Hypothesis 3 (“the probable impact will be increased when cases include multiple pieces of forensic evidence”) and part of Hypothesis 4 (“the impact will vary between disciplines and will depend on the information provided”), further statistical testing was conducted using logistic regression analyses that also included the results of biology and ballistics/tool marks examinations. By using logistic regression, the relationship between forensic evidence and the criminal justice

outcomes could be explored in a more comprehensive way as this approach encompassed potential interactive or synergistic effects between combinations of forensic evidence and could be used to gauge the relative importance of these various synergistic combinations as well as chemical trace evidence alone compared with other evidence types in predicting criminal justice system outcomes. Forced stepwise methodology was applied introducing chemical trace evidence at the first step (i.e. the primary forensic discipline of interest), biology and ballistics/tool marks results at the second step (i.e. the secondary forensic disciplines of interest) and finally the interaction terms between chemical trace evidence with biology and with ballistics/tool marks (to investigate the possibility of combined impact). Forward selection and backward elimination methods were also run and the model fit summary statistics were used to compare the three approaches. The forced stepwise method produced the best model fit statistics, although the values for the proportion of variance explained by the models were still quite low. The forced entry approach was adopted with the three steps for variable entry retained as the model fit statistics indicated that the models were improved at each step.

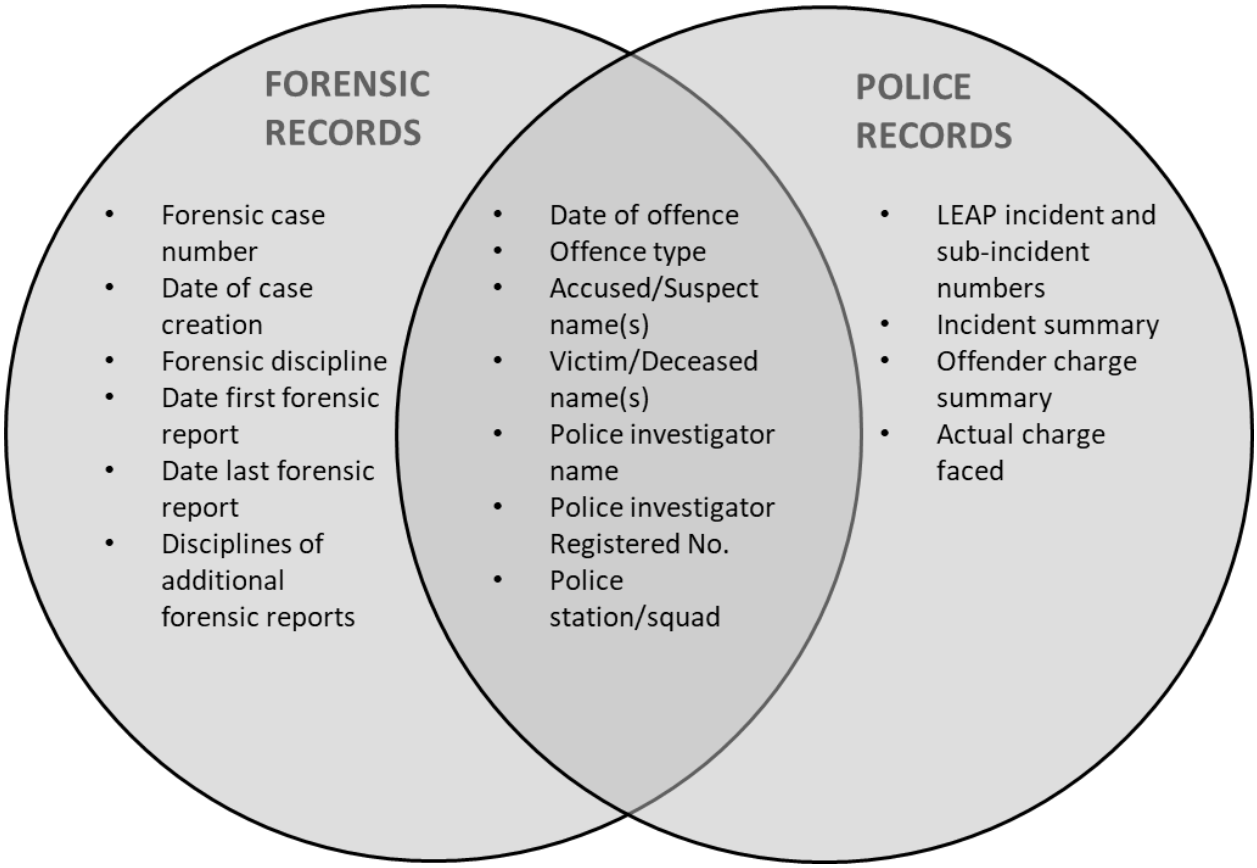

Figure 3. 1: Fields of information collected for the development of case databases for quantitative studies.

Study 2: Survey study of chemical trace evidence

In this study Hypotheses 1, 2 and 4 were tested and Research Question 5 was explored. A survey of police investigators was conducted to build on the findings of the quantitative case processing study of chemical trace evidence. This study was particularly aimed at capturing information on how forensic evidence is used and how it impacts on the process of criminal investigations, but also on court related processes. The survey was constructed and then piloted on two police investigators who were not on the database for the study. The survey approach allowed information to be captured that would test some aspects of Hypothesis 4 (i.e. *"the use and impact of forensic evidence during police investigation and criminal trial processes will depend on the information that the evidence provides"*). The survey study also provided a means to triangulate findings from the

database study regarding the impact of chemical trace and other forensic evidence in specific cases. Both quantitative and qualitative data were collected via the survey. To date the published research on the effectiveness of forensic science has comprised mostly quantitative analyses of case processing data.

Police investigators who had experience in utilising chemical trace evidence in criminal investigations were the target of the survey. Survey participants were selected from the lead investigators in a selection of cases from the database that was previously developed for Study 1, the quantitative case processing study of chemical trace evidence. As some sections of the survey related to the specific cases within the quantitative database, a distribution strategy was applied with the aim of obtaining responses that related to cases which varied in terms of: (i) the results of the chemical trace evidence examinations (i.e. whether the results did or did not support the prosecution case); (ii) the reporting timeframe for the chemical trace evidence (i.e. whether the report was issued before or after a suspect was charged); and (iii) whether charges were laid in the case (i.e. whether a suspect was charged for committing the investigated offence).

The survey was structured with sections aimed at capturing information relating to: (i) details of the specific case in the quantitative database; (ii) the intended purpose of using forensic chemical trace evidence services in that case; (iii) the impact that the evidence had on the final outcome of that case; and (iv) general perceptions of forensic science and chemical trace evidence more specifically. Various question formats were used including multiple choice selection, scaled ratings, rankings, close-ended questions and free text responses. The responses from the completed surveys were entered into an SPSS file and free text responses were collated in a separate Word document.

Frequency statistics were prepared for the responses to some survey questions that were based on formats such as multiple-choice selection, scaled ratings, rankings and closed questions. For some other questions that were based on scaled ratings (e.g. how important various forms of evidence were in determining the case outcome) mean values and related statistics were calculated. The

qualitative data that was captured via free text responses was thematically analysed for both information relevant to the research hypothesis and for new themes relevant to the use and impact of forensic evidence.

Study 3: Forensic fire examination. Quantitative case processing study and structural fire interpretation study

This study consisted of two distinct parts: first, a quantitative case processing analysis testing Hypotheses 1, 2 and 4; and second, a mixed methods analysis addressing Research Question 5. Forensic fire examination can produce evidence that can assist with establishing whether a fire was a criminal offence (i.e. an act of arson) which can be crucial to both police investigations and court trials.

The quantitative case processing analysis in Study 3 tests Hypothesis 4 using forensic fire examination data, which adds a different category of forensic evidence (i.e. establish whether a crime has been committed) to the disciplines previously examined in Study 1 (i.e. evidence that establishes a direct connection between a suspect and a crime; and evidence that establishes an indirect connection between a suspect and a crime).

The same methodology that was applied in Study 1, the quantitative case processing study of chemical trace evidence with other disciplines, was utilised in this study of forensic fire examination. The procedures for the collection of examination results, forensic case information and the outcomes of police investigations and court trials are as described in Study 1. Similarly, the process for the construction of a database of cases relating to the forensic examination of structural fires is also as described in Study 1.

A profile of the qualities of the constructed database, the forensic evidence in the cases and the associated criminal investigations was developed using descriptive statistics. In addition to testing Hypothesis 4, it was intended that Hypotheses 1 and 2 would also be tested in Study 3 using bivariate and logistic regression analyses to examine the relationship between the results of the forensic fire examinations and the criminal justice outcomes of charges laid and the determination of guilt. However, due to highly skewed categorical data and small numbers of observations in infrequent categories it was not possible to apply inferential statistical testing of this dataset to determine the impact of forensic evidence on judicial outcomes of arson cases. Consequently, the examination of the impact of forensic evidence in this dataset was limited to comparing frequencies of criminal justice outcomes (i.e. frequency of suspects charged and frequency of guilty findings in court) between groups of cases that did, and did not, include evidence that supports the prosecution case.

The second part of Study 2 focused on Research Question 5 and explored the decision-making process followed by the forensic fire examiners in reaching their conclusion of the cause and origin of structural fires (domestic and commercial). Forensic fire examiners obtain a variety of evidential information from scene and laboratory examinations, which can be either indicative of the fire being accidentally caused or deliberately lit. The forensic scientists who conducted the examinations in the cases within the database provided details of the forms of evidence in individual cases and the conclusion they reached regarding the cause and origin of the fires in each case. Descriptive statistics were prepared to facilitate the comparison of how frequently various forms of evidence contribute to the conclusion that is reached by the forensic fire examiners. Potential associations between the different forms of evidence and the judicial outcomes in cases were examined by crosstabs analysis (i.e. the proportion of “charges laid” cases where the findings supported prosecution compared with the proportion of “charges not laid” cases where findings supported prosecution). However, although some relationships were indicated they were not statistically tested.

Sampling

Studies 1 and 2 utilised the same sampling strategy to select cases for quantitative case processing. The cases that were included in these two quantitative studies, and also the chemical trace evidence survey study (in Study 2), met the following criteria.

(i) The cases were associated with criminal investigations conducted by the Victoria Police.

(ii) The cases included forensic evidence of the discipline selected for each study.

(iii) The results of the examinations of the selected forensic disciplines had been officially issued by VPFSD in written report format (i.e. in a statement or certificate of expert evidence).

The sampling period for case selection was determined with the aim of meeting three criteria. First, that the sampling period would be as recent as possible such that it would provide contemporary data that is most reflective of the current status. Second, the sampling period would be old enough to allow sufficient time for almost all cases to have been processed to finality in the criminal justice system. And third, that the length of the sampling period would be long enough to provide an appropriate number of completed cases to support the statistical testing planned for the quantitative studies. Based on the assumption that chemical trace evidence may have a small to medium effect size, a sample of three hundred cases was set as the target (Cohen 1992). A starting date of two years prior to the commencement of data collection was established as the most recent date of the sampling period. The length of the sample period was established with consideration of achieving an adequate sample size of chemical trace evidence cases, as of the various disciplines included in this research, this discipline had the lowest annual case completion. The sampling period was set at four years, as based on casework statistics for the VPFSD, the estimated number of chemical trace evidence cases to be completed in this period should provide a sufficient sample size, based on the assumption that chemical trace evidence may have a small to medium effect size (Cohen 1992), and with allowance for the exclusion of invalid cases. Data collection for the research

began in 2012. Consequently, cases were sampled from a four-year period from 1 July 2006 to 30 June 2010.

The quantitative database study of chemical trace evidence included all cases in the sampling period which met the set criteria. For the quantitative database study of forensic fire examination, which had a much higher annual case completion rate than chemical trace evidence, a target sample size of four hundred cases was set. This target sample size was established based on the assumption that forensic fire examination evidence may have a small to medium effect size (Cohen 1992). A full list of all cases completed by the forensic fire examination unit during the sample period was prepared. The cases in this list were sorted into a random order. Cases to be included in the study were selected sequentially until the target sample size was achieved. Cases which did not meet the criteria for this study (e.g. examinations which did not relate to structural fires) were progressively eliminated.

The sample of cases in Study 2, the survey study of chemical trace evidence, was a subset of Study 1, the quantitative case processing study of chemical trace evidence.

Ethics

The research associated with this thesis, and the major project that this research is a component of "The effectiveness of forensic science in the criminal justice system" (Julian 2016), was approved by the Tasmanian Social Sciences Human Research Ethics Committee (Ethics Reference Number: H0016013 and H0010713). Approval was also obtained from the Victoria Police Human Research Ethics Committee (reference VPHREC 98/10) to access Victoria Police and forensic laboratory records and to collate information relating to criminal investigations and forensic examinations. Case identifying information was included with the data initially collated, however this information was

removed once data collection was completed and case identifying information was not present in the final datasets that were subject to analyses by statistical testing and other means.

Part 4: Insider research

Multiple definitions of insider research that have been presented in the published literature. However, Coghlan and Holian provide a clear and simple definition that an insider researcher is a member of an organisation who is undertaking "an explicit research role in addition to the normal functional role that they hold in the organisation" (2007, p. 5). As a clear majority of this research was conducted while I was employed as a Forensic Officer within the forensic laboratory where this research was based, it is appropriate to consider this work to be insider research and to explicitly acknowledge this. The strengths and weaknesses of qualitative research being conducted by insiders have been discussed in the literature with particular attention to observation, field research and ethnography (Dwyer & Buckle 2009). One aspect of insider research that has been criticised is the validity of the data that is collected and that the researcher's tacit knowledge can lead to misinterpretation of data, the occurrence of false assumptions and to potentially miss important information (Galea 2009). It has also been suggested that insider researchers will be inherently biased and that their personal beliefs, experiences and values may influence the study methodology, design and results (Greene 2014). However, several advantages have also been ascribed to the insider positioning of the researcher including the ability to undertake research that is relevant to the organisation (Galea 2009), having an understanding of the culture and sub-culture of the organisation (Teusner 2016) and access to knowledge within the organisation (Galea 2009; Greene 2014). Kanuha has described being drawn to studying her own kind with the desire to contribute to the knowledge of, and enhance the provision of services to her own group, as important motivating factors associated with insider research (2000). The predominant experience from conducting this

research has been that the benefits of being an insider have assisted with the development and conduct of multiple aspects of the research.

Status as an insider researcher

Prior to the commencement of this research for academic qualifications, I was employed at the Victoria Police Forensic Services Department for more than two decades. Initially employed as a forensic scientist performing casework examinations associated with criminal investigations, I had experience in number of analytical services and I had conducted casework examinations in the disciplines of drug analysis, blood alcohol analysis and chemical trace evidence (including paint, glass, fibres, lachrymatory agents and other miscellaneous sample forms). My experience extended to fire and explosion examinations as I had also performed a technical support role in the examination of crime scenes relating to these disciplines. Starting in the immediate years prior to the commencement of the research, and continuing beyond the completion of data collection, I was performing the role of a middle level manager of a group of forensic services and I was responsible for the delivery of services encompassing chemical trace evidence (including gunshot residue), fire and explosion, and motor vehicle examinations.

As a forensic caseworker and service manager at the VPFSD I developed considerable knowledge regarding the laboratory's operations at multiple levels, starting from the level of the laboratory bench where examinations are conducted and rising up to the branch and laboratory wide level where strategies for service delivery are set and high-level initiatives are implemented.

From my experience performing forensic examinations, I developed familiarity with the policies, procedures and working practices followed in the VPFSD which related to the conduct of casework, including case vetting and submission processes, and important decision making that occurs through the examination of exhibits and practices that are applied in reporting the results of examinations. I

also gained knowledge relating to the management of service delivery at the unit (forensic discipline) level including the policies and procedures relating to scene attendance, managing casework backlogs, assigning case prioritisation, and practices that were routinely applied to multidisciplinary forensic cases. As a middle level manager, I developed an understanding of how strategies may be applied to resourcing, broader casework policy, and the implementation of special initiatives such as the introduction of mobile laboratories, the development of regional laboratory hubs and the introduction of a laboratory wide efficiency reform program.

The majority of this research was conducted while I was employed at the VPFSD, including the important components of creation of the research concept, development of the research design, completion of data collection and the majority of the data analysis and interpretation.

The research studies, methodology and the implications of insider research

The greatest portion of this research is quantitative and two of the studies are based on quantitative case processing methodology (refer chapter 4 chemical trace evidence and chapter 6 forensic fire examination studies). The data collected for the quantitative case processing studies were used to produce databases of cases with information relating to the forensic examinations, the police criminal investigations and subsequent court processes brought together. No eligible cases were excluded from the databases and cases were de-identified prior to analyses being conducted. Statistical analysis was applied to the data to test the significance of relationships between variables. The potential for the collected data to be negatively impacted by potential biases stemming from the insider research circumstance is greatly limited as most of the information was absolute and not open to subjectivity (i.e. the outcomes of judicial steps, dates of events). The status of the forensic evidence in each case, and whether it did, or did not, support the prosecution case, was established via the interpretation of official reports. This process was conducted by the forensic scientists with

relevant expertise, and for forensic fire examinations and ballistics/tool marks examinations, the interpretations were completed by the individuals who performed the actual examinations. Criteria were clearly defined to minimise the risk of subjectivity in this interpretation process. The application of statistical testing also limited the potential for bias in the interpretation of the data.

There may be potential for bias in the quantitative study regarding the questions asked and the variables chosen. However, a strength of the mixed methods approach is that the data collected related not only to the variables specified *a priori* through quantitative deductive approaches, but also on variables not previously considered which emerge through qualitative analysis and which overcome in part this potential bias.

The survey of police investigators (refer chapter 5) generated both quantitative and qualitative data. In order to mitigate against any potential bias from insider research, no survey responses were excluded from the dataset and cases were de-identified prior to analyses being conducted. The responses to many of the survey questions were converted into figures or tabulated data which presented the frequency of responses to closed questions and questions that involved rating or ranking various parameters. However, there were a number of survey questions that produced free text responses. The free text responses were collated and examined for recurring themes. The investigators that were surveyed were Victoria Police members sworn to an oath and given powers to arrest and detain individuals. As a forensic scientist, and an unsworn member of the Victoria Police at the time of conducting the survey, it is extremely doubtful that the survey participants would have considered me an insider. Additionally, the potential for observer effects were reduced as the surveys were distributed and returned via email and there was no personal contact between the participants and members of the research team.

The forensic scientists who had performed the original examinations of structural fires were involved in the study of the decision making process of the forensic fire examiners. The data collected in this study were based on the assessments by the forensic fire examiners of the various pieces of

evidence in each case that they had considered in reaching their conclusions on the cause and origin of the fires. Each of the forensic scientists were provided with instructions in person. In terms of the organisational positioning, the forensic fire examiners were employed in a unit under my management. There is potential for impact on the collection and interpretation of the data relating to insider research. However, to mitigate against the risk that this would impact on data collection and interpretation, defined categories of evidence were established to minimise the subjectivity applicable to case assessments performed by the forensic fire examiners and the collected data was analysed in terms of their frequency of occurrence of each category.

The insider researcher experience in this research

Advantages experienced

My insider positioning within the forensic service department and Victoria Police brought about multiple benefits to the development and conduct of this research. Most importantly the genesis of this research was tightly connected with my experience and role within the organisation. Three tightly entwined factors led to the creation and development of the concept of this research: (i) motivation to make a contribution to how forensic service delivery is managed; (ii) reflection on the current status of the linkages between forensic science, policing and the legal system; and (iii) recognition of a gap in the knowledge available to support forensic service delivery. The motivation for this research originated from a desire to build greater knowledge about the forensic services that I was managing and to contribute to the field in a way that was not based on the science or conventional service management but rather was connected to the contribution of forensic science to the judicial system. Reflecting as a manager on the provision of forensic services, the important interactions within the realm of forensic science between science, policing and the law was obvious. However, it was also apparent that within the forensic science community, there was significant

attention to the science supporting the field and attention to the business of managing service delivery, but linkage between forensic science and the social sciences was lacking. The absence of empirical evidence to describe how effectively forensic services were supporting the criminal justice system was identified as a void in a laboratory manager's resources for fulfilling their role. Bringing these points together led to the creation of the concept of evaluating how effectively forensic science was fulfilling its role in the criminal justice system, and to approach this task from the perspective of the forensic service provider. It is almost certain that the research concept would not have been developed in its eventual form without my experience within forensic science and the impetus connected with my role in the organisation.

As noted by Coghlan and Holian, my insider status supported the development of a substantial research plan and the determination of research questions that are important to forensic service providers (2007). The effectiveness of forensic science can be viewed in differing ways, but for this research a means for assessing the effectiveness was formulated to be based on the influence of forensic evidence on the outcomes of police investigations and court processes. This provides a perspective of effectiveness that is relevant and of practical value to forensic service providers as it has potential to produce empirical findings that could guide the deployment of forensic services. The diversity of forensic evidence forms and the variation in impact that may exist between disciplines was accounted for in the research plan, so that the findings of this research may have relevance to a broad proportion of the forensic science community.

Obtaining the support and approval of the forensic laboratory and the Victoria Police was an essential requirement. My position as an experienced forensic scientist and manager of a group of forensic disciplines, along with having developed a clearly defined research plan, is likely to have been favourable with senior laboratory managers and policing representatives who approved the access to official records, forensic and police personnel, and other resources that were utilised in the research. My insider status was of particular importance in obtaining the formal approvals required

to access and utilise sensitive data as it provided a mechanism to prevent the exposure of information subject to privacy standards to persons external to Victoria Police.

The quantitative case processing methodology used in this research had not previously been performed in this jurisdiction. As part of the method development it was necessary to determine what data were required (i.e. identify the fields of information that would need to be collected), locate where the data could obtained (i.e. identify the relevant computer-based systems and file collections) and determine how the data could be collected (i.e. via manual or automated processes). This was achieved through consultation with multiple individuals in diverse roles in the Victoria Police and the VPFSD including police detectives, police managers, intelligence officers, police statistics experts and departmental researchers. The support provided by these individuals was contingent on my status as a forensic scientist employed within their own department.

There were also components of the research that was conducted that were reliant on the participation of personnel within the VPFSD and the Victoria Police. This included the interpretation of official reports by forensic personnel for the quantitative studies and the completion of surveys by police investigators. The support from a variety of police personnel was essential for learning how to navigate the Victoria Police LEAP incident database, locate the required data and interpret codes and terminology that characterised the police incident records. As an insider, I was able to draw upon existing working relationships and develop new productive relationships with other personnel. My experience as a forensic scientist in the VPFSD also supported the data collection from the forensic case management system, forensic case files and official reports.

Disadvantages experienced

Few adverse impacts were encountered which may be connected with being an insider researcher. Conducting quantitative studies and utilising the laboratory casework data raised some challenges, not in regard to the value of the study itself but rather who was responsible for the data used in this

research and who should conduct the study. This is consistent with a political disadvantage that can arise with insider research (Galea 2009). The risks associated with bias as a result of insider research were taken into account in the mixed-methods research design and, as discussed above, a number of strategies were included to mitigate against these risks.

Summary

Conducting this research as an insider has brought about multiple important benefits. My position as an insider to the VPFSD and Victoria Police was tightly linked with the genesis of this research. It was also a key factor in developing methodology and addressing a variety of challenges relating to the access, collection and interpretation of essential data. The potential of some adverse impacts relating to insider research is acknowledged however the methodologies utilised in this research have limited vulnerability to the cons of insider research. It is concluded that for this research the benefits of being positioned as an insider researcher have outweighed the cons that can sometimes apply.

The three studies that form the basis of this research are presented in the following chapters, commencing with Chapter 4, the quantitative case processing study of chemical trace evidence.

CHAPTER 4

Can Forensic Evidence Improve Justice Outcomes? Exploring the Value of Chemical Trace Evidence with Other Disciplines

Chapter 4 Introduction

This chapter is a manuscript that was submitted for publication in a peer-reviewed journal and is the first part of the study of chemical trace evidence. The study examines the impact of chemical trace evidence on judicial outcomes. The impact of some other disciplines of forensic evidence, and the interaction between these disciplines and chemical trace evidence, is also examined.

The results of this chapter contribute to the exploration of the following research questions and hypotheses:

RQ1 and H1 – the impact of forensic evidence on investigation outcomes;

RQ2 and H2 – the impact of forensic evidence on court outcomes;

RQ3 and H3 – enhanced impact on judicial outcomes when cases include multiple pieces of forensic evidence;

RQ4 and H4 – varied impact of forensic disciplines, depending on the information that the evidence provides.

This manuscript has subsequently been published in the journal Forensic Science International (Woodman et al. 2020b).

Abstract

The focus of this research was to examine the contribution chemical trace evidence makes to criminal justice outcomes. The value of this work was to place the discipline of chemical trace evidence under the spotlight as there is a dearth of robust research on the efficacy of this discipline. In this study, data relating to the forensic examinations in a sample of 238 cases which included chemical trace evidence, was collated with data from police investigations and court processes. The findings show that chemical trace evidence is frequently used in combination with other forensic disciplines to support the progress of high-level criminal cases through the justice system. The impact of forensic evidence in the sample of cases was analysed using methodology that considered the results of the examinations, and the ability of the evidence to implicate offenders or exculpate innocent parties. The possibility of chemical trace evidence having impact when applied in combination with other forensic disciplines was also examined. The relationship between the results of chemical trace evidence examinations and the determination of guilt by the courts was found not to be significant, although the results of biological examinations was found to be a significant predictor. However, results were obtained that indicate that chemical trace evidence in combination with ballistics/tool marks examinations can be significant. The findings of this research indicate that, to assess the full impact of any discipline of forensic evidence on the criminal justice system, the analysis must take into account the potential for important synergies that may exist with other forensic and non-forensic evidence.

Introduction

Background

Forensic science plays a role in the criminal justice system through the support it provides to policing and the courts. Forensic resources are finite and the demand for forensic services generally exceeds the capacity of forensic service providers. Therefore, it is important that forensic science is utilised strategically so that the services provided to policing and the courts deliver maximum benefits and ultimately flow on to serve the public, such as through the rapid resolution of criminal investigations, achieving high clearance rates of criminal offences and reducing crime rates in general. Consequently, it is essential to understand how effectively forensic science is fulfilling its role in the criminal justice system (Julian et al. 2011).

The first question that arises is how to assess the effectiveness of forensic science in the criminal justice system? Consideration of the basic principles of forensic science provides a useful starting point for answering this question. The role of forensic science is to apply science to physical evidence, produce findings that will assist police investigations and the courts and ultimately contribute to achieving appropriate justice outcomes. It is critical to recognise that the value of forensic science is not limited to detecting offenders and producing evidence that implicates suspects. The role of directing police investigations away from innocent suspects and protecting accused parties in court against wrongful convictions is equally important. Thus forensic science should be having an impact on criminal investigations and trials, but the nature of the impact will be dependent on the results of the forensic examinations in each case.

It follows that, if forensic science is having an impact on criminal investigations and trials, it would be expected that there will be an alignment of the results of forensic examinations with the outcomes of police investigations and court trials. Exploring the relationship between the results of forensic examinations, the laying of criminal charges and the determination of guilt could therefore provide a

mechanism for assessing the influence of forensic science on the criminal justice system. Certainly, if these three variables do not align (e.g. the frequency of suspects being charged and defendants being found guilty is not higher when there is forensic evidence that supports the prosecution case), the impact of the forensic evidence and the value that forensic science has added to these criminal justice processes would be in doubt.

Previous Studies

There is a relatively small body of research, conducted in association with academic institutions or other research organisations that has evaluated the impact of forensic evidence on investigative and judicial processes. Wilson et al. (2011) highlighted this gap in 2011 when they reported their findings following an extensive search of existing literature for evidence that DNA testing was effective in supporting police investigations. There are some published studies that report significant relationships between forensic evidence and the outcomes of a number of events in the criminal justice process. Research by Briody (2004) examined official forensic and police records pertaining to 150 homicide cases in Queensland, Australia and found that there was a significant relationship between the inclusion of DNA evidence that implicated the accused and convictions in court. Roman et al. (2009) conducted a randomised trial in the US involving 500 property crime cases for which biological evidence had been collected. Half of the cases were randomly assigned as the treatment group and DNA analysis was added to the traditional investigation process. This study found that applying DNA testing increased the identification of suspects, the arrest of suspects and the acceptance of cases for prosecution. McEwen and Regoeczi (2015) used police case files and forensic records to study 284 homicide cases investigated in Ohio. The forensic evidence in these cases consisted predominantly of DNA, fingerprints and ballistics. This study found that when cases included probative forensic evidence (i.e. where matches or exclusions were obtained as opposed to inconclusive findings) higher level charges were laid, proceeding to trial was more likely, conviction

rates were higher and sentences were longer. A randomised field trial was conducted in Australia which sought to evaluate the potential to enhance the police response to residential burglaries (Antrobus & Pilotto 2016). This study found that forensic evidence, either fingerprints or DNA, was used to support investigations and to assist in solving cases (measured in terms of charges being laid). Furthermore, increasing the capabilities of crime scene examiners in terms of a combination of forensic technical capabilities and also their approach to interacting with victims in a more procedurally just way, resulted in a higher proportion of cases being solved. It was found that there was scope to improve the collection of fingerprints, which in turn contributed to a higher rate of solving cases. However, the results obtained in relation to the collection of DNA samples did not follow a similar trend (that is greater training in collecting DNA samples, along with capability to collect more DNA samples, did not significantly increase the rate of identifications and cases solved).

Other research has produced findings that certain investigation and court outcomes are not significantly related to forensic evidence. Schroeder and White (2009) examined case files relating to 593 homicide investigations conducted by the New York Police Department between 1996 and 2003 for the purpose of investigating whether DNA evidence affected case clearance (i.e. investigations resulting in suspects being arrested). In this study, the presence of DNA evidence was not related to case clearance. Additionally, a body of research performed by a combination of researchers, utilising the same pool of data and employing similar methodology, resulted in variable and sometimes conflicting findings in regard to the impact of forensic evidence on criminal justice processes. Data was collected from police, forensic and prosecution case files for 4205 randomly selected cases relating to a range of crime types from five US jurisdictions. In the first three studies logistic regression methodology was used to examine the relationship between forensic evidence and various stages of case processing (e.g. arrest, referral for prosecution, laying charges, convictions). However, the studies varied in terms of: (i) which cases were analysed (the whole sample pool (Peterson et al. 2010), homicide cases (Baskin & Sommers 2010) or burglary cases (Baskin & Sommers 2011); and (ii) how the forensic evidence was factored into the statistical testing (i.e.

presence of evidence, evidence examined at the laboratory or evidence that linked a suspect to a crime). The predictive power of the forensic evidence was found to vary between crime types and also to vary with different stages of case processing. A common finding across these three publications was however that forensic evidence did not significantly impact on convictions. In a fourth study the whole sample pool was reanalysed using a combination of statistical testing and without applying correction factors for selection bias as per the first three studies (Peterson et al. 2013). The results obtained confirmed the findings of the first aggregate study that forensic evidence could be a predictor for arrest, referral for prosecution and laying of charges. But most notably, and in contrast to their previous reports, it was found using bivariate analysis that convictions were significantly influenced by forensic evidence.

The inconsistencies in the relationship between forensic evidence and the outcomes of criminal justice processes that is presented in the research discussed above, result in an unclear picture of the impact of forensic evidence. There are a number of points of variation in the methodology that has been applied in these studies which may contribute to the variation in the findings. Although some research has examined the impact of forensic evidence at a range of points in the criminal justice system, information about the use of forensic evidence in the investigation phase is limited (Ludwig et al. 2014) and a number of studies have also not assessed the important relationship between forensic evidence and court outcomes. Another notable point of variation is the way that the existing studies have factored forensic evidence into their analysis, with approaches including whether forensic samples had been collected, whether forensic samples were analysed, whether forensic evidence was probative and whether the forensic evidence implicated the accused. Forensic evidence can make a valuable contribution to achieving just outcomes by both implicating offenders and clearing innocent persons and both modes of impact need to be considered in order to evaluate the full value provided by forensic science. Greater attention has been directed to the forensic identification disciplines of DNA and fingerprints, however, different disciplines should not be considered alike. As a result, there is a gap in the knowledge of a number of forensic evidence types

which although important, do not have the high profile of DNA and fingerprints that prevails both in the public and in the forensic science community. This gap has been recognised by Robertson and Roux (2010) who stated that more than anecdotal evidence was required to demonstrate the value of trace evidence and that it actually needed to be measured. Further to there being a gap in knowledge of many forensic evidence types, previous research has overlooked the fact that criminal cases often include evidence pertaining to multiple forensic disciplines and the potential for additive effects has also not been investigated.

A number of recent studies have noted that the contribution of forensic science is complex, and that forensic evidence can add value in varied ways at multiple points of the justice system (Bitzer et al. 2017; Ludwig 2016; Williams & Weetman 2013). This is a relevant point to consider when evaluating the variation in published findings. In the published research, significantly varied methodology has been used to measure the impact of specific types of forensic evidence on the outcome of a number of defined events in the justice process. As such the existing body of relevant research could be considered a small and varied sample of the much broader and more complex contribution of forensic science, and consequently it is not surprising that there are variations in the findings.

This study and the hypotheses to be tested

In this study, a quantitative approach has been used to examine the relationship between the forensic evidence and criminal justice outcomes of a sample of cases which included chemical trace evidence. For each case, data relating to the forensic examinations, the police investigation and applicable court processes were collected from disconnected sources and brought together to build a database. The constructed database was used to analyse the relationships between the forensic results and the criminal justice outcomes and to test the following hypotheses.

1) *For police investigations of criminal incidents, the proportion of cases in which suspects are charged will be higher when the cases include forensic evidence that connects the suspect to the offence*.

2) *For police investigations of criminal incidents, the proportion of cases in which guilt is determined by the courts will be higher when the cases include forensic evidence that connects the suspect to the offence*.

3) The probable impact on the outcomes of police investigations and criminal trials will be increased when cases include multiple pieces of forensic evidence that align in terms of implicating or exculpating suspects.

The current study expands previous research by taking into account the results of the forensic examinations, and the scope for the evidence to either implicate a suspect and support their prosecution or to clear a suspect and support their defence. Chemical trace evidence has been chosen as the primary forensic discipline in this study. Previous research in this field has tended to focus on evidence that directly identifies individuals connected with criminal incidents, such as DNA and fingerprint evidence. In contrast chemical trace evidence provides a different form of evidence. Through the comparison of samples such as paint glass and fibres, or the identification of key materials such as gunshot residues, chemical trace evidence can form a nexus between trace samples and items related to a criminal incident (e.g. clothing, vehicles and firearms) and in turn form an indirect connection between individuals and a crime. Collating a data set with a focus on chemical trace evidence, but also having a portion of cases in the sample that include other forensic evidence, has provided a means to: (i) examine the impact of forensic disciplines which vary in the

information that they provide; and (ii) explore the additive effects of different forensic evidence in combination over and above the influence on any one form of forensic evidence used in isolation.

Forensic services providers currently do not have a means to monitor the contribution that they make to the criminal justice system that is based on empirical data. Another aim of this study is to evaluate whether the quantitative database methodology could provide a model that can be adopted by forensic service providers for the ongoing monitoring of the impact and the effectiveness of their services.

Method

Case Sample and Data collection

Criminal cases that were investigated by the Victoria Police (i.e. a state police jurisdiction in Australia), and which included forensic evidence that was reported by Victoria Police Forensic Services Department, were used in this study. A four-year sample period from July 2006 to June 2010 was chosen, which at the time that data collection commenced equated to cases that had been lodged at the forensic laboratory between 2 and 6 years ago. Approval was obtained from the Victoria Police Human Research Ethics Committee (reference VPHREC 98/10) to access Victoria Police and forensic laboratory records and to collate information relating to criminal investigations and forensic examinations. Case identifying information was included with the data initially collated, however this information was removed once data collection was completed and case identifying information was not present in the final database that was subject to statistical analyses.

Laboratory records were used to obtain a list of all chemical trace evidence cases from within the established sample period. However, to be included in the database the cases needed to meet the following criteria:

(i) the cases related to the investigation of potentially criminal incidents that occurred in Victoria;

(ii) the cases included chemical trace evidence which was reported officially by the Victoria Police Forensic Services Department;

(iii) the police record of the corresponding incident could be identified and accessed; and

(iv) the cases had reached a point of finality such that the case outcomes had been documented in the police incident record.

Cases that did not meet the specified criteria and which were excluded from the database fitted into the following categories: cases that related to coronial matters or internal police investigations; cases that related to police investigations in jurisdictions outside of Victoria (also cases that related to the Australian Defence Force); cases in which the chemical trace evidence examinations were not completed or official reports were not issued (e.g. for some cases the laboratory was notified that the forensic examinations were no longer required and the forensic examinations were not completed and/or the results were not formally reported); and mock cases that were quality tests (i.e. proficiency tests that were part of the laboratory's quality assurance program).

Three categories of data were collected for each case: (i) information relating to the reported forensic examinations; (ii) case identifying information; and (iii) criminal justice outcomes. The data were obtained from forensic case records (both hard copies and computer files), the forensic laboratory's computer based case management program and the Victoria Police computer database that is used for recording all incidents that are subject to investigation.

The case identifying information was initially collected from the forensic case records. Case identifying information included the names of persons involved (e.g. victims, suspects, etc.), the date of the offence, the type of offence, details of the police investigator (i.e. name and registered number) and details of the policing unit (i.e. station or squad name). Some forensic case records also included unique codes used by Victoria Police to identify incidents that had been investigated and persons of interest in criminal investigations. These codes could be searched in the Victoria Police incident database to locate the corresponding incident record.

Data were collected which related to the chemical trace evidence examinations that was reported in the cases. The results of biology and ballistics/tool marks examinations were also reported in many of the cases and data relating to these two forensic disciplines were also collected. The official reports issued by the forensic laboratory were reviewed by forensic practitioners who had expertise in the relevant discipline. From these reviews the reported results of the examinations were classified according to the following three categories: (i) the results provided support to the prosecution case; (ii) the results provided no support to the prosecution case; and (iii) the results were inconclusive. For chemical trace evidence, these interpretations were based on the assumptions that: for the comparison of samples, when it is reported that samples could share a common origin (and may therefore establish a nexus with a crime) the results are most likely to support the prosecution case; and when target materials are identified (i.e. the identification of gunshot residue particles may be evidence of an association with a firearm) the results are most likely to support the prosecution case. Ballistics comparisons and tool marks examinations were interpreted similarly to the comparison examinations in chemical trace evidence. In the case of DNA profiling, consideration was given to whether the results implicated a suspect.

For the statistical analyses the interpretations were collapsed to the binary categories of the results provided “support to the prosecution case” or the results provided “no support to the prosecution case”. Cases categorised as providing “support to the prosecution case” included cases in which multiple results were reported but included some results which did “support” the prosecution case. Cases categorised as providing “no support to the prosecution case” included cases with inconclusive results.

Some examinations for chemical trace evidence are directed at identifying unknown substances (e.g. a residue that was collected from a crime scene). The results that are reported in these cases state what compounds were chemically identified and may also indicate what material or common product the sample may be derived from (e.g. “the unknown substance was found to contain an

epoxy substance which can be a component of some adhesives"). Without having detailed knowledge of the corresponding criminal investigation and the reason why the police investigators had submitted the samples, there can be no logical basis for drawing a conclusion as to whether the reported results do or do not support the prosecution case. Consequently, these cases were excluded from the database.

The criminal justice outcomes for each case were obtained from records in the Victoria Police incident database. The case information that was obtained from the forensic case records was crossed checked with the police incident data base records to ensure correct alignment of the data from the two sources. Once alignment of the forensic case and the police criminal investigation was confirmed, data were collected from the police incident data base including the outcome of the police investigation and the outcome of associated court proceedings (when applicable).

In many instances the police incident data base records connected with the forensic cases related to multiple persons and multiple charges. The data collated for these cases was condensed to a single criminal justice outcome according to the following conventions.

- If the case included multiple persons of interest with some being charged and others not, the incident record for the charged person was selected.
- If there were multiple charges for a single defendant, and some charges resulted in guilty findings and others not, the incident record for the proven charge was selected.
- If there were multiple proven charges in a case, either for a single defendant or multiple defendants, the incident record for the highest proven charge was selected.

As a result of the approach adopted, cases were classified as having charges laid when some suspects were charged and others were not. Similarly, cases were classified as resulting in a finding of guilt when some defendants were found guilty and others were not.

Statistical analyses

A variety of descriptive statistics have been used to describe the qualities of the constructed database, the forensic evidence in the cases and the associated criminal investigations. A combination of bivariate analysis and logistic regression was applied to explore the relationships between forensic evidence and the outcomes of police investigations and court proceedings. The dichotomous dependant variables in the analyses were: criminal charges were laid (coded as 1) or not (coded as 0); and a finding of guilt was reached (coded as 1) or otherwise (coded as 0). The predictor variables for the binary logistic regression were the results of chemical trace, biology and ballistics/tool marks examinations, with results which "support the prosecution case" (coded as 1) and results which "did not support the prosecution case" (coded as 0).

Assumptions relevant to binary logistic regression were tested. The adequacy of the sample sizes was assessed using EPV values (events per variable). The values obtained for the dataset of all cases (n = 238, EPV = 23.6) and the dataset consisting only of cases in which criminal charges were laid (n = 179, EPV = 11.8) were both above the threshold of 10 (Field 2009).

Multicollinearity was tested by regressing each predictor variable against all other variables and calculating the variance inflation factors (VIF). VIF values below 3 were obtained for the majority of variables. However, some VIF values just below 5 were also obtained. There is variation in the literature as to what is an acceptable VIF threshold, with values of 10, 5 and 3 having been cited (Field 2009; Kock & Lynn 2012; O'Brien 2007). Regardless of the threshold, the values obtained that were just below 5 indicate that there may be a mild level of multicollinearity between chemical trace evidence results, ballistics/tool marks results and the associated interaction term. Given that the inclusion of each form of forensic evidence, and the interaction terms involving combinations of outcomes from each type of forensic evidence, are integral to the research hypotheses, it was not possible to simply remove any of these variables (or interactions) from the analysis.

To ensure robustness of findings, given the possibility of a mild degree of multicollinearity, different methods for variable selection were also tested. The initial approach was based on addressing the research questions and used forced stepwise methodology, introducing chemical trace evidence at the first step (i.e. the primary forensic discipline of interest), biology and ballistics/tool marks results at the second step (i.e. the secondary forensic disciplines of interest) and finally the interaction terms between chemical trace evidence with biology and with ballistics/tool marks (to investigate the possibility of combined impact). Forward selection and backward elimination methods were also run and the model fit summary statistics were used to compare the three approaches. The forced stepwise method produced the best model fit statistics, although the values for the proportion of variance explained by the models were still quite low. The forced entry approach was adopted with the three steps for variable entry retained as the model fit statistics indicated that the models were improved at each step.

Results

Descriptive statistics

Offence categories and the police investigative units

The dataset consists of 238 criminal investigation cases conducted by Victoria Police. For all cases, one or more written report was issued by the forensic laboratory in relation to the results of examinations for chemical trace evidence.

At the time that these cases were investigated, Victoria Police categorised the incidents that they investigated into four groups. Using these categories, the cases within the dataset consisted of: 60% “crimes against the person” (e.g. affray, reckless conduct, kidnapping, rape, murder); 30% “property crime” (e.g. criminal damage, burglary, aggravated burglary, obtain property by deception); and 10% “other” (such cases in this data set predominantly related to possessing, using and making firearms, explosives or weapons not specified). Many cases related to multiple, and sometimes varied,

offences. Some cases in the dataset did relate to offences in the fourth category “drug offences” (e.g. possess, traffick and manufacture illicit drugs) but all such cases also included other offences. For the purpose of this study, these cases were classified according to the non-drug offences for the reasons that the chemical trace evidence was more relevant to the non-drug offence and the non-drug offences were a higher level of change.

The types of policing units that were responsible for the investigation of the cases in the dataset were: 38% local crime investigation units (responsible for the investigation of serious crime in local regions and staffed by detectives); 32% crime department squads (specialised according to offence type and staffed by detectives); 17% uniform policing (responsible for localised lower level crime); and the remaining 13% by miscellaneous policing units with specialised functions but not specifically staffed by detectives. As such, detectives, either from local crime investigation units or from crime department squads, conducted the majority of the investigations in the data set.

The range of forensic evidence in the cases

The results reported in these cases related to various sub-disciplines of chemical trace evidence and, in some cases, results for evidence types other than chemical trace evidence were also reported. That is, cases could include multiple reports for chemical trace evidence and/or evidence types other than chemical trace evidence. Table 4.1 presents the sub-disciplines of chemical trace evidence that were reported in the cases in the data set. The large majority of cases consisted of a single sub-discipline of chemical trace evidence (91% of cases). However, 25 cases included chemical trace evidence relating to between 2 and 4 different sub-disciplines. Examinations relating to paints and polymers, glass, fibres and dyes were most common in these cases.

Table 4. 1: The sub-disciplines of chemical trace evidence relating to the cases in the data set.

Sub-discipline of chemical trace evidence	Percent (n = 238)
Gunshot residue	41%
Paint / polymers	28%
Glass	13%
General chemical & physical	9%
Chemical irritants	8%
Dyes	5%
Fibres	5%
Lubricants / oils	2%
Cosmetics	0.8%
Metal	0.4%
Soil	0.4%

The Victoria Police Forensic Services Department (VPFSD) provides a broad range of forensic services. Case records in the laboratory case management system were accessed to obtain details of the forensic reports for disciplines other than chemical trace evidence that were also issued in these cases. Written reports relating to Victoria Police forensic laboratory services other than chemical trace evidence were issued in 140 of the cases in the data set (58.8%). There were complex cases in the data set which included reports for up to 7 different forensic disciplines in addition to the chemical trace evidence (refer Figure 4.2). Cases varied in the range of forensic disciplines that were reported but the most frequent non-chemical trace evidence forensic disciplines reported in this dataset were ballistics/tool marks and biology. The cases varied in the total number of written

reports issued (for both chemical trace evidence and other forensic disciplines). It should be noted that, although fingerprint examinations are conducted at the Victoria Police forensic laboratory, written formal reports issued for the results of these examinations were not recorded on the laboratory case management system during the period of these cases and consequently data relating to the inclusion of fingerprint evidence in the cases could not be captured.

Of the cases that included biology evidence, 91% involved DNA profiling with the remainder consisting of blood pattern analysis, body fluid identification or textile damage examination. Of the cases that included ballistics/tool marks evidence, 87% of the cases included ballistics comparisons and 13% tool marks examinations (note that in this discipline cases could include a combination of examination types). Range determination, trajectory and firearm safety were also included in many of the cases.

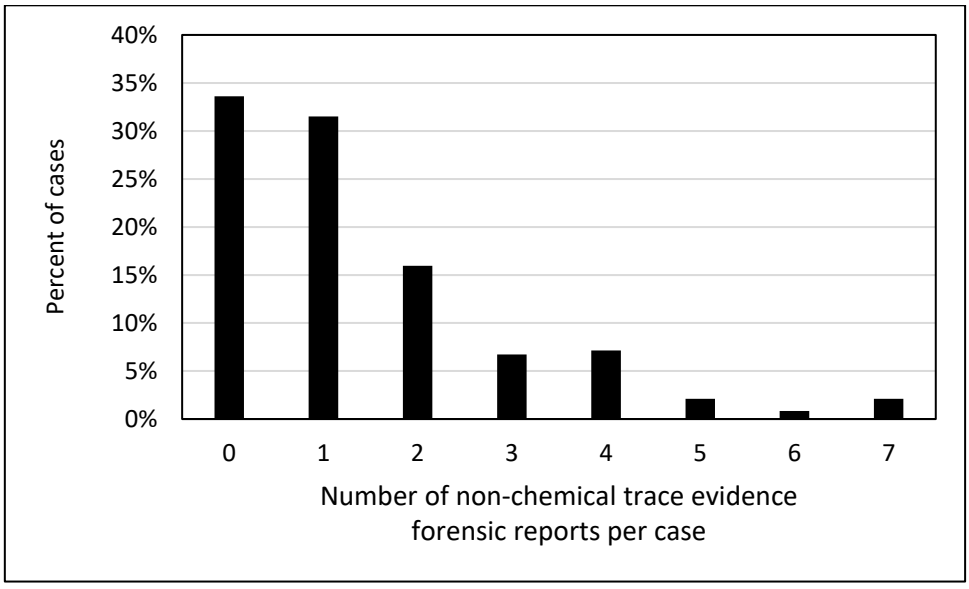

Figure 4. 1: The number of non-chemical trace evidence forensic reports issued per case (n = 238).

The timeliness of the forensic reports

The timing for reporting the results of examinations may influence the impact that forensic evidence has on a case. Details regarding the timing of reports for the chemical trace, ballistics/tool marks and biology evidence are presented in Table 4.2. The tabled data is derived from a combination of official Victoria Police incident records (i.e. the date of offence) and the forensic laboratory records (i.e. the date that first official written forensic reports were issued). In terms of the actual time to issue reports, there is variation between the three disciplines with the median reporting time for ballistics/tools marks (6.5 weeks) being much shorter than both chemical trace evidence (30 weeks) and biology (36.5 weeks). However, when considering the proportion of cases in which reports were issued before charges were laid in cases, there is less variation in the timeliness of the disciplines. Very low minimum reporting times of 1 week for chemical trace evidence and ballistics/tools marks suggests that there were cases in the dataset that had received prioritisation (i.e. they had been examined ahead of other cases in the backlog awaiting examination) and rapid completion of some examinations for these two disciplines. There may be other factors that could also contribute to the short reporting time, including the possibility of there being little or no useful information in the case. However, as case backlogs typically cause delays of multiple weeks or months before case examinations are commenced, there is a high degree of confidence that these cases were prioritised for examination.

For chemical trace evidence, in 76% of the cases written reports were issued within 12 months of the date of the offence, and 46% with 6 months. However, there were 12 cases (5%) in the data set in which the results of the chemical trace evidence examinations were reported more than two years after the date of the offence. It should also be noted that preliminary results may or may not have been provided informally by the forensic practitioners, either verbally or via email, before the official written reports were issued.

Table 4. 2: Timing of the written reports for chemical trace evidence results.

	Chemical Trace Evidence	Ballistics / Tool marks	Biology
Median (weeks)	30	6.5	36.5
Minimum (weeks)	1	1	12
Maximum (weeks)	368	119	205
[A] Proportion of cases in which the earliest report was issued before charges were laid	14.5%	16.4%	10.7%

Timing equates to the time in weeks from the date of offence (as per Victoria Police records) to the date the first official chemical trace evidence written report was issued (according to forensic laboratory records).

Median values are reported instead of the mean due to the fact that the median better captures the skewed nature of the data and is less influenced by the outliers.

[A] Cases without charges have been excluded. The number of cases in which charges were laid: chemical trace evidence n = 179; ballistics / tool marks n = 67; biology n = 56.

The potential of forensic evidence to impact on the decision to charge suspects is a primary point of interest. Charges were laid in 179 cases in the chemical trace evidence data set (75.2% of the total). The potential for forensic evidence to impact on the decision to charge suspects is likely to be increased when the results of forensic examinations are reported before that decision is made. At the VPFSD the primary means of reporting the results of forensic examinations is via written reports issued by the laboratory. For this dataset, the average time for reporting the results of chemical trace examinations (39.8 weeks after the date of offence) is much later than the average time for laying charges (14.8 weeks after the date of offence). To examine more deeply the potential of forensic evidence to influence the decision to charge suspects, the relative timing of the date of issue of written reports of chemical trace evidence and the date suspects were charged were analysed in individual cases. Written reports of the chemical trace evidence were issued before

charges were laid in only 14.5% of cases in which charges were laid. Similar results were obtained for ballistics/tool marks evidence (16.4 % of cases in which charges were laid) and biology evidence (10.7 % of cases in which charges were laid). It should be noted that there is scope for police investigators to receive preliminary reports prior the laboratory issuing the formal written report. However, of the cases in which criminal charges were laid, charges were laid on or before the date that the forensic case was created in 67.6% of the cases. In this scenario, it is almost certain that no results of forensic examinations were available at the time that the charges were laid for the three disciplines for these cases, although preliminary information may have had scope to influence the laying of charges in the third of cases where forensic case records were created before the laying of charges.

Statistical analysis of the impact of forensic evidence on criminal justice outcomes

Descriptive statistics of this dataset have indicated that the results of forensic examinations could not be considered in making the decision to charge suspects in the majority of cases. A chi-square test of independence was performed which confirmed that the relationship between the results of chemical trace evidence examinations and laying criminal charges was not significant in this data set (χ^2 (1, n = 238) = .821, p = .365). A chi-square test of independence was also performed to examine the relationship between the results of chemical trace evidence examinations and the determination of guilt in the associated case. The relationship between these variables was also not significant (χ^2 (1, n = 238) = .252, p = .615).

The descriptive data indicate that the cases which include chemical trace evidence frequently also include other forms of forensic evidence, with almost 60% of the cases in the dataset including evidence of at least one other forensic discipline, and approximately 19% of the cases in the data set

including results from three or more other forensic disciplines. This suggests that it may be more realistic to analyse the relationship between chemical trace evidence and criminal justice outcomes in a way that is inclusive of other evidence in the cases. Consequently, further statistical testing was conducted using logistic regression analyses that also included the results of biology and ballistics/tool marks examinations, the two disciplines most frequently present in cases which included chemical trace evidence.

The relationship between forensic evidence and the determination of guilt – analysis of all cases in the dataset

A logistic regression analysis was conducted to explore the effect of forensic evidence on the determination of guilt in all 238 cases (refer Table 4.3). Analysis of the entire dataset, including cases in which suspects were charged and cases in which no charges were laid, has potential to capture the impact of evidence at multiple points in the processing of a case (i.e. charges being laid, the case proceeding to court and findings of guilt or otherwise in court).

As per Table 4.3, the introduction of the predictor variable *results of chemical trace examinations* into the model at the first step did not significantly improve the constant only model (χ^2= 0.25, df = 1, p = .615). The inclusion of *results of biology examinations* and *results of ballistics/tool marks examinations* at the second step did significantly improve the model (χ^2= 12.71, df = 2, p = .002). At this step the *results of biology examinations* was the only significant variable in the equation (p = 0.001). At the final step, the interaction terms between the *results of chemical trace and biology examinations* and the *results of chemical trace and ballistics/tool marks examinations* were introduced. Although the introduction of these interaction terms was not significant (χ^2= 3.75, df = 2, p = .154) the model was improved as indicated by an increase in the Nagelkerke R Square value from steps 2 to 3 (see Table 4.3). However, the Nagelkerke R Square value indicated that only 9% of the

variance in the determination of guilt was accounted for in the final model. The *results of biology examinations* remained as the only significant variable in the equation.

For the final model, with all predictor variables included, the prediction success overall was 60% with no determination of guilt correctly predicted in 74% of cases and guilty determinations correctly predicted in 47% of cases. The odds ratio for the predictor variable, *results of biology examinations*, was 4.51 (95% CI 1.45-14.04). That is, the odds of a case resulting in a guilty finding are approximately 4 times more likely when a case includes results of biology examinations that support the prosecution case than when a case does not. Although the interaction term of *results of chemical trace and ballistics/tool marks examinations* was not significant, the odds ratio for this predictor was 3.14 (95% CI 0.90-10.99).

Predictor variables in the final model that were found not to be significant were the *results of chemical trace examinations* ($p = 0.841$), the *results of ballistics examinations* ($p = 0.120$) and interaction terms between the *results of chemical trace and biology* ($p = 0.433$) and the *results of chemical trace and ballistics/tool marks* ($p = 0.074$) examinations.

Table 4. 3: Logistic regression analysis of the determination of guilt or innocence in 238 cases which included chemical trace evidence.

	Predictor	B	Wald	d.f.	Sig	Exp(B) Odds Ratio	95% C.I. for Exp(B)	
							Lower	Upper
Step 1	**Chemical Trace results**	.134	.252	1	.615	1.143	.679	1.924
Step 2	**Chemical Trace results**	.132	.232	1	.630	1.141	.667	1.952
	Biology results	1.162	11.679	1	.001	3.196	1.641	6.223
	Ballistics / tool marks results	-.069	.056	1	.813	.933	.524	1.659
Step 3	**Chemical Trace results**	-.069	.040	1	.841	.933	.475	1.832
	Biology results	1.506	6.752	1	.009	4.509	1.448	14.043
	Ballistics / tool marks results	-.819	2.423	1	.120	.441	.157	1.236
	Chemical by biology results	-.564	.614	1	.433	.569	.139	2.331
	Chemical by ballistics results	1.143	3.191	1	.074	3.136	.895	10.990

Step	Variables introduced	Chi-square	df	Sig.	Nagelkerke R Square
Step 1	**Chemical trace evidence results**	.252	1	.615	0.001
Step 2	**Biology & Ballistics results**	12.711	2	.002	0.071
Step 3	**Interaction terms**	3.745	2	.154	0.090

The relationship between forensic evidence and the determination of guilt - analysis of only the cases in which suspects were charged

In order to focus on the impact of forensic evidence in court, the logistic regression analysis was applied to only the cases in which criminal charges had been laid (n = 179) (refer Table 4.4).

As demonstrated in Table 4.4, again, the introduction of *results of chemical trace examinations* at the first step did not significantly improve the constant only model (χ^2= 0.001, df = 1, p = .978). The inclusion of *results of biology examinations* and *results of ballistics examinations* also did not significantly improve the model (χ^2= 5.90, df = 2, p = .05). However, at this second step the *results of biology examinations* was a significant variable in the equation (p = .033). The introduction of the interaction terms in step 3 did not result in a significant improvement in model fit (χ^2= 4.47, df = 2, p = .107) although once again the variance accounted for by the model increased from steps 2 to 3 and the Nagelkerke R Square value indicated that 7.8% of the variance in the determination of guilt was accounted for by the final model. In the final step of the model, as shown in Table 4.4, the interaction term of the *results of chemical trace and ballistics/tool marks examinations* was a significant predictor (p = .04) but the *results of biology examinations* was no longer significant (p = .19). The *results of ballistics examinations* was also a significant variable in the equation but with a negative correlation (p = .02). The negative B coefficient for this variable, in addition to the results of the assumption testing that indicated possible multicollinearity, suggest that this may be a spurious result.

For the final model, with all predictor variables included, the prediction success overall was 70% with no determination of guilt correctly predicted in 15% of cases and guilty determinations correctly predicted in 97% of cases. The odds ratio for the interaction effect variable, *results of chemical trace and ballistics examinations*, was 4.62 (95% CI 1.10 - 19.40). That is, the odds of a case resulting in a guilty finding are approximately 4 times more likely when a case includes results of chemical trace

and ballistics examinations as a combination that support the prosecution case than when a case does not. Although the interaction effect of *results of biology examinations* was not significant, the odds ratio for this predictor was 2.40 (95% CI 0.65 - 8.88).

Predictor variables in the final model that were found not to be significant were the *results of chemical trace examinations* (p = .32), the *results of biology examinations* (p = .19) and the interaction term of the *results of chemical trace and biology* (p = 0.94).

Table 4. 4: Logistic regression analysis of the determination of guilt or innocence in 179 cases which included chemical trace forensic evidence and for which criminal charges were laid.

	Predictor	B	Wald	d.f.	Sig	Exp(B) Odds Ratio	95% C.I. for Exp(B)	
							Lower	Upper
Step 1	**Chemical Trace results**	-.009	.001	1	.978	.991	.520	1.887
Step 2	**Chemical Trace results**	.043	.016	1	.899	1.044	.541	2.015
	Biology results	.855	4.531	1	.033	2.351	1.070	5.166
	Ballistics results	-.391	1.302	1	.254	.676	.346	1.324
Step 3	**Chemical Trace results**	-.445	.991	1	.319	.641	.267	1.539
	Biology results	.875	1.721	1	.190	2.400	.649	8.876
	Ballistics results	-1.386	5.490	1	.019	.250	.078	.797
	Chemical by biology results	-.066	.006	1	.938	.936	.180	4.880
	Chemical by ballistics results	1.530	4.361	1	.037	4.616	1.098	19.397

Step	Variables introduced	Chi-square	df	Sig.	Nagelkerke R Square
Step 1	Chemical trace evidence results	.001	1	.978	.000
Step 2	Biology & Ballistics results	5.902	2	.052	.045
Step 3	Interaction terms	4.469	2	.107	.078

The relationship between forensic evidence and the determination of guilt – analysis of cases which included gunshot residue evidence

The finding that the interaction effect of the *results of chemical trace and ballistics/tool marks examinations* was a significant variable in regard to the determination of guilt in cases where suspects have been charged prompts the question of "what is the important connection between these two disciplines?". The descriptive statistics has shown that gunshot residue examination was the most frequent sub-discipline of chemical trace evidence in the dataset. With consideration to the fact that there is a logical connection between gunshot residue and ballistics examinations as both provide evidence in relation to firearms, the statistical analysis was replicated on the dataset consisting only of cases which included gunshot residue evidence. A logistic regression analysis was conducted to explore the effect of forensic evidence on the determination of guilt in the 98 cases which included gunshot residue (GSR) forensic evidence (refer Table 4.5). It should be noted that the events per variable (EPV) value for the regression analysis of this data set is 9.8 and therefore is at the limit of what is considered to be acceptable (Field 2009).

The introduction of the predictor variables was not significant at any of the three steps. However, as with the previous analyses, the model did improve in terms of the percentage of variance accounted for (i.e. the Nagelkerke R Square value, see Table 4.5) at each step and at the final step the Nagelkerke R Square value indicated that 13.3% of the variance in the determination of guilt was accounted for by the forensic results supporting the prosecution case. Also, at the final step the interaction term of the *results of chemical trace and ballistics/tool marks examinations* was a significant variable in the equation ($p = .05$).

For the final model, with all predictor variables included, the prediction success overall was 63% with no determination of guilt correctly predicted in 59% of cases and guilty determinations correctly predicted in 67% of cases. The odds ratio for the interaction effect variable, *results of chemical trace*

and ballistics/tool marks examinations, was 6.43 (95% CI 1.03 – 40.07). That is, the odds of a case resulting in a guilty finding are approximately 6 times more likely when a case includes results of chemical trace and ballistics/tool marks examinations as a combination that support the prosecution case, than when a case does not. However, the true effect size is uncertain due to the extremely wide confidence intervals. Although the *results of biology examinations* was not significant, the odds ratio for this predictor was 5.29 (95% CI 0.81 - 34.61).

Predictor variables in the final model that were found not to be significant were the *results of chemical trace examinations* (p = .44), the *results of biology examinations* (p = .08), the *results of ballistics examinations* (p = .23) and interaction effects between the *results of chemical trace and biology* (p = .41).

Table 4. 5: Logistic regression analysis of the determination of guilt or innocence in 98 cases which included gunshot residue evidence.

	Predictor	B	Wald	d.f.	Sig	Exp(B) Odds Ratio	95% C.I. for Exp(B)	
							Lower	Upper
Step 1	Chemical Trace results	.447	1.105	1	.293	1.563	.680	3.595
Step 2	Chemical Trace results	.383	.773	1	.379	1.467	.625	3.444
	Biology results	.954	3.742	1	.053	2.597	.988	6.828
	Ballistics results	.318	.541	1	.462	1.374	.589	3.206
Step 3	Chemical Trace results	-.581	.610	1	.435	.559	.130	2.404
	Biology results	1.666	3.024	1	.082	5.292	.809	34.612
	Ballistics results	-.912	1.446	1	.229	.402	.091	1.776
	Chemical by biology results	-.934	.685	1	.408	.393	.043	3.590
	Chemical by ballistics results	1.861	3.971	1	.046	6.428	1.031	40.071

Step	**Variables introduced**	**Chi-square**	**df**	**Sig.**	**Nagelkerke R Square**
Step 1	Chemical trace evidence results	1.114	1	.291	.015
Step 2	Biology & Ballistics results	4.630	2	.099	.076
Step 3	Interaction terms	4.566	2	.102	.133

Discussion

The aim of this study was to assess the impact of forensic evidence in the criminal justice system and to produce empirical data pertaining to the relationships between forensic evidence and the outcomes of police investigations and court processes. This task was approached from the perspective of the forensic science (rather than case type) and chemical trace evidence was chosen as the primary discipline of interest. Chemical trace evidence provides information to assist police investigators and the courts in a form that differs to DNA and fingerprints, which have been the subject of many other studies. A quantitative methodology was applied, which addressed inadequacies of some previous research. In particular, the results of examinations were factored into the analyses to cover the ability of forensic evidence to not only implicate suspects but to also exculpate innocent accused parties. Furthermore, in acknowledgment of the fact that criminal cases can often include multiple forensic evidence types, this study also examined the impact of chemical trace evidence in combination with other forensic disciplines.

The first stage of this study involved collating data which defined the profile of cases in which chemical trace evidence is typically present. The majority of cases in the data set related to offences that are classified as crimes against the person and the investigations were predominantly conducted by policing units staffed by detectives. This reflects that in Victoria, Australia chemical trace evidence is most frequently being applied to high level crimes. One factor contributing to this is that, although the chemical trace evidence in this study covers a range of sample forms, a large portion of the cases included examinations for gunshot residue and were therefore related to offences involving firearms.

The cases in the dataset, all of which included chemical trace evidence, were also found to frequently include reports relating to examinations conducted at the Victoria Police forensic laboratory for other forensic disciplines. Almost 60% of the cases included at least one other form of forensic evidence in addition to chemical trace evidence, however this figure is likely to understate

the true proportion. The methodology in this study did not capture reports relating to fingerprint evidence (as these reports were recorded on a separate system) or forensic medical testing such as pathology and toxicology (services provided by a separate organisation to the Victoria Police Forensic Services Department). A sizable proportion of cases included forensic evidence relating to multiple disciplines with approximately 19% of the cases in the data set including chemical trace evidence and results from at least three other forensic disciplines. These cases predominantly related to major crimes against the person with murder, manslaughter and intentionally cause serious injury being the three most frequent offences in this group. This is consistent with chemical trace evidence being part of a suite of forensic examinations that can be applied when a comprehensive approach is adopted in the investigation of a major crime.

The timeliness of service delivery is a prominent criterion that is considered by both policing services and the courts in assessing forensic services. Anecdotally, timeliness has been a factor previously raised by police investigators when responding to service satisfaction surveys or providing feedback to forensic service providers by other means (Julian et al. 2005). Forensic service providers frequently prioritise components of their work to meet deadlines set by prosecutors and the courts. And the timeliness of service delivery has featured in past reviews of the effectiveness of forensic services providers (Bourn 2003; Home Office 2007). The viability of chemical trace evidence has been brought into question (Roux et al. 2015) on the grounds which include the examinations are considered to be highly resource intensive and the analyses are very time consuming. In this study, the timeliness of chemical trace evidence services was not dissimilar to ballistics/tool marks and biology evidence. In terms of the actual time elapsed between the date of offence and the date of issue of official reports, chemical trace evidence was positioned between ballistics/tool marks as the timeliest and biology as the least timely. And notably, the proportion of cases in which the official forensic reports were issued before charges were laid did not vary greatly across the three disciplines. Reports were issued before charges were laid in a low proportion of cases for all three disciplines, with each being 16% of the total or less.

To assess the impact of chemical trace evidence, the relatively simple methodology of bivariate analysis was initially applied. The relationship between chemical trace evidence and the laying of criminal charges was found to be not significant using bivariate analysis. The fact that charges were laid in the majority of cases in the data set before chemical trace and other forensic evidence was reported coincides with this finding. Further still in approximately two thirds of the cases in the data set, charges were laid on or before the date that the corresponding forensic case was created, therefore providing no opportunity for the results to influence the decision to lay charges. This represents strong evidence that chemical trace and other forensic evidence is often not a factor that impacts on the charging process. Consequently, the first hypothesis "*the proportion of cases in which suspects are charged will be higher when the cases include forensic evidence that connects the suspect to the offence*" has not been proven. However, the reason that the hypothesis is not valid is not because forensic evidence has failed to impact on the police investigations but rather because the majority of cases in the data set have been processed via the provision of the power of police to arrest suspected offenders and then proceed to prosecution, a process in which the investigation will typically continue after charges have been laid. As such, in this jurisdiction the decision to lay charges is not an appropriate criminal justice outcome for measuring the impact of chemical trace, biology or ballistics/tool marks evidence on police investigations. The impact of timeliness of both preliminary and formal reports will be explored in further detail in a forthcoming publication.

The relationship between the results of chemical trace evidence examinations and the determination of guilt was tested using bivariate analyses with both: (i) all cases; and (ii) only cases in which charges were laid. The analysis was applied to all cases (i.e. with and without charges laid) because it would be valuable to know whether the results of chemical trace examinations can be used to predict the likelihood of whether cases will proceed to court and ultimately reach a guilty finding (or not). However, statistically testing only cases in which charges have been laid focuses the analyses on the impact of chemical trace evidence on the court process. Consequently, separate analyses of both the whole data set (all cases) and only cases in which charges were laid were

conducted. Using Chi square testing the relationship between the results of chemical trace examinations and the determination of guilt was found to be not significant for either the whole data set or only cases in which charges were laid. There are many factors that collectively may contribute to the determination of guilt or innocence, and this bivariate approach is likely to be too simplified to test the complex relationship between chemical trace evidence and court outcomes. The descriptive statistics have shown that chemical trace evidence is often only a component of the forensic evidence in the case. Therefore, it would be appropriate to apply testing of the dataset that takes into account the potential contribution of a combination of forensic evidence types. Ballistics/tool marks and biology were the additional forms of forensic evidence that were most commonly present in the cases with chemical trace evidence and these disciplines were included in subsequent logistic regression analysis of the data set.

In the logistic regression analysis of all cases in the data set, the impact of chemical trace evidence on the finding of guilt or otherwise in court was not evident (i.e. the results of chemical trace examinations were not a significant predictor of the determination of guilt). In contrast biology results were a significant predictor variable in the determination of guilt. This finding is consistent with research by Briody (2004) and McEwen & Regoeczi (2015), which respectively found that DNA evidence that supported the prosecution and DNA evidence that was probative were significantly related to convictions. In contrast the studies by Peterson et al (2010) and Baskin & Somers (2010; 2011) based their analyses merely on the inclusion of forensic evidence in cases and did not consider the results of the examinations. These studies did not find forensic evidence (such as DNA) to be a significant predictor of conviction.

Differences in the information provided by the forensic disciplines in this study may contribute to the differences observed in their impact. DNA analysis can provide direct identification of persons involved in a crime whereas chemical trace evidence can establish a nexus between an item and a crime (e.g. glass from a window at the scene of the offence or paint from a vehicle used in

committing a crime) but additional evidence is required to link a person to the item. One possible interpretation of the results is that the direct identification of individuals via DNA is perceived in court as more powerful evidence than a secondary nexus established via chemical trace evidence. Results were obtained that suggested that chemical trace evidence and ballistics/tool marks evidence in combination may be impacting on determinations of guilt with the odds ratio for the interaction term having a value of 3.14. However, this relationship was not significant and there was a wide range in the 95% confidence intervals of .90 to 10.99, which raises doubt about the reliability of this effect.

The logistic regression analyses when applied only to cases in which charges are laid are expected to be more indicative of the impact of evidence in court. The testing of this selected sample indicated that the interaction term of chemical trace and ballistic evidence was significant. To further investigate the possibility that this significant relationship may be based on a beneficial connection between gunshot residue and ballistics evidence, logistic regression testing was also applied only to cases which included the results of gunshot residue examinations. Once again, the interaction term of chemical trace and ballistic evidence was significant suggesting that there may be a synergy between these disciplines. Logically the combination of GSR and ballistics examinations could provide more complete evidence about the involvement of firearms in a crime. The significance of this combination of evidence provides support for the third hypothesis that *"the probable impact of forensic evidence on criminal justice outcomes will be increased when cases include multiple pieces of forensic evidence that align in terms of implicating or exculpating suspects"*.

The results obtained from logistic regression analyses overall do also provide support for the second hypothesis that "the proportion of cases in which guilt is determined by the courts will be higher when the cases include forensic evidence that connects the suspect to the offence". However, the support for the hypothesis varies between the tested forensic disciplines with biology being significant alone and chemical trace and ballistics evidence being significant in combination.

There are some limitations in this research that should be acknowledged. The approach taken has been directed at determining whether there are general relationships that are apparent across a large pool of cases, and assumptions have been made for cases with multiple chemical trace evidence reports, multiple defendants and multiple charges. The possibility exists that within such cases the forensic evidence may have had finer points of impact, such as influencing decisions to downgrade or drop charges (or the reverse) which would not be reflected in the results of this study. Also, there are a number of other important steps in the criminal justice system that could be impacted by forensic evidence which were not examined in the research (e.g. pleas by defendants and length of sentence).

There are limitations associated with the interpretation of the forensic reports and how the results of the forensic examinations have been factored into the statistical analyses. The chemical trace evidence reports were reviewed using set criteria based on general trends of examination results and whether they are likely to provide support for the prosecution case or not. It is possible that there were cases in which it was found that samples could share a common origin (e.g. paint, glass, fibres, etc.) or target materials were identified (e.g. gunshot residue) but the forensic evidence did not support the prosecution case. However, in the absence of having detailed knowledge of the circumstances of the crime and the cases presented by the prosecution and defence, it is necessary to apply generalised criteria based on the most likely status of whether forensic reports supported or did not support the prosecution case. It should also be noted that within the cases categorised as providing no support for the prosecution, there is likely to be varied potential for the forensic evidence to clear suspects or accused persons as this category consists of cases with forensic results that: refute the prosecution case; neither support the prosecution or the defence case; or are inconclusive.

In this research the impact of biology and ballistics/tool marks evidence has been examined as additional evidence forms in the sample cases, but it would be beneficial to study these disciplines

with a case sample size of similar scale to the chemical trace evidence dataset and to include other forensic evidence forms that are common to those cases. Another point that may be important is that the chemical trace, biology and ballistics/tool marks evidence in the cases each consist of a range of examination types or sub-disciplines. However, the results have been factored into the statistical analyses under their respective overall discipline. Quantitative methodology requires an adequate sample size and to achieve this with the forensic discipline of chemical trace evidence, which has a relatively low throughput of cases per time, it was necessary to combine the sub-disciplines. There was a predominant examination type in each of the three disciplines: for chemical trace evidence 41% of the cases included GSR examinations; 91% of the biology examinations were DNA profiling; and 68% of the ballistics/tool marks cases included ballistics comparisons. However, there may be variation between different examination types in how they impact on criminal justice outcomes. As an example, one examination type in ballistics/tool marks was for firearm safety and function. Establishing that a firearm was in working order can be a piece of evidence that would support the prosecution case, but it would seem likely to have less impact on the determination of guilt than ballistic comparison evidence which establishes whether a bullet recovered from a shooting victim was fired from a specific firearm. The possibility exists that significant relationships between the results of some sub-disciplines and criminal justice outcomes may not be detected when a data set of mixed sub-disciplines is analysed. Analysis of the cases which included GSR evidence provided a means to investigate a dataset of cases that was more uniform and specific in terms of the chemical trace evidence and results were obtained that confirmed the interaction term of results of chemical trace and ballistics/tool marks examinations as being a significant variable.

One aim of this study was to test quantitative database methodology as a potential model for monitoring the impact of forensic services on an ongoing basis. Forensic laboratories are widely committed to providing the highest level of forensic services. In pursuit of this target they typically have well established systems for monitoring and developing their services. Quality programs are embedded in forensic laboratories which include a range of processes that are aimed at ensuring

that their results are scientifically correct. Research and development programs are run to keep pace with advancing technology. And service delivery is closely managed by monitoring a range of business statistics, such as the volume of cases completed and the timeliness of the service. This investment in quality programs, research and development and monitoring service delivery reflect that within the forensic science community there is a focus on managing the business of forensic services. However, there is also scope for forensic laboratories, and the forensic science community more widely, to benefit by assessing how well forensic science is fulfilling its role in the criminal justice system. If forensic laboratories can access empirical data which describes the impact that their services are having in regard to supporting police investigations and assisting the courts to reach just outcomes, it should increase their ability to strategically utilise their resources and to provide maximum value to the criminal justice system. In this study, disconnected data relating to forensic examinations, police investigations and court processes have been brought together so that the impact of forensic evidence in the criminal justice system could be analysed. Although there have been significant limitations to the findings of this study, particularly in regard to the investigation phase of cases, the methodology applied has brought to light that there is variation in the impact of different forensic disciplines on the outcomes of court processes and overall has demonstrated that important information can be obtained by drawing together and analysing forensic, policing and court data.

Conclusion

Chemical trace evidence is a discipline of forensic science that is utilised to support the progress of high level crime cases through the criminal justice system. It is frequently used in combination with other forensic disciplines. One of the aims of this study was to quantify the outcomes of cases that included chemical trace evidence. This aim was applicable to the outcomes of both police investigations and court trials. It was found that the quantitative methodology used in this study could not be used to establish the impact of chemical trace evidence on police investigations. The

relationship between the results of chemical trace evidence examinations and the laying of criminal charges was examined as a means of assessing the impact of chemical trace evidence on the criminal investigations. But the fact that a large proportion of cases are processed via an arrest pathway meant that this approach was flawed. In these cases, the decision to lay charges cannot be made with the full knowledge of the complete range of evidence that would ultimately be available to present in court, as the police investigation will actually continue after charges have been laid.

The realisation of these circumstances prompts further questions. Firstly, how then can the relationship between the forensic evidence and criminal investigation outcomes be measured using quantitative methodology? Would the progression of cases to court provide a measure of sufficient evidence for prosecution having been achieved, and would it therefore be a suitable variable to test for the impact of forensic evidence on criminal investigations? And secondly, might the use of an alternate approach to the database method that has been applied in this study provide a better means to accurately assess the impact of forensic evidence on criminal investigations? This question is examined further in a study conducted by the authors that is based on a survey of police investigators and which included a focus on the contribution of chemical trace evidence to criminal investigations (see Chapter 5).

The impact of chemical trace evidence on court outcomes was successfully examined in this study. Bivariate analysis of criminal case data did not indicate a significant relationship between the results of chemical trace evidence examinations and the determination of guilt or innocence in court. Consideration should be given to the fact that chemical trace evidence is often presented in combination with other forensic evidence, such as the disciplines of ballistics and biology, and that it is likely to be necessary to factor this into the assessment as opposed to testing the impact of chemical trace evidence in isolation. Consequently, logistic regression was used to examine the relationships between the forensic disciplines of chemical trace evidence, ballistics/tool marks and

biology, and these forms of forensic evidence in combination, with the determination of guilt or otherwise by the courts.

Biology evidence was found to be the only discipline in isolation of the three tested using logistic regression that was a significant variable in regard to court findings. However chemical trace evidence in combination with ballistics was a significant interaction variable. Of the three tested disciplines, biology is the only one which provides evidence that directly identifies individuals connected with a potentially criminal incident. In contrast, chemical trace evidence and ballistics can establish a nexus between items (such as clothing, tools, vehicles and firearms) and the crime scene or another individual involved with the crime. In turn chemical trace evidence and ballistics can indirectly link a person to a potentially criminal incident. It may be that identification evidence has greater impact in the courts than evidence which provides an indirect link. However chemical trace evidence does have potential to add further support to other evidence and this may account for the significant relationship of chemical trace evidence and ballistics combined with court outcomes. There is a logical link between ballistics and chemical trace evidence, particularly gunshot residue evidence, with both relating to firearms. Ballistics and gunshot residue evidence in combination has scope to provide a more complete picture regarding the involvement of firearms and how they were used in a crime, than does either discipline on its own.

This study has attempted to use the coarse relationship between the results of forensic examinations and the outcomes of two events in criminal justice pathway as a means of measuring the contribution of forensic evidence to achieving fair and just outcomes. The approach was adopted with consideration to the possibility that it may provide a model that could be employed by forensic service providers to monitor the impact of their services on an ongoing basis. However, it is apparent that a more sophisticated methodology is required, which encompasses the impact of synergies that can exist between forensic disciplines, and potentially between forensic and non-forensic evidence, to measure the full value provided by forensic science. This finding adds support to the conclusions

reached by others that the value provided by forensic science to the criminal justice system is complex and multifaceted.

CHAPTER 5

To Trace or Not to Trace: A Survey of How Police Use and Perceive Chemical Trace Evidence

Chapter 5 Introduction

This chapter is a manuscript that was submitted for publication in a peer-reviewed journal and is the second part of the study of chemical trace evidence. The study is based on a survey of police investigators from a sample of cases from within the dataset used in the quantitative study of chemical trace evidence (Chapter 4). The survey of the police investigators was directed at exploring what their expectations were when they applied chemical trace evidence services and how they used the forensic evidence in their investigation.

The results of this chapter contribute to the exploration of the following research questions and hypotheses:

RQ1 and H1 – the impact of forensic evidence on investigation outcomes;

RQ2 and H2 – the impact of forensic evidence on court outcomes;

RQ4 and H4 – varied impact of forensic disciplines, depending on the information that the evidence provides;

RQ5 - how forensic evidence influences decision-making relating to criminal investigations.

This manuscript has subsequently been published in the journal Forensic Science International (Woodman et al. 2020a).

Abstract

There is limited information available about the impact of chemical trace evidence and it has tended to be anecdotal and mostly pertaining to court outcomes. Very little is known about the use of chemical trace evidence by police investigators or the impact that this evidence form has on criminal investigations. This survey, which was conducted in Victoria, Australia, was aimed at addressing these inadequacies by capturing information from police investigators about: (i) the purpose of using chemical trace and other forensic services; (ii) the expectation of what value forensic services would provide; (iii) the actual impact of forensic evidence in specified cases; and (iv) the general perceptions of forensic science. Police officers who were the lead investigators in a sample of criminal investigations were selected as the subjects for this survey. Each of the sample cases included chemical trace evidence and many of the cases also included other forms of forensic evidence. The police investigators indicated that they use chemical trace evidence with the expectation that it will support their investigations and contribute to building a case for court. Survey responses indicated that chemical trace evidence can impact on multiple stages of a case and that this form of evidence can play a part in guiding police investigators in making decisions about how their cases progress through the criminal justice system. It was found that an important aspect of the impact of chemical trace evidence can involve connections with other forensic and non-forensic evidence in the cases. The provision of preliminary results, prior to the formal written reports that are issued for use in court, enables chemical trace evidence to contribute timely support to investigations. The findings of this survey study contradict prevailing perceptions that the contribution of chemical trace evidence is limited to the presentation of evidence in court.

Introduction

Forensic laboratories operate within the limits of their resources and the demand for their services can exceed their capacity to deliver (Johns & Kahn 2004; Strom & Hickman 2010). Laboratories may employ a level of control to their case workload by applying acceptance criteria to the cases that are submitted by investigators. Additionally, the awareness among police investigators of backlogs of uncompleted cases and delays in case completion times, can also have the effect of deterring investigators from instigating the application of forensic services in some cases (National Research Council 2009). Under these circumstances, where decisions are made about the provision of forensic services that can impact on how cases progress through the criminal justice system, it is important to align forensic services with the needs and expectations of police and the courts so as to maximise the value of the services that are provided. To do this effectively forensic laboratories need to understand how their services are used by police investigators and the courts and they need to know what impact their forensic evidence is having on criminal justice outcomes.

There is an existing body of research that has been directed at evaluating the impact of forensic evidence on criminal justice outcomes. This body of research has produced conflicting findings, and as noted by a number of researchers (Bitzer 2019; Ludwig 2016; Ribaux et al. 2016; Williams & Weetman 2013), it has proven difficult to establish what the contribution of forensic science is to the criminal justice system. There are some important variables to be selected when undertaking such research which include: the type of crime (e.g. homicide, property crime, sexual offences, etc.); the discipline of forensic science (e.g. DNA, fingerprints, ballistics, etc.); and the points within the criminal justice process at which the impact is to be measured (e.g. identification of offenders, arrest, conviction, sentencing, etc.). There are also options relating to the methodology of the research (e.g. using data from official records, conducting a randomised trial, etc.) and how the collected data is evaluated (e.g. qualitative or statistical analysis). A critical point is also how the forensic evidence is factored into the evaluation (e.g. samples collected, samples submitted, samples

analysed, evidence that is probative and evidence that supports the prosecution case). The existing literature is based on various combinations of the key variables of crime type, forensic science discipline and research methodology. These points of variation complicate the comparison of research findings and contribute to the resultant unclear picture of the impact of forensic science on criminal justice outcomes.

Although conflicting findings have been published on the impact of forensic evidence across the criminal justice process in general, a number of studies have reported that forensic evidence does have an impact on the investigation stage and on certain pre-court events. In a randomised trial of property crimes it was found that applying forensic DNA services during the investigation increased identification and arrest of suspects (Roman et al. 2009). From a study based on police homicide case files and forensic records, McEwen and Regoeczi (2015) reported that higher level charges were laid in cases which included forensic evidence, which in this study was predominantly DNA, fingerprints and ballistics. Peterson et al (2010) conducted a large study of official record data relating to 4,205 cases. Separate analyses were conducted for groups of cases based on the offence types of aggravated assaults, burglaries, homicides, rapes and robberies. For all of the tested crime types, the inclusion of crime scene evidence in these cases was a consistent predictor of arrest (although a very low percentage of physical evidence had been analysed before the arrests), referral of cases to the prosecutor and charging of suspects. In a related study of residential burglaries, evidence collected at the crime scene in general was a significant predictor of arrest and referral to the prosecutor, although fingerprint evidence specifically was not (Baskin & Sommers 2011). And in a further study by Peterson et al (2013) which utilised the same data as the two previously mentioned studies, the analysis was applied to the aggregate of all 4,205 cases, and it was found that the examination of forensic evidence was a predictor of referral to the prosecutor and charging of suspects. A randomised field trial was conducted in Australia which sought to evaluate the potential to enhance the police response to residential burglaries (Antrobus & Pilotto 2016). This

study found that forensic evidence, either fingerprints or DNA, was used to support investigations and to assist in solving cases (measured in terms of charges being laid).

Other research has produced results that are not as clear in demonstrating that forensic evidence is making a valuable contribution to criminal investigations. Schroeder and White (2009) examined case files relating to homicide investigations for the purpose of investigating whether DNA evidence affected case clearance (i.e. investigations resulting in suspects being arrested). In this study, the presence of DNA evidence was not related to case clearance. In a study of rape cases, the arrest and charging of suspects was more likely in cases which included physical evidence, however this did not apply to the referral of cases to the prosecutor (Johnson et al. 2012). The findings of King et al (2017) were that untimely reporting of forensic results could hinder the potential of forensic evidence to impact on criminal investigations. Ballistics evidence was the subject of this study. Data was collected for 65 cases of violent crimes and interviews were conducted with 45 investigators within the case sample. In these cases, hit reports had been issued for the results of analysing ballistics imaging evidence against a national database, which could establish a link with a firearm connected with another crime. The authors found that the ballistics hit reports rarely contributed to the identification, arrest or charging of suspects due to the delays in reporting the results.

The authors of this article have reported the results of a quantitative study which examined the impact of a group of forensic disciplines, including chemical trace evidence, on the outcomes of criminal investigations and associated court proceedings (Woodman et al. 2020b). One purpose of the quantitative study was to test whether monitoring the relationship between the results of forensic examinations and the criminal justice outcomes of corresponding cases could provide a means of evaluating the contribution made by forensic laboratories to the criminal justice system. The results of that study suggested that there can be important relationships between evidence relating to different forensic disciplines which need to be considered when assessing the impact of forensic evidence on case outcomes. It was also apparent that there were limits to the quantitative

methodology and, as stated by Williams and Weetman (2013) in reference to other quantitative research on the impact of forensic evidence, the approach does not provide insight into the different ways that investigators can use forensic science to support their investigations.

The present study

The survey-based research presented in this article seeks to build on the quantitative study of the impact of chemical trace evidence (Woodman et al. 2020b) and to add to the existing body of published research on the impact of forensic evidence in the criminal justice system. Police members who were the lead investigators in cases that included chemical trace evidence were surveyed. The aim of the survey was to capture information relating to the use of chemical trace evidence, and forensic science more broadly, by police investigators. Questions were directed at exploring: (i) the purpose of using forensic services; (ii) the expectation of what value forensic services would provide; (iii) the actual impact of forensic evidence in specified cases; and (iv) the general perceptions of forensic science. Survey questions were designed to be inclusive of the entire processing of a criminal case and cover all the potential points that may be impacted by forensic evidence. However, surveying police investigators has enabled particular attention to be applied to the investigation phase. The study is also inclusive of all forms of forensic evidence in the sample of cases but with emphasis on chemical trace evidence which is a forensic discipline that has largely been neglected in previous related research.

Method

Prior to conducting the surveys, approval was obtained from the Tasmanian Social Sciences Human Research Ethics Committee (reference H0016013) and the Victoria Police Human Research Ethics Committee (reference VPHREC 98/10) for surveying the Victoria Police members and for using case information relating to the criminal investigations. Although case identifying information (i.e. name of suspect/accused, etc.) was included with the survey distribution, completed surveys were returned with only a unique study survey code as the identifier and no details which could identify persons involved in the crime or its investigation.

Police investigators who had experience in utilising chemical trace evidence in criminal investigations were the target of the survey. Survey participants were selected from the lead investigators in a database that was developed in a previously conducted quantitative study (Woodman et al. 2020b). The demographics of the investigators was not collected. The survey participants were not selected according to their policing experience or profile, but rather were selected on the basis of being connected with a specific case. The database consisted of 238 criminal investigation cases for which items had been lodged at the Victoria Police Forensic Services Department (VPFSD) for chemical trace evidence examinations, between a four-year period of July 2006 to June 2010. The database included information obtained from official forensic laboratory and police records relating to the forensic examinations and the outcomes of the associated police investigation and court proceedings in each case. All cases were considered to have reached a conclusion, although some cases remained unsolved and therefore could be subject to cold case investigations at a later time. The cases in the database covered a broad range of offence types including crimes against a person, property crime and other offence types.

Sourcing participants from the database provided the opportunity to capture the views of lead investigators regarding the application and impact of chemical trace evidence in specific cases. It also provided the advantage of being able to adopt a sampling strategy aimed at obtaining a survey

pool that was balanced in a number of important variables. It was anticipated that the forensic results, the timeliness of reporting the forensic evidence, and the outcome of the investigation were factors that could influence the views of the police investigators. Accordingly, the pool of survey participants was determined by selecting cases which varied in: (i) the results of the chemical trace evidence examinations (i.e. whether the results did or did not support the prosecution case); (ii) the reporting timeframe for the chemical trace evidence (i.e. whether the report was issued before or after a suspect was charged); and (iii) whether charges were laid in the case (i.e. whether a suspect was charged for committing the investigated offence).

Surveys were prepared in the form of an active PDF document and consisted of three parts. Part A was directed at capturing details of a specified incident that was investigated (i.e. the case in the source database), including the criminal justice outcomes of the case. The questions in Part B related to the same specified case and were directed at: (i) the intended purpose of using forensic chemical trace evidence services in that case; and (ii) the impact that the evidence had on the final outcome of that case. The aim of Part C was to capture more general perceptions of the police investigators in regard to forensic science and to chemical trace evidence more specifically. Surveys were distributed to the investigators via email. The survey was conducted in early 2017 which meant that the cases that were the subject of the questions in Parts A and B related to investigations that were active six to eleven years earlier (based on the period when items were lodged for forensic examinations). This delay was in part a result of the need to select cases that had reached a conclusion. The investigators were provided with brief details to identify the specified case that was the subject for Parts A and B of the survey. The case identifying details that were provided consisted of the type of offence investigated, date of the offence, name of the suspect/accused, name of the victim/deceased and other details such as addresses or names of commercial businesses when applicable. Completion of the surveys was voluntary.

The surveys included questions that captured a combination of quantitative and qualitative data (refer Appendix A). Case outcomes were captured in Part A with some questions enabling triangulation of data that was captured in the database study (i.e. whether charges were laid and what outcomes resulted in court) and other questions providing additional information about the cases (i.e. what pleas were entered and whether there were changes in the plea). Part B began with questions that explored the opinions of police investigators regarding which steps in processing cases they expected would be supported by chemical trace evidence (e.g. the course of the investigation, the decision to charge suspects, etc.) and how (e.g. by determining that an incident was a crime, by linking a suspect to a crime, etc.). Further questions in Part B explored the impact of chemical trace and other evidence and were directed at: the specific case processing steps that were influenced; ratings of the importance of different evidence types (forensic and non-forensic) in determining the final case outcomes; timeliness of reporting; and the use of preliminary reporting. The questions in Part C were not case specific and were used to capture data about the general perceptions of the police investigators regarding: the usefulness of chemical trace evidence to support specific case processing steps; what constitutes suitable reporting timeframes and why; and the usefulness of preliminary reports. There were also opportunities through the survey for participants to provide free text responses.

Thirty completed surveys were received, resulting in a response rate of 22%. The profile of the cases in the survey sample obtained, in terms of variables relating to the forensic evidence, the police investigation and the criminal justice outcomes, was compared to the whole database. The whole database consisted of all criminal investigation cases conducted by the Victoria Police during a four-year period which included chemical trace evidence, with the exception of only 28 cases which could not be included because their criminal justice outcomes could not be determined. Table 5.1 presents a comparison of the survey sample with the whole database, regarding these important variables (i.e. “results of the chemical trace examinations”, “criminal charges laid” and “determination of guilt

or innocence"). For these variables the survey sample was similar to the whole database, although the frequency of results supporting the prosecution case was higher in the survey sample.

Table 5. 1: Profile of the survey cases regarding: (i) the results of the chemical trace evidence; (ii) whether charges were laid; and (iii) whether the cases resulted in a guilty finding.

	Whole database (n = 238)	Sample obtained (n = 30)
Chemical trace evidence supports the prosecution case [a]	61%	70%
Charges laid	75%	77%
Guilt determined	50%	53%

[a] Results were deemed to support the prosecution case when items such as paint, glass and fibres were matched or when target compounds such as gunshot residue or the active components of chemical irritants (e.g. capsaicin) were identified.

In regard to other case characteristics, the survey sample obtained was generally similar to the whole database however some differences were noted. In terms of the criminal investigations, in the survey sample there was a higher proportion of cases relating to offences against the person (67% in the survey sample compared with 60% in the whole database) and cases that were investigated by detectives, either from specialised squads (43% in the survey sample compared with 38% in the whole database) or local criminal investigation units (40% in the survey sample and 32% in the whole database). Differences regarding the forensic evidence in the cases were that the chemical trace evidence in the survey sample received included a higher proportion of gunshot residue evidence than the whole database (53% in the survey sample compared with 50% in the whole database) and the proportions of cases with biology evidence (33% in the survey sample and 28% in the whole

database) and ballistics/tool marks evidence (50% in the survey sample and 37% in the whole database) were also higher in the survey sample obtained.

The timing of the provision of the results has scope to influence the impact of forensic evidence on the processing of a case through the criminal justice system. Details regarding the timing of reports for the chemical trace evidence in the whole database and the survey sample are presented in Table 5.2. The tabled data is derived from a combination of official Victoria Police incident records (i.e. the date of offence) and the forensic laboratory records (i.e. the date that first official written forensic reports were issued). Two cases in the sample obtained could be considered outliers in that the results of the chemical trace evidence examinations were reported more than two years after the date of the offence. In 70% of the cases, written reports for the chemical trace evidence were issued within 12 months of the date of the offence, and 43% within 6 months. It should be noted that preliminary results may or may not have been provided by the forensic practitioners, either verbally or via email, before the official written reports were issued.

Table 5. 2: Timing of the written reports for chemical trace evidence results.

	Whole database (n = 238)	Sample obtained (n = 30)
Median (weeks)	30	29
Minimum (weeks)	1	1
Maximum (weeks)	368	206
Chemical trace evidence reported before charges were laid [a]	13%	26%

Notes:

1. Timing equates to the time in weeks from the date of offence (as per Victoria Police records) to the date the first official chemical trace evidence written report was issued (according to forensic laboratory records).
2. Median values are reported instead of the mean due to the fact that the median better captures the skewed nature of the data and is less influenced by the outliers.

[a] Percentage of cases in which charges were laid (i.e. cases without charges have been excluded).

Results

Survey Part A: Case outcomes

Survey participants were asked questions about the specific case that included chemical trace evidence and for which they were the lead investigator. The survey responses regarding the progress of these cases through the criminal justice system were as follows.

- In most cases the police investigation resulted in suspects being charged (77% of all surveyed cases).
- Of the twenty-three cases in which charges were laid, all but one case proceeded to court.
- In the majority of cases some defendants pleaded guilty (65% of the cases in which suspects were charged).
- Cases in the survey sample could have multiple defendants and there were two cases (9% of the cases that proceeded to court) in which both guilty and not guilty pleas were entered.

- In five of the cases that proceeded to court (23%) defendants changed their plea at some point during the court process.
- Police investigations had been finalised in the majority of cases (90% of all surveyed cases).

Survey responses specified that three cases had not been finalised. Official Victoria Police incident records indicated that two of these cases, one a rape and the other a murder, were unsolved. Victoria Police incident records for the third case indicated that an offender had been processed, convicted of burglary and sentenced to imprisonment. The survey response that this case was not finalised may indicate that there were other outstanding suspects in this case.

The survey responses regarding the outcomes of the twenty-three cases that did proceed to court were as follows.

- The accused were acquitted in four cases (17%).
- Guilty findings were reached in eighteen cases (78%).

For the cases that proceeded to court, one investigator did not provide a response to the question regarding court outcome. It should also be noted that in addition to the twenty cases that proceeded to court for criminal charges, one case of murder-suicide was subject to a coronial inquest.

The police investigators were asked questions about whether the cases included other forensic evidence in addition to the chemical trace evidence. Survey responses indicated that, of the 30 cases in the survey sample obtained the majority (90%) included at least one other forensic discipline. The cases ranged from having no other forensic evidence in addition to chemical trace evidence, to having a maximum of seven other forensic disciplines utilised. The forensic disciplines additional to chemical trace evidence, that were most frequently included in cases in the survey sample received, were ballistics/tool marks (50%), biology (47%) and finger prints (43%).

Survey Part B(i): The purpose of using forensic services in specific criminal cases

The police investigators were asked a series of questions relating to their expectations of chemical trace evidence and other forensic services. Survey participants were specifically asked whether the request for examination related to the investigation, the process of charging suspects, for the court and for intelligence, and participants were instructed to select all that applied (i.e. allowing for multiple purposes within a case). The following responses were received.

- 57% to influence the course of the investigation
- 50% to determine whether to charge a suspect
- 97% to build the case for court
- 23% to provide intelligence (e.g. linking cases)

The mode by which the police investigators anticipated that the chemical trace evidence may impact on their case was also questioned and the following responses received.

- 37% by determining that a crime had been committed
- 50% by identifying individuals involved in a crime
- 93% by establishing a nexus between suspects and a crime

Survey Part B(ii): The impact of forensic evidence in specific criminal cases

There is potential for forensic evidence to impact on the processing of cases at different stages and in different ways. The police investigators were asked whether they believed that the chemical trace evidence had influenced various aspects of the processing of their cases (refer to Figure 5.1). The

aspects of case processing that most of the surveyed police investigators believed were influenced by chemical trace evidence were the course of the investigation (55%) and the outcome of court proceedings (64%). The lowest response was received for influencing the offence with which suspects were charged (28%).

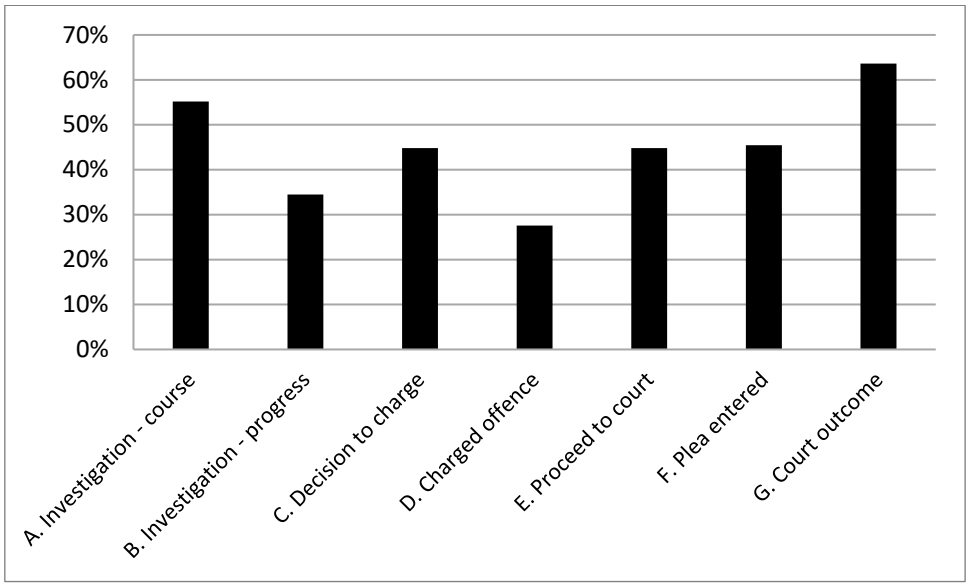

Figure 5. 1: Influence of chemical trace evidence on various aspects of case progression through the justice system.

Notes:

1. Key
   A. Course of the investigation (n = 29)
   B. The rate of progress of the investigation (n = 29)
   C. The decision to charge or not charge suspects (n = 29)
   D. The offence suspects were charged with (n = 29)
   E. Whether the case proceeded to court (n = 29)
   F. The plea entered by accused persons (n = 22, i.e. cases which did not proceed to court were excluded)
   G. The outcome of court proceedings (n = 22, i.e. cases which did not proceed to court were excluded)

The police investigators were asked to rate how important the forensic and other evidence was in determining the outcome of the case (refer Table 5.3). A five-point scale was used for rating the importance with 1 equating to “not important at all” and 5 equating to “extremely important”. Chemical trace evidence had a mean score of 4.0 (SD = 1.295, n = 29) with a range from 1 to 5. Other forensic disciplines with mean ratings above 4.0 included audio-visual, ballistics/tool marks, biology

(DNA), crime scene, fingerprints and vehicle examination. Non-forensic evidence (e.g. witness accounts, admissions by suspects, etc.) was rated with a mean value of 4.6 (SD = 0.929, n = 24). Thirteen of the surveyed police investigators provided comments in regard to what non-forensic science evidence was included in their case. The most frequent response related to witness evidence (ten of thirteen responses, 77%). Other types of evidence referred to were offender admissions, CCTV footage and an identification parade. Survey participants selected “an overall lack of evidence” as being an important factor in a minority of cases (n = 9), predominantly in cases in which no guilt was found (n = 7) where it received a high mean rating of 4.7 with a range of 3 to 5.

Table 5. 3: Police investigator ratings of how important various forms of evidence were, where applicable, in determining the outcome of specified criminal cases.

Form of evidence	n	Mean rating	Standard deviation	Minimum rating	Maximum rating
Chemical trace evidence	29	4.0	1.295	1	5
Audio-visual	5	4.2	0.837	3	5
Ballistics / tool marks	14	4.5	0.760	3	5
Biology (DNA)	15	4.5	0.915	2	5
[a] Crime Scene	14	4.3	0.994	2	5
Document examination	2	2.5	0.797	2	3
Drug analysis	3	3.7	1.155	3	5
Fire & explosion	2	4.0	1.414	3	5
Fingerprints	13	4.2	1.363	1	5
Vehicle examination	11	4.6	0.674	3	5
[b] Other forensic – Police laboratory	2	4.5	0.707	4	5
[c] Other forensic – non-police laboratory	4	4.8	0.500	4	5
Non-forensic evidence	24	4.6	0.929	1	5
An overall lack of evidence	9	4.1	1.269	2	5

Notes:

1. A five-point scale was used for rating the importance with 1 equating to “not important at all” and 5 equating to “extremely important”.

[a] Crime scene services predominantly involve the recording of crime scene details (as written notes, photographs and video) and the collection of exhibits but can also include examinations of exhibits such as shoe and tyre prints.

[b] The VPFSD provides a broad range of forensic services including the disciplines listed individually in the table. This group relates to disciplines not listed specifically.

[c] The non-police laboratory disciplines will consist predominantly of forensic medical services such as pathology, toxicology, etc.

With regard to receiving the formal written report of the chemical trace evidence in the specified case, 26 out of 29 responses (87%) deemed the results were provided within the required timeframe, with an additional 2 (7%) responding that the results were received sooner than required. Only 1 (3%) police investigator considered that the written report was received later than required. The police investigators were questioned about what factors determined whether the reporting timeframe met the case requirements and the following responses were received:

- 60% to support an on-going investigation
- 43% to assist with the decision to charge a suspect
- 13% relevance to a bail application
- 60% required for service of the brief

Twenty-four out of thirty (80%) surveyed police investigators indicated that they received some form of preliminary results for the chemical trace evidence in their case. Of the cases in which preliminary results were provided, the most common means of receiving the preliminary results was verbally (e.g. by telephone) with a frequency of 67% (14 out of 21 responses). Forty-three percent (9 out of 21 responses) received preliminary results via email and 24% (5 out of 21 responses) received preliminary results in the form of a written laboratory report. Five responses indicated that they had received preliminary results by multiple means (i.e. covering various combinations of verbally, via email and written laboratory report).

The police investigators were asked whether the value that the chemical trace evidence provided to the case was influenced by the timeliness of receiving the results. Fifty-nine percent (17 out of 29 responses) of police investigators considered the time taken to receive the results increased the usefulness of the evidence. Forty-one percent (12 out of 29 responses) considered the timing had no influence on the usefulness of the evidence. None of the surveyed police investigators considered the time taken to receive the results decreased the usefulness of the evidence in their case.

Survey Part C: General perceptions of forensic science and chemical trace evidence

The police investigators were asked to rate the usefulness in general of chemical trace evidence for assisting with key aspects of processing a case through the criminal justice system (refer Figure 5.2). Determining the course of the investigation received the highest score with a mean rating of 4.2 (SD = 0.898) and a range of 2 to 5. The usefulness of chemical trace evidence to assist with the rate of progress of the investigation (mean score 4.1, SD = 0.944), the plea entered by the accused (mean score 4.1, SD = 0.868) and the outcome of court processes (mean score 4.1, SD = 0.907) were also rated highly. The influence of chemical trace evidence to assist with determining the offence that suspects are charged with was rated lowest, scoring a mean rating of 3.4 (SD = 1.331) with a range of 1 to 5.

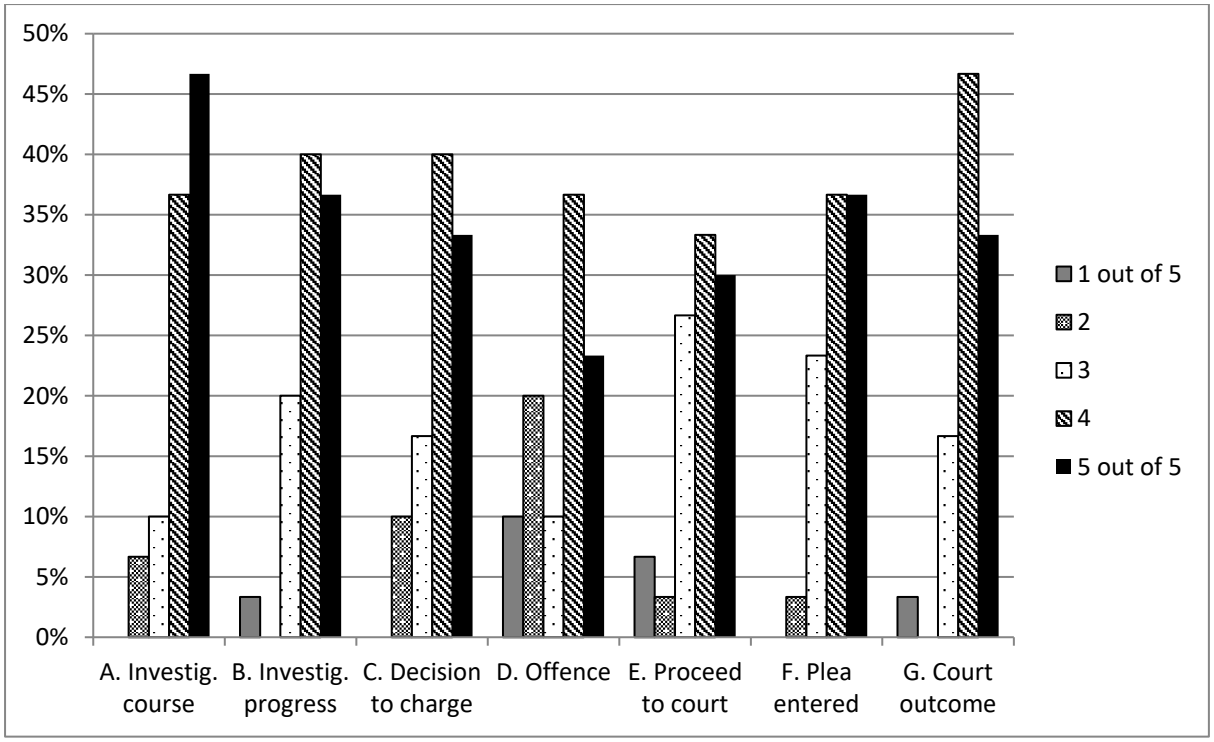

Figure 5. 2: Rating of the usefulness of chemical trace evidence for assisting with key aspects of processing cases through the criminal justice system (n = 30).

Notes:

1. A five-point scale was used for rating the importance with 1 equating to "not important at all" and 5 equating to "extremely important".
2. Key
   A. Determining the course of investigations
   B. The rate of progress of investigations
   C. The decision to charge or not charge suspects
   D. The offence suspects are charged with
   E. Whether cases proceed to court
   F. The plea entered by accused persons
   G. The outcome of court proceedings

A series of survey questions were directed at the timeliness of the provision of chemical trace evidence examination results in general and the value of preliminary reports. The majority of surveyed police investigators (18 out of 30 responses, 60%) deemed a reporting time of within 1 month to be sufficiently timely for most cases (refer Figure 5.3). The police investigators were asked to rank the following factors according to which most often determined whether the results of

examinations have been provided in a suitable time: (i) provided in time to support an on-going investigation; (ii) to assist with the decision of whether to charge a suspect; (iii) for consideration of an application for bail; or (iv) in time to serve the brief of evidence. Survey participants ranked reporting the results in time to support on-going investigations as most often being the factor that determined suitable timeliness (refer Figure 5.4). In time for serving the brief of evidence was ranked lowest.

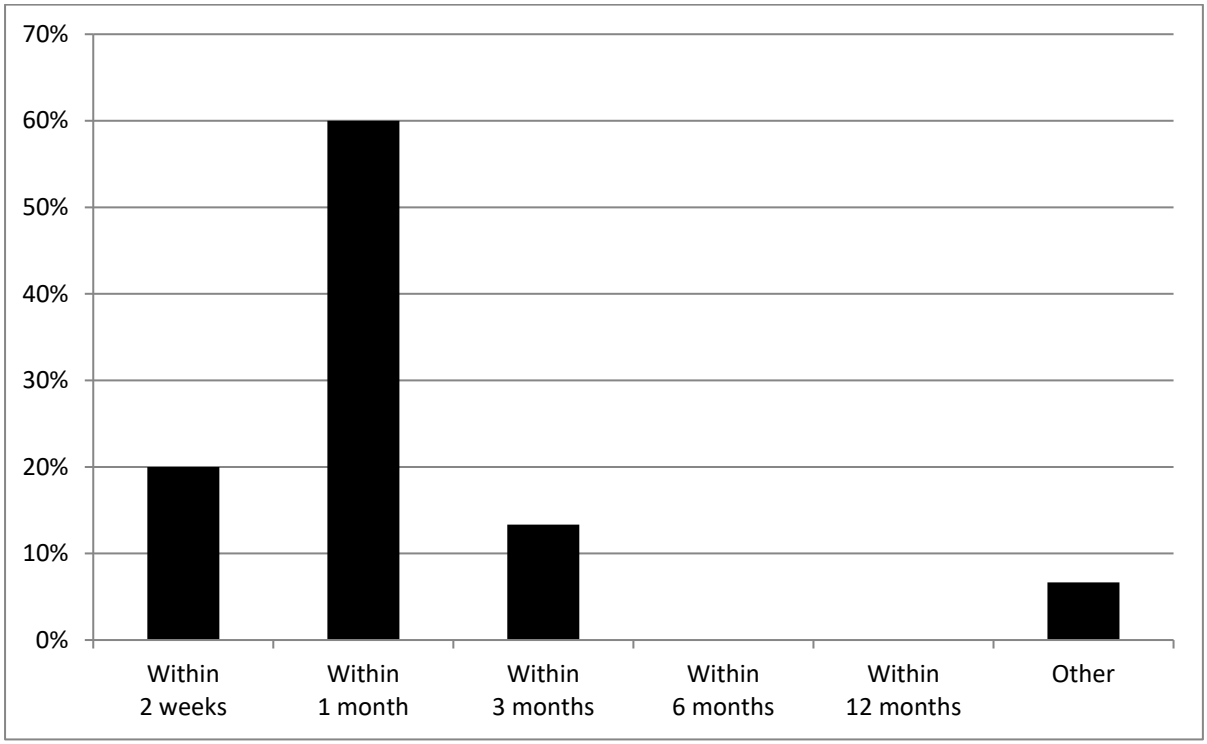

Figure 5. 3: Suitable timeframe for the provision of chemical trace evidence results (i.e. sufficiently timely for most cases).

Notes:

1. One surveyed investigator did not select one of the timeframe options provided (i.e. shown above as “Other”) and stated “preliminary results within 1 month would be suitable in most cases”.

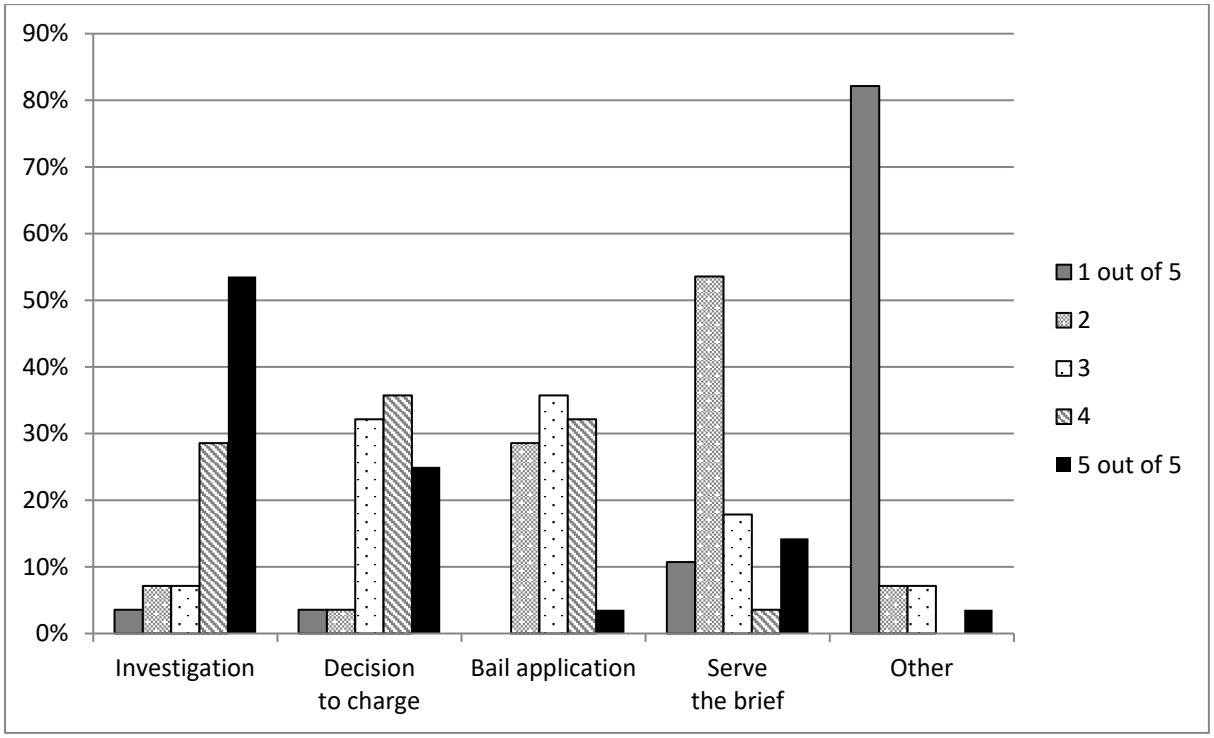

Figure 5. 4: Ranking of factors according to which most often determined whether the results of examinations have been provided in a suitable time (n = 28).

Notes:

1. Surveyed investigators were asked to rank from 5 to 1, with 5 being most often and 1 being least often.

The police investigators were asked to score the usefulness of a range of modes of communication for reporting preliminary results of chemical trace evidence examinations ahead of receiving the formal written report intended for use in court (refer Figure 5.5). A five-point scale was used for rating the importance with 1 equating to “not important at all” and 5 equating to “extremely important”. Reporting preliminary results via email scored the highest with 83% (n = 30) of investigators providing a rating of 5. The use of intelligence reports scored lowest with only 28% (n = 30) deeming this form of reporting as “extremely important”.

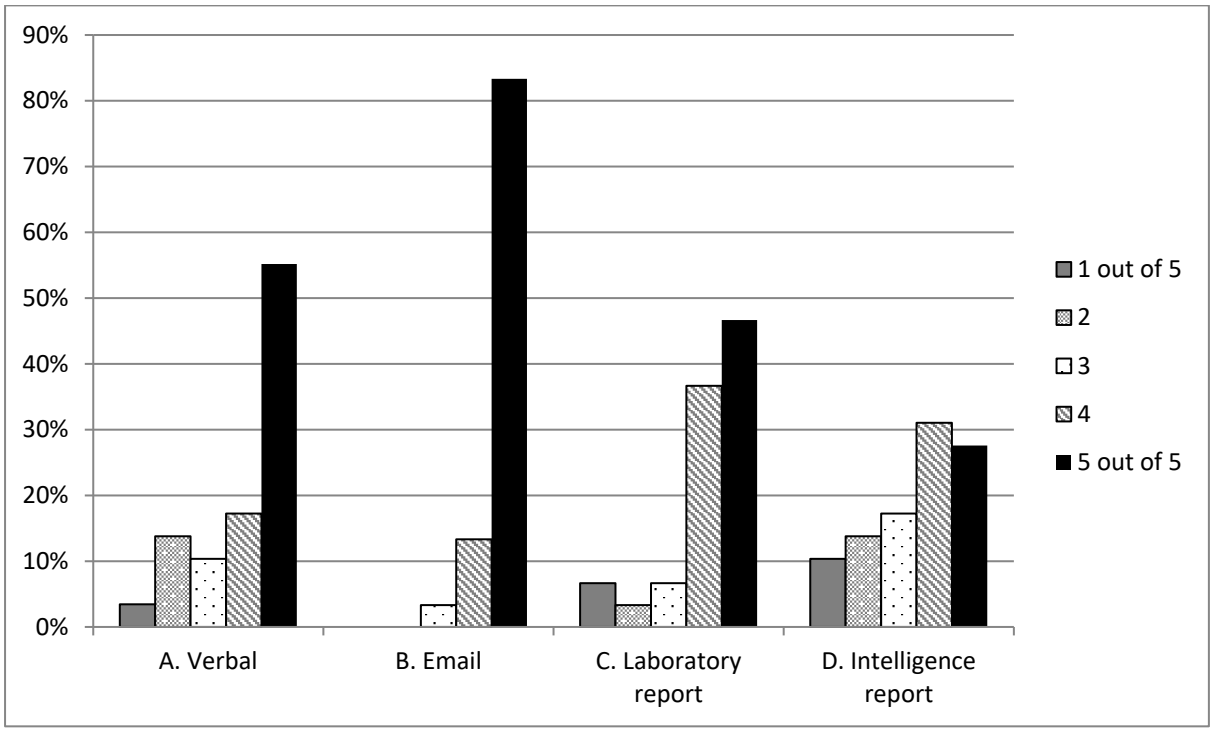

Figure 5. 5: Perceived usefulness of receiving preliminary results of chemical trace evidence examinations by mode of communication.

Notes:

1. A five-point scale was used for rating the importance with 1 equating to "not important at all" and 5 equating to "extremely important".
2. Key
   A. Verbally (e.g. via telephone) (n = 29)
   B. Via email (n = 30)
   C. In the form of a laboratory report stating "not to be used in court" (n = 30)
   D. In the form of an intelligence report stating "not to be used in court" (n = 29)

Free text responses

In addition to the information captured via specific and targeted questions, the survey participants were also provided the opportunity to make open comments on forensic science and the criminal justice system. In regard to the specific case which included chemical trace evidence and for which they were the lead investigator, the police investigators were able to make comments on whether it was useful to receive preliminary results of chemical trace evidence for their investigation and if so, how. The responses received indicated that the police investigators valued preliminary reporting and that the value provided could extend beyond the investigation component of their cases. With regard to supporting investigations, comments received stated that the preliminary results could be useful for determining whether to continue the investigation, determining the urgency of the investigation, determining what resources should be allocated and influencing the direction of the investigation. One respondent commented that "*gunshot residue* (along with DNA) *on a discarded t-shirt was a pivotal decision to charge the accused*" (survey number E05). Multiple police investigators also commented that preliminary results were useful for the preparation of the brief of evidence. Additionally, preliminary results could also be useful in relation to bail applications. One police investigator commented that preliminary gunshot residue evidence had been reported in the brief of evidence and that "*this enables the defence to be on notice as to the evidence the prosecution intend to lead at an early stage of the investigation*" (survey number F18).

Comments received indicated that preliminary reports can be useful in multiple ways. Preliminary reports can provide a useful indication to police investigators as to whether they can rely on the trace evidence to support their case. Preliminary reports can also be useful for determining whether additional samples require forensic testing. Survey responses indicated that investigators found preliminary results useful for corroborating other evidence. One of the ways that chemical trace evidence can be useful to investigators is by providing evidence as to what has happened in the incident being investigated. One investigator commented that "*gunshot residue located in the*

vehicle identified the positioning of the offender within the vehicle" and that as a consequence the "*accused/driver* (was) *identified*" (survey number F30). Another investigator commented that it was "*very useful to understand what happened during the commission of an offence and check the veracity of witness/suspects*" (survey number D22). Another means by which preliminary results were deemed to be useful was that "*it assisted with the interview preparation of the suspect*" (survey number D23).

The surveyed police investigators were also able to make comments about their investigation, the forensic evidence involved and the criminal justice outcome of the case. Once again responses were received that indicated there can be an important connection between forensic (chemical trace) evidence and other evidence in the case, such as witness reports. As an example, one response stated "*the evidence supported and corroborated a victim whose own evidence was not very credible*" (survey number C31). Another stated that "*the results of the paint samples gave a complete history of the vehicle's life confirming 100% the accuracies of the owner disproving the accused clone vehicle*" (survey number E12). General comments by one survey participant added to this point stating that forensic evidence is "*critically important these days as the weight given by the court to eye witness evidence including police evidence is a lot less*" (survey number F02). Continuing on with the connection between forensic evidence and witness evidence, one police investigator commented that defendants can sometimes counter forensic evidence by shifting their account. This police investigator referred to a case where the defendant based their defence on self-defence and they stated that "*the GSR examination may have influenced her decision to defend the case in this manner*" (survey number F18).

There were other comments in relation to forensic evidence in the investigators' cases that related to having impact on how the case proceeded, but not so much by influencing the investigation directly. An investigator commented that "*chemical trace evidence was utilised to strengthen the criminal charges*" (survey number C18) suggesting that there is scope for forensic evidence to not

only influence whether to proceed with charging suspects, but also to influence the level of seriousness of the charges. Another investigator also stated that "*forensic evidence provided further weight to the case… rather than assisting with the direction the case took*" (survey number F03).

The survey closed with the police investigators being invited to make comments about forensic science in general and how it can impact on investigations and the courts. Again, the responses indicated that police investigators believe that forensic evidence can have impact at various points as cases are processed through the criminal justice system. Comments included that "*chemical trace evidence is a vital tool to assist investigators and the direction various lines of inquiry will take*" (survey number B04). There were a number of comments on the value of chemical trace and other forensic evidence in bringing about guilty pleas, such as "*forensic evidence is often a key to an early plea of guilty*" (survey number F02). Comments about forensic evidence influencing how a case is processed were also provided including "*whether to charge someone or proceed by summons*" and "*assisting investigators with bail/remand applications*" (survey number F09). A comment that forensic evidence had "*greatly improved the chance of conviction at the County Court*" (survey number E06) is consistent with the belief that forensic evidence can influence the final court outcome.

Some responses touched on the evidence itself. One investigator stated that "*technology used by chemical trace evidence is not always understood by investigators and chemical trace evidence services are underestimated*" (survey number F02). This point is consistent with a previous study conducted in a number of Australian jurisdictions which examined how police understand forensic science and found that their knowledge and awareness of forensic science, including how it can add value to policing, could be improved (Julian 2005) and also consistent with the recent findings of Mousseau et al that police senior managers have limited knowledge of forensic science and underestimate its potential. Another response on the importance of "*early engagement and liaison between investigators and examiners to discuss uses, available evidence, available testing, potential*

results" (survey number C31) builds on the point that sound communication may influence the impact that the chemical trace evidence has in a case. Also, as per other previous comments, the value that chemical trace evidence can provide can be dependent on how it is connected with other evidence within a case; "*usefulness of results for gunshot residue also depend on the other evidence and circumstances of the case*" (survey number F18).

Discussion

There is a lack of published research on the impact of chemical trace evidence on criminal investigations and court processes. A quantitative study previously conducted by the authors (Woodman et al. 2020b) was aimed at addressing this knowledge gap. This quantitative study provided an insight into the relationship of chemical trace evidence, and a number of other disciplines of forensic evidence, with the outcomes of court processes, but produced limited information on the impact of forensic evidence on police investigations. This was in part due to a weakness in the methodology (i.e. the decision to charge suspects proved not to be a true measure of the impact of forensic evidence on the criminal investigation). But most significantly, quantitative methodology based on coarse relationships between forensic evidence and the outcome of steps within the justice process, will not reveal the nuances of how police investigators utilise forensic evidence. Therefore, a qualitative methodology was applied in this study so that more detailed and case specific information could be obtained. To build on the findings of the quantitative research, a survey of Victoria Police investigators was used to collect information regarding their use and expectations of chemical trace evidence and to capture their assessment of the impact of forensic evidence in specific cases.

The survey findings indicate that when the police investigators utilise chemical trace evidence services they do so with multiple purposes in mind. Building a case for court was an overwhelmingly

common response and as such could be considered the primary purpose of police investigators utilising chemical trace evidence forensic services. However, in just over half the cases subject to this survey, the investigators sought chemical trace evidence to also support their investigation. It has been proposed that "trace evidence tends only to be considered for high-profile cases as 'supporting evidence' and primarily for court purposes" (Roux et al. 2015). Whilst this may be true as a general trend, the survey responses indicate that the intentions of a sizeable proportion of police investigators is to utilise chemical trace evidence in a broader manner.

The results of the survey indicate that police investigators are knowledgeable in regard to the mode by which the examination of trace samples can produce valuable evidence. All but two responses indicated that the investigators anticipated that the chemical trace evidence could establish a nexus between suspects and a crime. This corresponds well with the information that can typically be provided by chemical trace evidence. The examination of materials such as paint, glass and fibres routinely involve the comparison of samples collected from a crime scene with other samples collected from items associated with a person of interest (e.g. clothing, tools, vehicles, etc.). Such comparative examinations can contribute to the establishment of a nexus between the object and a crime. Notwithstanding the current debate regarding gunshot residue (GSR) examinations (Blakey et al. 2018; McGuire 2008; Trimpe 2011), this sub-discipline can provide evidence of an association of a person with firearms, via the identification of particles sampled directly from the person (e.g. their hands), their clothing or other items (e.g. a vehicle). As such, in appropriate circumstances GSR evidence can also contribute to the establishment of a nexus between suspects and a crime. Survey respondents who anticipated that the chemical trace evidence could identify individuals involved in a crime may have based their expectation on the potential of the nexus between an object and a crime being used to achieve the indirect identification of the owner, wearer or driver of that object.

In regard to the impact of chemical trace evidence in the cases that were the subject of this survey, the multipurpose potential of chemical trace evidence was again evident. In the progression of the

surveyed cases through the criminal justice system, the outcome of court proceedings was found to be the stage most influenced by the chemical trace evidence. Additionally, in just over half the cases, the investigators considered the chemical trace evidence to have also influenced the course of their investigations. These results align: (i) the purposes of using chemical trace evidence; and (ii) the stages at which chemical trace evidence has impact, as primarily being valuable in court but also valuable in supporting police investigations. The finding of this survey that chemical trace evidence can have impact on investigations adds to previously reported research relating to DNA and fingerprints, that forensic evidence can assist investigations and lead to suspects being charged (Antrobus & Pilotto 2016; McEwen & Regoeczi 2015; Roman et al. 2009).

For the cases that were the subject of this survey, the police investigators rated chemical trace evidence highly as a form of evidence that was important in determining the outcome of those cases. However, a number of other forensic disciplines, including DNA and ballistics, were scored more highly. Notably, survey participants listed non-forensic evidence, in particular witness evidence, as being relevant in a very high proportion of cases (80%), with an average score above nearly all forensic disciplines. This response is consistent with the findings published by a group of researchers, that eye witness reports are one of the most powerful predictors of criminal case processing (Baskin & Sommers 2010; Baskin & Sommers 2011; Johnson et al. 2012; Peterson et al. 2013; Peterson et al. 2010). A theme that emerged from the comments provided by the surveyed investigators was that the impact of chemical trace evidence can occur through important connections between chemical trace evidence and other evidence in the case. This is applicable to witness evidence and can apply during the investigation phase (e.g. enabling investigators to assess the truth and accuracy of witness accounts) and in the courts (e.g. provide support to the evidence presented by a witness whose credibility is being challenged). Comment was also received on the value that chemical trace evidence can provide in corroborating other forensic evidence, which is consistent with a finding from the quantitative study which demonstrated a significant relationship between chemical trace evidence and ballistics evidence in the determination of guilt or innocence

in court trials (Woodman et al. 2020b). However, in a study of the conversion of fingerprint identifications to suspects being charged, Bond found that a combination of fingerprints with DNA which identified the same suspect, did not improve the conversion rate (Bond 2009). Fingerprints and DNA are both forensic identification disciplines and provide the same class of information (i.e. direct identification of individuals). In contrast, chemical trace evidence can provide information which aids the reconstruction of a crime and clarify how important events occurred (Roux et al. 2015), which may contribute to synergies with other evidence forms.

The ability of chemical trace evidence to contribute to the understanding of "what has happened" and the fact that chemical trace evidence can have impact when in combination with other pieces of evidence, are qualities that have important implications for sample collection at crime scenes and the process of case vetting and triage at laboratories. The perceived value of different forensic evidence types can affect how forensic science is applied in an investigation (Bitzer et al. 2016; Ludwig 2016). Evidence types may not be collected at scenes or may be overlooked during vetting and triage if there is an inadequate understanding of the value that the forensic evidence can provide (Bitzer et al. 2015; Cunningham et al. 2001). The importance of knowing how forensic evidence types can impact on investigations and court processes is highlighted in the example of major crimes when a variety of exhibits have been collected. During the submission of these multidisciplinary cases for forensic testing, the potential of each examination type is evaluated, sometimes with consideration of which discipline is likely to provide the strongest evidence. This can lead to rationalising the exhibits to be examined based on the perceived potential value of individual forensic disciplines in isolation. However the survey findings add support to the view of Robertson and Roux (2010) who have previously promoted the importance of applying a holistic approach to the management of cases, which considers the potential impact of combinations of pieces of evidence and the role that trace evidence can play in testing hypotheses about the mode of a crime.

In relation to the timing of the provision of the results of the chemical trace evidence examinations, the survey raises a number of questions. A very large majority of the surveyed investigators (94%) deemed the formal written reports were received within the required timeframe for the applicable cases. The forensic laboratory records indicate that in only 43% of the surveyed cases were the formal written reports issued within 6 months of the date of the offence. In contrast 80% of the surveyed investigators considered a reporting time of 1 month or less to be sufficiently timely for most cases, which is a timeframe considerably shorter than for most of the cases that were in this survey. However, investigators received preliminary results in a large majority of the survey cases (80%), with most being provided verbally (e.g. via telephone). It was not possible to capture details about the provision of preliminary results by verbal means or email and consequently their timing in the surveyed cases is unknown. However, free text responses indicate that the police investigators greatly value receiving preliminary results to support their investigation, not merely in relation to its direction, but also to guide what might be described as the management of the investigation with scope to influence decisions on whether the investigation is still required, the level of urgency and the appropriate resourcing. Survey responses indicated preliminary results were also used in making the decision to charge suspects and in the preparation of the brief of evidence. The combination of the high frequency of receiving preliminary results, the value assigned by the police investigators to the preliminary results and a high level of satisfaction indicated in the timeliness of receiving the evidence in their cases, is suggestive of the fact that the timing of formal written reports is not a good measure of whether forensic services are delivered within suitable timeframes. This has important implications for other case processing studies that use formal written reports as a variable in the analysis of the effectiveness of forensic services.

There are a number of limitations that need to be considered in relation to the survey. The number of cases in the sample obtained is relatively small compared to the total number of chemical trace evidence cases completed by the VPFSD in the relevant time period (i.e. 30 cases surveyed from a total of 281 cases relating to criminal investigations and for which results were officially reported).

Three rounds of surveys were distributed to police investigators in an attempt to gain a larger sample size but ultimately the sample size was dependant on the willingness of the investigators to participate. The age of the cases surveyed may have had some effect on the ability of the investigators to recall details in their cases. Some comments were made in the completed surveys which did refer to difficulty in answering some questions because the investigators had a limited memory of certain aspects of the case (e.g. whether preliminary results had been received). In contrast some very detailed free text responses were received which indicated a strong recollection of specific aspects of cases. The question arises as to whether the survey responses could be skewed as a consequence of differential memory of cases according to case outcomes. It is likely that investigators will have a better recollection of cases that were noteworthy, which from an investigators' point of view may amount to cases that were successfully investigated and prosecuted. However, it may also be that investigators might note cases in which they believe the evidence, including forensic evidence, had failed them and as a result suspects were not charged or defendants were not found guilty. The answer to this question is not known but the potential issue was anticipated, hence the adoption of a sampling strategy which was aimed at obtaining a sample pool that would be balanced in terms of: (i) whether charges were laid; (ii) whether the chemical trace evidence did or did not support the prosecution case; and (iii) the timeliness in which the chemical trace evidence results were reported. In regard to these factors it should also be noted that within the whole database (consisting of all relevant cases within the four year period) these factors were not in equal balance either (e.g. charges were laid in approximately three quarters of all cases).

A further consideration regarding potential skewing of the survey responses is how police investigators judge the importance of evidence in determining case outcomes. A higher mean rating of how important the chemical trace evidence was in determining the case outcome was obtained for cases that supported the prosecution case (mean = 4.4) than cases which did not (mean = 3.3). This may reflect a concerning bias on the part of the investigators if they are overlooking the value that can be provided by forensic evidence to clear suspects. However, there is another logical

explanation as to why chemical trace evidence that supports the prosecution case can be more valuable to investigators. Results of chemical trace evidence examinations that support the prosecution case often equate to the establishment of a nexus that can direct an investigation towards particular suspects, lead to charges being laid and support the prosecution of a defendant in court. That is, the evidence can contribute to the resolution of a crime that has occurred. In contrast, examination results that do not establish a nexus, do not necessarily support the defence case but rather may simply amount to a lack of evidence which makes no contribution to the resolution of the crime. Nevertheless, in regard to the potential for investigator bias, a survey of prosecutors may also be valuable for evaluating the impact of forensic evidence in the lead up to and the conduct of court trials. However, only surveying or interviewing police officers will probe the purpose and expectations of utilising forensic services in criminal investigations.

Conclusion

Chemical trace evidence can have an impact on cases in varied ways and at multiple stages as cases progress through the criminal justice system. Ludwig (2016) has likened the contribution that forensic science can provide to the progress of criminal cases through the justice system to a value chain, with there being potential for forensic evidence to impact at multiple points within the chain. The responses from the police investigators indicate that they value all of the varied benefits that chemical trace evidence can provide. These points are relevant to assessing the effectiveness of chemical trace evidence in supporting the achievement of fair and just outcomes. Measuring the frequency of the impact of chemical trace evidence on determining key justice outcomes (e.g. charging of suspects and court findings) does provide an assessment of some important aspects of the contribution made to supporting the criminal justice system. However, for a police investigator who is contemplating whether chemical trace evidence may be useful in their case, the important consideration may not be the likelihood of the evidence impacting on any particular point. Instead, as Bitzer found in her study of other forensic disciplines (2015; 2016), it is likely that police

investigators will want to use the chemical trace evidence to provide support in as many ways as is possible, including to both the investigation and the court process. Similarly, a comprehensive assessment of the effectiveness of chemical trace evidence would need to include all points of contribution within the value chain.

Chemical trace evidence examinations are generally labour intensive and the services are not typically provided in short time frames. Consequently, the prevailing impression within some quarters of the forensic community is that the value of chemical trace evidence is largely limited to evidential applications and to be used in court. This study has found that the police investigators use, and have expectations of, chemical trace evidence services that are not confined to the limits of evidence in court, but rather they require it to support their investigations and to guide them in making decisions about how cases progress through the criminal justice system. A factor that appears critical in this regard is the provision of preliminary results prior to the formal written reports that are issued for use in court.

Amongst forensic trace evidence practitioners, the benefits of chemical trace evidence in providing corroboration of other evidence in cases has long been appreciated. The survey findings provide support for this belief and clarify that there can be important connections between chemical trace and other forensic and non-forensic evidence, which has scope for impacting on both investigative and court processes. The ability of forensic evidence to add value via corroboration of other evidence is not confined to chemical trace evidence. However, chemical trace evidence has the potential to provide information and detail about “what has happened” and “how it happened”. When combined with the forensic identification disciplines, such as DNA and fingerprints, chemical trace evidence can become an important piece of evidence that helps complete the puzzle. The survey findings indicate that police investigators recognise and value the capacity of chemical trace evidence to provide information about “what” and “how” important events have occurred.

This survey study has been conducted in follow-up to a quantitative database study. A finding from the quantitative study was that in the majority of cases that included chemical trace evidence, charges had been laid before the chemical trace evidence results had been formally reported. Consequently, the scope for chemical trace evidence to make a valuable contribution to the investigation phase seemed to be greatly reduced. The findings of this survey indicate otherwise and produce evidence that the police use chemical trace evidence to support investigations only fractionally less often than for building a case to present in court. The survey study has also highlighted the fact that chemical trace evidence is typically just one component of many pieces of evidence that contribute to an investigation and build a case for presentation in court. This supports a finding in the quantitative study that the coarse relationship between chemical trace evidence results and court outcomes is too simplified to provide a meaningful measure of the full impact of the chemical trace evidence on cases.

In recent times doubts have been raised about the future of trace evidence. Focus on identification sciences (e.g. DNA and fingerprints), the perception that trace evidence services are demanding in terms of expertise, time and cost and the belief that the value of trace evidence is generally confined to court purposes are factors that have contributed to this uncertainty (Robertson & Roux 2010; Roux et al. 2015). However, the findings from this survey provide support for chemical trace evidence to continue to play a role in supporting the criminal justice system. The findings from this survey demonstrate that police investigators value chemical trace evidence, can be knowledgeable about this form of evidence, use it to support their investigations in multiple ways and believe that it has impact on case outcomes.

CHAPTER 6

“Burning Down the House”: The Forensic Examination of Structural Fires in Victoria, Australia

Chapter 6 Introduction

This chapter is a manuscript that has been submitted for publication and consists of two study components based on forensic fire examination.

The first component is a quantitative study of the impact of fire examination evidence on judicial outcomes. Forensic fire examination was chosen as the subject for this study as this discipline provides a different category of evidence to those included in the quantitative study of chemical trace evidence (Chapter 4). The results of the first study component contribute to the exploration of the following research questions and hypotheses:

RQ1 and H1 – the impact of forensic evidence on investigation outcomes;

RQ2 and H2 – the impact of forensic evidence on court outcomes;

RQ4 and H4 – varied impact of forensic disciplines, depending on the information that the evidence provides.

The second study component examines the variety of evidence forms relating to both scene examinations and laboratory analyses that impact on the conclusions reached by forensic fire examiners regarding the cause and origin of structural fires. The results of the second study component contribute to the exploration of the following research question:

RQ5 – how forensic evidence influences decision-making relating to criminal investigations.

Abstract

There is a body of published research that has evaluated the contribution of forensic science to the criminal justice system, but many disciplines of forensic science remain unexplored in this regard. The aim of this study was to examine the contribution that forensic fire examination services provide to criminal investigations and court processes in arson cases. Forensic fire examination services differ in a number of ways to the disciplines covered in previous research on the impact of forensic evidence on justice outcomes. Forensic fire examinations involve a combination of scene examination and laboratory analyses, and the results can provide critical evidence of whether an incident that has occurred is a criminal offence (i.e. whether a fire has occurred as the result of an act of arson). Forensic fire examination is also a discipline that has faced challenges and undergone development in recent decades regarding its scientific basis and the issue of contextual bias. In this study, data were collated for 273 structural fires that were examined by the forensic fire services in Victoria, Australia. In this jurisdiction, scene and laboratory forensic services are delivered within short time frames with a focus on providing impartial scientific and investigative services to assist criminal investigations conducted by police. The current dataset was highly skewed in terms of criminal justice outcomes and was not suitable for conducting the planned statistical analyses. Nonetheless, the pattern of findings obtained suggested that the inclusion of forensic evidence which supported the prosecution of arson, may be associated with an increased likelihood of suspects being charged and defendants found guilty. Examination of the decision-making process of the forensic fire examiners has provided insight into the variety of evidence that is considered by forensic experts in reaching the important conclusion about the cause and origin of structural fires.

Introduction

There have been multiple studies that have aimed to evaluate the contribution of forensic science to the criminal justice system (Antrobus & Pilotto 2016; Baskin & Sommers 2011; Bitzer et al. 2015; Bitzer et al. 2016; Briody 2004; Johnson et al. 2012; King et al. 2017; McEwen & Regoeczi 2015; Peterson et al. 2013; Peterson et al. 2010; Roman et al. 2009; Schroeder & White 2009). Many of these studies used quantitative methods and have produced statistical measurements of the relationships between specific forensic disciplines and certain justice outcomes. These studies have often focused on the identification disciplines of DNA and fingerprints and other less prominent specialist forensic disciplines have been overlooked (Roux et al. 2015; Williams & Weetman 2013). The findings regarding the impact of forensic evidence on criminal justice system outcomes have varied markedly. Differences in the methodology, the forensic disciplines and the crime types upon which these studies have been based are factors that are likely to have contributed to the variation in the results obtained. These findings have led some researchers to the conclusions that the contribution of forensic science to the criminal justice system is complex and difficult to evaluate (Bitzer et al. 2017; Ludwig 2016), that quantitative methods based on analyses of case level data do not provide full insight into the multiple and varied ways that forensic science is used (Williams & Weetman 2013) and that the assessment of the value provided by forensic science needs to capture its broader contribution that extends beyond its use in court (Ribaux et al. 2016).

The authors of this paper have previously examined the impact of chemical trace evidence, a discipline of forensic science, which has been subjected to little empirical evaluation, yet has come under scrutiny regarding its future viability. This research consisted of two distinct studies; one a quantitative database study (Woodman et al. 2020b) and the second a survey of police investigators who had utilised chemical trace evidence (Woodman et al. 2020a). Although results were obtained that provide support for the contention that chemical trace and other forensic evidence does have impact on court outcomes, it was also found that the value provided by chemical trace evidence is

multifaceted, can often involve connections with other evidence and is challenging to measure. Surveying police investigators brought to light that chemical trace evidence can have an impact on both the investigation and court phases of cases in ways that could not be measured by quantifying justice outcomes (i.e. decision to charge suspect, court findings). It has been previously reported that quantitative methodology that analyses data to identify the relationships between forensic evidence and the outcomes of judicial steps, cannot fully reveal the multiple dimensions of utility of forensic science (Bitzer et al. 2017) and how it is used in varied ways to support investigations (Williams & Weetman 2013).

Although there have been a number of studies that have examined the impact of forensic evidence, it is important that the contribution of a broader range of disciplines of forensic science is explored. There are some points of difference between forensic disciplines that have the potential to influence how the evidence is used and how the evidence can have impact. These points of difference include: (i) whether the services are crime scene or laboratory based; (ii) the degree to which the evidence produced is based on subjective assessment or the results of analytical testing; and (iii) the type of information that the evidence provides. Forensic disciplines such as DNA and fingerprints provide evidence that can support the identification of individuals and assist with determining whether or not an individual was physically present at a crime scene. Other disciplines such as chemical trace evidence and ballistics can establish a nexus between items and a crime, which can subsequently be used to establish or refute an indirect link between an individual and a crime. The evidence produced by some other disciplines, such as the identification of illicit drugs and the measurement of alcohol in blood samples taken from automobile drivers, can establish whether or not a criminal offence has occurred. It is logical to expect that such points of difference between disciplines will lead to variation in how the evidence is used in investigations and by the courts.

The impact of forensic evidence on judicial outcomes may also vary due to differences in the perceived value and reliability of forensic disciplines. In a study based on surveys of undergraduates

and people who had previously completed jury duty, Lieberman et al (2008) found that for both survey groups, there was variability in the perceived accuracy of DNA, fingerprint, and hair and fibre evidence. Results were also obtained in these surveys that indicated that the participants considered DNA evidence to be more persuasive than hair and fibre evidence. Koehler (2016) conducted a study in which a group of jury-eligible people were required to estimate the chance of a false positive error occurring in five different forensic disciplines. Although all estimates were low, the estimations varied between disciplines, with DNA estimated to have the lowest error rate and handwriting analysis the highest.

Arson investigation and forensic fire scene examination

Fire investigation has come under scrutiny in the United States during the preceding decades, which has led to changes in what is expected of this discipline, particularly in regard to the scientific basis for the examination of fire scenes and the qualifications of the forensic practitioners who investigate fires. Historically fire investigators were not necessarily scientifically trained or qualified but rather they developed their knowledge in fire investigation as understudies to experienced fire investigators (Dioso-Villa 2013). Prior to 1992 when the National Fire Protection Association (NFPA) developed the first edition of the NFPA 921, "Guide for Fire and Explosion Investigations", there were no published documents that set out appropriate standards for fire investigation. Through the 1990s and beyond, there were significant court rulings that scientific testimony needed to be based on sound foundations and supported by factors such as peer review, error rates and acceptability in the relevant scientific community (*Daubert v. Merrell Dow Pharmaceuticals Inc.* 1993). Fire investigation was also one of a number of forensic disciplines that was criticised in the National Academy of Sciences report, “Strengthening Forensic Science in the United States: A Path Forward” (National Research Council 2009) for lacking scientific foundations. Fire investigation has subsequently been a part of the “paradigm shift in professional knowledge in the forensic sciences from experience-based to scientifically informed expertise” (Dioso-Villa 2013). The commitment

within this discipline to conducting scientific scene examinations has resulted in improvement in the reliability of fire cause and origin determinations (Lentini 2008). There are now manuals and guidelines produced by various leading forensic technical groups for the investigation of fire scenes (ENSFI-BPM-FEI-01 2017), and as detailed in “Kirk’s Fire Investigation” (refer 1.7.8 “Authoritative Scientific Testing”), multiple standards are published for the range of scientific tests that are applicable to fire investigation, such as the analysis of fire debris samples (*Kirk's fire investigation* 2018).

In some countries and jurisdictions fire investigators can be responsible for both the examination of fire scenes and the criminal arson investigation. Concerns have been raised about the impact of contextual bias on the conclusions reached by fire investigators operating under this model (Almirall et al. 2017; Dehghani-Tafti & Bieber 2016; Dioso-Villa 2013). In Victoria, Australia, the conduct of fire scene examinations and related laboratory-based analyses of samples, are separated from the criminal investigation of potential cases of arson. The Victoria Police Forensic Services Department (VPFSD) employ a team of forensic practitioners, who are not police officers but rather scientists with a degree majoring in chemistry (hereafter referred to as forensic fire examiners). The forensic fire examiners are trained in the science and dynamics of fires, the examination of fire scenes, the collection and analysis of samples from fire scenes and the presentation of evidence relating to fires. Fire scene and laboratory examinations are conducted by the forensic fire examiners. Criminal investigations of arson are however conducted by officers of the Victoria Police, who typically are trained detectives but do not necessarily have specialised training in the investigation of arson.

In the state where this study has been conducted, a vetting process is applied before cases are referred to the forensic laboratory for examination. The fire services that attend premises to control and extinguish structural fires make a determination as to whether the cause of the fire is accidental or otherwise. The fire services have personnel trained in the examination of fire scenes (although to a lower level than the forensic fire examiners) who participate in the initial assessment of the cause

of the fires and the determination of fires that are deemed to be suspicious. Fires that are deemed to be not clearly accidental are referred to the police Arson and Explosion Squad, who also scrutinise details of the incident before initiating a request to the forensic laboratory for the fire scene examination. Police services take control of the scenes of fires that are deemed not clearly accidental and an appropriate policing unit is allocated responsibility for investigating the potential criminal aspect of the incident.

Arson crime in Victoria, Australia

Arson has long been considered a crime that is difficult to investigate and prosecute. A National Institute of Justice study in 1984 found that suspects were identified in less than one third of arson cases and that only 4% resulted in the conviction of an offender (Weisberg et al. 1984). Statistics from the FBI in 1985 cited only 19% of reported arson were cleared by arrest ((Federal Emergency Management Agency 1988). Clearance of arson crime in New South Wales, Australia, when assessed as either suspects charged or criminal proceedings commenced, has also been reported as having the lowest clearance rates of all criminal offence categories in that jurisdiction, prompting Anderson to state that identifying and successfully prosecuting arsonists is largely elusive (Anderson 2016).

In Victoria, arson is an indictable offence, triable before a judge and jury in the County or Supreme Court. There is however provision for arson cases to be tried summarily in the Magistrate's Court under certain conditions, including that the cost of the damaged or destroyed property does not exceed $100,000 (*Criminal Procedure Act 2009* 2019; Australasian Legal Information Institute 2019). Crime statistics for Victoria police quoted that there were 4480 recorded arson offences between October 2015 to September 2016 (Crime Statistics Agency 2016). Of these recorded offences, 19% resulted in an arrest and 11% resulted in a summons being issued. However, 63% remained unsolved (as at 18 October 2016). Statistics from the Sentencing Advisory Council reported that only 28 people were sentenced for arson in the County or Supreme Courts of Victoria in the calendar year of 2015-2016 (Sentencing Advisory Council 2017). Although the time periods for the reported data

from these two sources do not fully align, these statistics do provide an approximation that less than 1% of recorded arson incidents in Victoria during the period between 2015 to 2016 resulted in a person being convicted and sentenced in the County or Supreme Courts. However, some arson cases with property damage not valued in excess of $100,000, will not be accounted for in these statistics.

Under the criminal laws of Victoria, Australia, to intentionally and without lawful excuse destroy another person's property by fire, is to commit the crime of arson. Arson is a form of "criminal damage" and is categorised as a "property and deception offence" for crime statistics in this jurisdiction (Crime Statistics Agency 2015). There are four elements of arson that must be proved beyond reasonable doubt for a court to reach a guilty finding (Judicial College of Victoria 2019).

1. That the accused damaged or destroyed property by fire.
2. That the property belonged to another.
3. That the accused purposely damaged or destroyed the property by fire, or knew or believed that damage or destruction by fire was the likely result of his/her actions.
4. That the accused had no lawful excuse for damaging or destroying the property.

The examination of fire scenes and the analysis of samples by forensic fire examiners can produce evidence that either supports or refutes the prosecution of an arson offence. When forensic fire examiners report that their examinations provide support for the possibility that the fire may have been deliberately lit, this provides some support for a component of element 3 (purposely damaged or destroyed). Other aspects of the evidence reported by forensic fire examiners may also support or refute competing hypotheses on the intention of the accused to damage or destroy (e.g. presence or absence of multiple seats of fire, use of fuel, use of an incendiary device). The forensic report will describe and provide details of the damage to the premises caused by fire and this information will be relevant to element 1 (damage or destruction of property). However, the forensic report will not address element 2 (that the property belonged to another) or element 4 (the accused had no lawful excuse for damaging or destroying the property). Alternatively, forensic fire examiners may

determine that the evidence provides support to the hypothesis that the fire was accidental, not deliberately lit, or that no determination can be made regarding the potential cause due to either a lack of evidence or the presence of unresolvable or ambiguous evidence.

The present study

This research explores the value that forensic fire services can provide to the investigation and court phases of arson cases. The forensic laboratory that is the subject of this study employs a model for the provision of fire investigation services in which both scene and laboratory examinations are delivered as an integrated service by scientifically qualified practitioners. Forensic fire investigation has been chosen as the subject of this study as the contribution of this discipline to the criminal justice system has not been well researched. A prime function of forensic fire examination is to produce evidence that assists with the determination of whether a fire is a criminal incident (i.e. arson), which contrasts with many other disciplines of forensic science. Additionally, this forensic discipline is associated with a crime type that is challenging to prosecute and is associated with low clearance rates.

Insider research

The lead author of this study was previously employed as the manager of the fire examination unit at the VPFSD, including during the period of data collection for this research. Although not a qualified fire examiner, the lead author has performed a supporting role in forensic fire examination teams over many years and is experienced in the standard operating procedures for the examination of fire scenes in this jurisdiction. Some aspects presented in this study are based on this author's knowledge of the working practices followed by the VPFSD forensic fire examiners. Unless otherwise explicitly flagged as being quantitatively derived data from the cases included in this study or knowledge obtained directly from forensic fire examiners who worked on the cases comprising this

study, information provided on procedures and process is based on the lead author's working knowledge of practices and procedures.

Method

The case data set

Data were collected for cases that were based on the investigation of structural fires as potential acts of arson. The criminal investigations were conducted by the Victoria Police and in each case the scene of the fire had been examined by forensic fire examiners from the Victoria Police Forensic Services Department (VPFSD). Laboratory examinations of samples that were collected from the fire scenes (in some of the cases) were also conducted by the forensic fire examiners. Approval was obtained from the Tasmanian Social Sciences Human Research Ethics Committee (reference H0010713) and the Victoria Police Human Research Ethics Committee (reference VPHREC 98/10) to access Victoria Police and forensic laboratory records and to collate information relating to criminal investigations and forensic examinations. As an employee at the VPFSD the lead author was able to access data that was essential for the research while complying with conditions set by Victoria Police and the Tasmanian Social Sciences Human Research Ethics Committee to manage any conflict of interest and ethical concerns. Case identifying information was included with the data initially collated, however this information was removed once data collection was completed and case identifying information was not present in the final database that was subjected to statistical analyses.

A four-year sample period from July 2006 to June 2010 was chosen, which at the time that data collection commenced equated to cases that had been lodged at the forensic laboratory between 2 and 6 years ago. Reports for 1,950 fire and explosion cases were on file for the selected period. A list of all cases was prepared and then sorted into a random order prior to selection. However, to be included in this study the cases needed to meet the following criteria:

(v) the cases related to the investigation of structural fires (residential or commercial) as potential arson incidents;

(vi) the scene of the fire had been examined by forensic fire examiners from the Victoria Police Forensic Services Department (VPFSD);

(vii) the cases may or may not include laboratory analyses of samples collected from the fire scenes, which were conducted by the forensic fire examiners at the VPFSD;

(viii) official written reports pertaining to the fire scene examination, and the results of laboratory analyses where applicable, had been issued for the case;

(ix) the police record of the corresponding incident could be identified and accessed; and

(x) the cases had reached a point of finality such that the case outcomes had been documented in the police incident record.

The aim was to develop a database of cases that were consistent in the type of fire investigated (i.e. structural fires, the most common case type examined by the forensic fire investigation unit) so that analyses of the data would provide valid indications of trends and significant variables within the cases. Cases that did not meet the specified criteria and which were excluded from the database fitted into the following categories:

- Investigations of explosion scenes;
- Laboratory examinations of explosives or explosive devices;
- Laboratory examinations of items that were not connected with a fire scene examination that had been conducted by a forensic fire investigator from the VPFSD;
- Bush and grass fire scene investigation;
- Vehicle fire examinations; and
- Fatal fire scene investigations.

Data collection was completed for 409 cases. Fifty-two cases were excluded because the judicial outcome of the cases could not be determined (i.e. a file in the Victoria Police incident database that

corresponded to the fire scene investigation could not be located or the incident file was incomplete). A further 84 cases were excluded because they did not meet the established criteria (i.e. they did not relate to the investigation of a structural fire). The excluded cases consisted of the following.

- 71 vehicle fire cases.
- 5 bush or grass fire cases.
- 8 miscellaneous non-structural fire cases (2 caravan fires, 2 boat fires, a garden hedge fire, a fire relating to a ticket vending machine and a non-building fire type unspecified).

The final data set consisted of 273 valid cases which involved attendance at a structural fire scene by forensic fire examiners for the purpose of conducting examinations for the cause and origin of the fire.

Data collection procedures

A database of structural fire cases was developed that brought together data relating to forensic fire examinations with the criminal justice outcomes of each case. Some data relating to the forensic examinations (e.g. date of scene examination, date forensic report was issued) was obtained from forensic case records (both hard copies and computer files) and the forensic laboratory's computer-based case management program. The forensic case records included case identifying information which consisted of the address of the premises, the names of persons involved (e.g. victims, suspects, etc.), the date of the incident, details of the police investigator (i.e. name and registered number) and details of the policing unit (i.e. station or squad name). Some forensic case records also included unique codes used by Victoria Police to identify incidents that had been investigated and persons of interest in criminal investigations. The case identifying information (and the unique codes when available) were used in searches of the Victoria Police incident database to locate the corresponding incident record. Once construction of the database was completed, all identifying

information that had been collected by the lead author was removed. The de-identified database was used for analysis and was reviewed by the other members of the research team.

Details of the results of the forensic examinations in each case were obtained with the assistance of the actual forensic fire examiners who performed the examinations. The forensic fire examinations in the data set, both scene and laboratory based, were performed by four forensic fire examiners. The lead author of this article met with each forensic fire examiner and provided them with a list of their cases from the dataset as a spreadsheet file. The forensic fire examiners were instructed to review their reports, and case notes when required, for each case and to then enter the following summary details in the spreadsheet: (i) whether the case included samples collected from the fire scene to be analysed at the laboratory for ignitable liquid residues (ILR); (ii) the pieces of evidence in the case that were considered in reaching their conclusion; and (iii) the conclusion they reached in regard to whether the fire may have been deliberately lit.

For capturing the pieces of evidence that had been considered in each case, the forensic fire examiners were provided with a list of applicable evidence categories. The list of evidence categories had been developed in consultation with the forensic fire examiners and it consisted of forms of evidence routinely considered in the examination of structural fire scenes. The categories included evidence that can indicate that a fire may have been deliberately lit and evidence that can indicate that a fire may have been accidental. The list of evidence categories was not intended to be exhaustive of all possible evidence forms that can be present in structural fires, but rather was formulated with the aim of covering the more frequently encountered evidence forms and enabling the exploration of the variety of evidence involved in the decision making by the forensic fire examiners. The forensic fire examiners could also provide free text responses to describe any factors outside of the listed options and they could make any other remarks regarding notable aspects of each case.

It is important to note that the forensic fire examiners do not make any finding regarding arson in the official reports issued by the laboratory. Further, the forensic fire examiners do not reach conclusive findings of whether a fire was deliberately lit, but rather they report the relevant evidence that has been identified and provide a balance of the weight supporting or not supporting various possible ignition sources. However, for the purpose of this research, it was desirable to categorise each case according to whether the forensic evidence did, or did not, support the prosecution of arson. Consequently, in regard to their overall conclusion, the forensic fire examiners were instructed to select from the following three categories: (i) the results ***provided support*** for the possibility that the fire may have been deliberately lit; (ii) the results ***did not provide support*** for the possibility that the fire had been deliberately lit; and (iii) the results were ***inconclusive***.

The criminal justice outcomes for each case were obtained from records in the Victoria Police incident database. In the incident records, standardised terms are used to indicate the outcome of the investigation (e.g. “unsolved”, “offender processed”) and in cases in which a suspect was charged, the outcome of the court process (e.g. “imprisonment”, “quashed, acquitted”, “not authorised, insufficient evidence”). The case information that was obtained from the forensic case records was crossed checked with the police incident database records to ensure correct alignment of the data from the two sources. Once alignment of the forensic case and the police criminal investigation was confirmed, data were collected from the police incident database including the outcome of the police investigation and the outcome of associated court proceedings (when applicable).

Results

The forensic examinations

The dataset analysed in this study consisted of 273 cases of structural fires that were examined by forensic fire examiners for the purpose of determining the cause and origin of the fires. In 95 of these case (35%) samples were collected for laboratory analyses.

The VPFSD provide a highly responsive fire scene examination service with forensic practitioners rostered for out of business hours scene attendance. In 94.1% of the cases, the fire scene examinations were conducted by forensic fire examiners on either the day recorded in police records as the date of the offence (i.e. the day the fire occurred) or the day after.

Flammable[1] liquids, such as automobile fuel, kerosene and household solvents, can be used in arson incidents to initiate and accelerate the fire. During the course of scene examinations, samples may or may not be collected for laboratory analysis for the presence of ignitable liquid residues (i.e. residues of accelerant). Samples were collected for laboratory analyses in 95 cases (34.8% of the total dataset). For the remaining 178 cases (65.2%) the findings reported are based solely on the examination of the fire scene.

Following the examination of a fire scene, the forensic fire examiners will perform the laboratory analysis of samples collected from the scene, potentially follow up on observations made during the scene examination, complete case notes and prepare an official report that is issued for use in court. The number of days from when the offence was recorded to when an official report was issued ranged from 3 to 423 days, with a median value of 25 days. The timeliness of issuing the official

[1] The term flammable liquid is used as per Australian convention and in accordance with the GHS (*Globally Harmonized System of Classification and Labelling of Chemicals (GHS).* 2011).

reports of the forensic fire examinations is presented in Figure 6.1. The forensic fire investigation results were reported within 30 days in 56.0% of the cases.

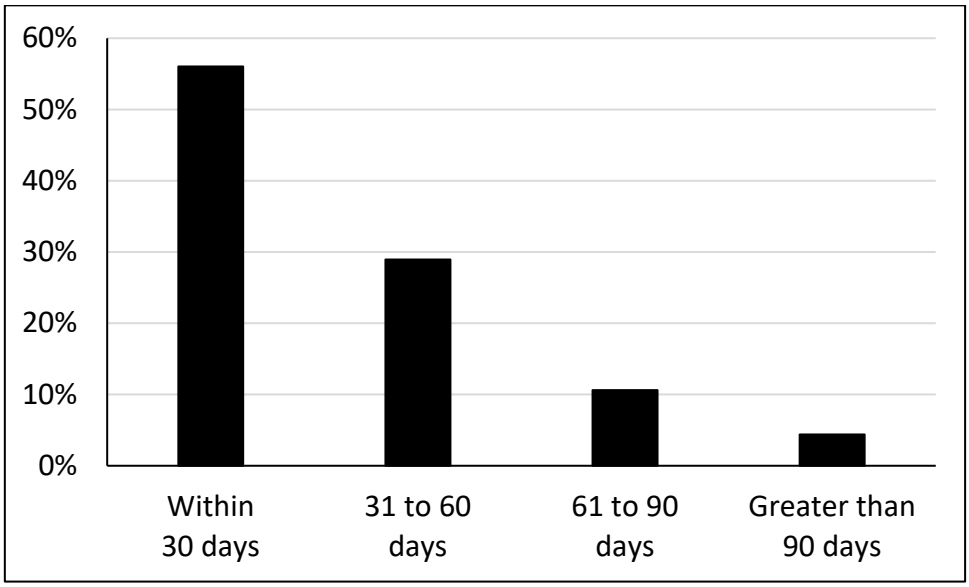

Figure 6. 1: Time after the date of offence for the forensic report to be issued (n=273).

Official reports for the forensic fire examination results were issued before charges were laid in 49.2% of the cases in which charges were laid. However, it is routine for the forensic fire examiners to brief the police investigator after completing their examination of the scene. These briefings will often occur at the fire scene and the police investigator will typically be informed of the findings of the scene examination, including whether a conclusion has been reached as to whether the fire may have been deliberately lit, although the forensic fire examiner may qualify their conclusion at this point (e.g. it may be subject to the results of laboratory testing that is still to be conducted). In the briefings, based on the findings of the scene examination, the fire examiners will also communicate how the fire occurred (i.e. potential modus operandi) and provide other information that may

provide investigative leads for police, such as details of items that may have been used (e.g. fuel container located in the scene, remnants of an incendiary device, etc.)[2].

Additionally, for cases that include laboratory analyses, the forensic fire investigators will in exceptional cases contact the police investigator and inform them of the results of the laboratory testing prior to issuing the official written report intended for use in court.

The VPFSD provides a broad range of forensic services. Case records in the laboratory case management system were accessed to obtain details of forensic reports for disciplines other than forensic fire examination that were also issued for the cases in the dataset. Five cases (1.8%) included official reports from other forensic disciplines conducted at the VPFSD. The forensic disciplines in these cases were as follows.

- Ballistics/tool marks – 3 cases
- Biology (DNA) – 2 cases
- Chemical trace evidence – 1 case
- Crime Scene – 1 case
- Drug analysis – 1 case

One case, in which the heard charge was “accessory after the fact to murder”, included reports for multiple forensic disciplines (three reports for biology, a report for ballistics/tool marks examinations, a report for chemical trace evidence and a crime scene report). This appears to be a major crime case that has received multi-disciplinary forensic support.

In this study it was not possible to capture whether the results of fingerprint examinations were reported in these cases. Although fingerprint services are provided by VPFSD, the records of

[2] These and proceeding descriptions of procedure and practice, unless otherwise attributed, are based on the previously mentioned lead author’s working knowledge and previous experience as manager of the fire investigations unit.

fingerprint examinations are maintained on a separate system. On some occasions the forensic fire examiners will collect items from the fire scenes, such as fuel containers, for fingerprint examinations. Additionally, forensic medical examinations such as pathology and toxicology, which are conducted by another forensic laboratory, have not been covered in this study. However, as fires which include fatalities have been excluded from the dataset, forensic medical examinations are unlikely to be applied in the structural fire cases comprising this dataset.

The criminal investigation and justice outcomes

The investigating police

The criminal investigations of structural fires were conducted by local crime investigation units in a clear majority of cases in the dataset (88%). Local crime investigation units are responsible for the investigation of a range of serious crime types in local regions and the detectives in these units are not specifically trained for arson investigation. The policing units responsible for the investigations in the remaining cases were: 6% uniform policing (responsible for localised lower level crime); 3% crime department squads (specialised according to offence type and staffed by detectives); and 3% by miscellaneous policing units with specialised functions but not specifically staffed by detectives.

The Arson and Explosives Squad in the Victoria Police is a group from the crime department that is specialised in the investigation of arson and explosion crimes, and this squad targets organised, serial and recidivist offenders. Although the Arson and Explosives Squad was only responsible for the investigations in 2.6% of the cases in the dataset, the squad does provide support to the detectives from local crime investigation units. The level of support is case dependant and can include attendance of squad detectives at the scene, guidance for the investigation process and assistance with interviewing witnesses and persons of interest. The Arson and Explosives Squad monitors all fires in the state of Victoria that have been reported by the fire services as suspicious and performs a

vetting function in the referral of cases to the forensic laboratory. Intelligence services relating to arson are also provided by the Arson and Explosives Squad.

Criminal justice outcomes

All 273 cases in the dataset relate to suspicious fires which were investigated by Victoria Police as potential cases of arson. However, when fires are cleared of the suspicion of arson via the forensic scene examination, the investigation may be discontinued. The investigations progressed to the stage where charges were laid in 59 cases (21.6% of all cases). The status of 138 cases (50.5% of all cases) were recorded as unsolved in the Victoria Police incident database. The status of the cases in the remaining portion of the dataset were varied but included 22 cases (8.1% of all cases) that were categorised as not authorised to proceed to prosecution.

The median value for the time from the recorded date of offence to the date charges were laid was 14 days. Of the cases which included charges, 66.1% were charged within 30 days and 86.4% within a year. In 8 cases it was more than 1 year after the date of offence that charges were laid, with the longest period being 1,111 days. Three of these 8 cases ended with findings of guilt, 2 of which resulted in imprisonment and 1 was discharged (i.e. a conviction was recorded but no other penalty was applied (Victoria Legal Aid 2013)).

Of the 59 cases in the dataset in which charges were laid, the heard charge (i.e. the actual offence that the accused was charged with) in 54 cases (91.5%) was a form of property damage by fire (arson). In two cases the heard charge related to crimes against the person. The heard charge in one of these cases was “accessory after the fact to murder” and in this case the structural fire may have been a secondary component of the murder (i.e. an attempt to destroy evidence). In the other case of a crime against the person the charge was “reckless conduct endangering serious injury”. The heard charge in one case was “attempt to commit an indictable offence” and the offences for two other cases could not be determined.

The judicial outcomes of cases in which charges were laid are presented in Table 6.1. Guilty findings were handed down in 45 cases which equates to 16.5% of all cases in the dataset (n= 273) and 76.3% of the cases in which charges were laid (n=59). A variety of sentences were applied in the cases where defendants were found guilty, ranging from no conviction recorded through to imprisonment.

Table 6. 1: Judicial outcome of cases with charges laid.

Outcome of charged cases	**Frequency**	**Percent (n=59)**
Charged but not presented	12	20.3%
Heard & acquitted	2	3.4%
Guilty but no conviction recorded	4	6.8%
Guilty, conviction recorded but no other penalty	3	5.1%
Guilty, Community based orders / justice plans / probation	8	13.6%
Guilty, Suspended sentence	5	8.5%
Guilty, Imprisonment	25	42.4%

The forensic evidence

The results of the forensic fire examinations

The results presented in the official fire examination reports, in terms of whether or not the results of the examination provided support to the possibility that the fire may have been deliberately lit, are presented in Table 6.2. As stated previously, the official reports do not include any form of conclusive statement to the effect of “the fire was deliberately lit”. Also importantly, official reports that indicate that the results of the examination provide support to the possibility that the fire may have been deliberately lit is not stating that the crime of arson has been committed, given there are

four elements of arson, as discussed in the introduction, which need to be proved. It is however likely that such reports will provide support to the prosecution of an arson case.

Table 6. 2: Reported findings of the forensic fire examiner in regard to whether the results of the examination provided support to the possibility that the fire may have been deliberately lit.

	All cases (n=273)		Charged only cases (n=59)	
Conclusion	Frequency	Percent	Frequency	Percent
Support for deliberately lit	235	86.1%	55	93.2%
Inconclusive	23	8.4%	3	5.1%
No support for deliberately lit	15	5.5%	1	1.7%

Fire scene interpretation

There are multiple forms of evidence that can be present at fire scenes that the forensic fire examiners consider in forming their conclusion as to the cause and origin of the fire. Additionally, the results of laboratory analyses of samples that have been collected from the fire scene (i.e. for the presence of ignitable liquid residues) will also be considered. The examination of structural fires requires knowledge of the dynamics of fires and how they can develop and spread (*Fire Investigation* 2004; *Kirk's fire investigation* 2018). The interpretation of burn and smoke patterns is routinely considered in reaching conclusions on the point of origin of fires and the cause of ignition. Although there are forms of physical evidence commonly found in structural fire scenes that can often be indicative of certain prior events (e.g. burn trail patterns on flooring where flammable liquid has been dispersed), the chemical and physical processes in a fire are complex and there can be alternative explanations (Almirall et al. 2017). Figure 6.2 presents the forms of evidence that

typically provide support for the contention that a fire may have been deliberately lit and the frequency that the forensic fire examiners found these factors present in the cases in the dataset.

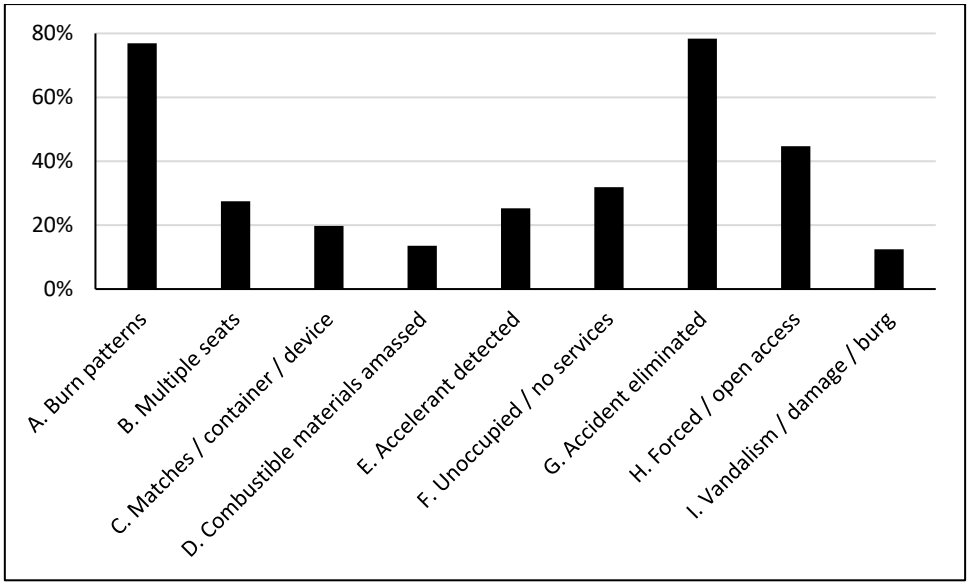

Figure 6. 2: Frequency that forensic fire examiners noted forms of evidence which typically contribute to reaching a finding of "deliberately lit" (All cases, n=273).

Key

A. Burn patterns
B. Multiple seats of fire
C. Matches / fuel container / incendiary device
D. Combustible materials amassed
E. Accelerant detected
F. Unoccupied / no services connected (i.e. electricity or gas)
G. Accident eliminated
H. Forced entry or open access to the premises
I. Vandalism / damage / burglary

Physical evidence

Physical evidence that can be present at fire scenes which may build support for the possibility that the fire may have been deliberately lit (*Kirk's fire investigation* 2018), include the following[3].

[3] Simplified explanations of the forms of physical evidence are presented with the intention of providing only a basic understanding, as the focus of this study is on the variety and frequency of the evidence forms considered in fire scene examinations, not their scientific basis or technical merit. Each evidence form is case specific and can be subject to alternative interpretation by the fire examiner.

Burn patterns

Burn characteristics, such as V patterns and variable depth of charring, can provide an indication of the point of origin of the fire and how the fire progressed. Interpretation of trailers (i.e. burn patterns on flooring that highlight trails where accelerant has been dispersed) can reveal how flammable liquid was decanted through premises to spread the fire. When the point of origin of the fire is located within a structure where there is an absence of potential accidental ignition sources (e.g. electrical appliances, sources of naked flame, etc.), this may support the possibility of the fire having been deliberately lit.

Multiple seats of fire

Identification of multiple seats of fire (i.e. points where fires started) can indicate that fires had started in multiple and separate locations, and can therefore be indicative of deliberate ignition.

Matches / fuel containers / incendiary devices

Remnants of items may be detected that may have been used to ignite/initiate a fire (e.g. matches, lighters, components of incendiary devices) or to spread/accelerate a fire (e.g. fuel containers).

Combustible materials amassed

A collection of materials may be found at a fire scene that had been used to fuel the initial fire (e.g. amassed combustible materials such as papers or highly flammable fabrics).

Burn patterns (i.e. V patterns, depth of charring, trailers) was the form of physical evidence most frequently cited by the forensic fire examiners as a factor considered in reaching their conclusion (cited in in 77% of the cases).

Evidence of the use of flammable liquid

The forensic fire examiners cited the identification of accelerant as a factor considered in reaching their conclusion in 32% of the cases. The possibility that accelerant (flammable liquids) has been used in creating a fire can be indicated during the scene examination via the detection of ignitable liquid residues either by using portable instruments which can detect volatile vapours, or by smell. Confirmation of the presence of ignitable liquid residues is achieved through laboratory analysis of samples collected at the scene, which is usually conducted in the days immediately following the scene examination.

Task relevant contextual information

The forensic fire examiners cited unoccupied premises and/or no utility services connected to the premises as a factor considered in reaching their conclusion in 32% of the cases. On some occasions there can be circumstances relating to the premises that the forensic fire examiners take into consideration. If the premises have been unoccupied and were not connected to utility services such as electricity or gas, the possibility of fire starting accidentally via occupant activities (e.g. while cooking on a gas stove, an electrical appliance such as an iron inadvertently left connected to the power supply, etc.) or as a result of an electrical fault (e.g. poorly maintained electrical wiring, faulty electrical appliances, etc.) are greatly reduced or eliminated.

Elimination of accidental causes

The elimination of accidental causes is actually not a form of evidence but rather a finding that is reached by forensic fire examiners (based on various pieces of evidence at the scene) as a conscious step in progressing to the conclusion that a fire may have been deliberately lit. The forensic fire examiners cited eliminating the possibility of the fire being accidental as a factor considered in reaching their conclusion in 78% of all cases and in 89% of cases concluded as being deliberately lit.

A critical component of the scene examination by the forensic examiners is to assess the possibility that the fire occurred as the result of accidental causes. Multiple pieces of evidence of different categories, including evidence indicative of accidental ignition and evidence indicative of deliberate ignition, will be considered collectively in evaluating the possibility that the fire resulted from accidental causes.

Evidence of other activities at the premises

Forensic fire examiners can become aware of suspicious activities that have either occurred at premises as part of the incident or have occurred sometime prior to the fire. Forensic fire examiners may detect forced entry through the inspection of doors and or windows that are sufficiently intact after the fire (note that consideration would also be given to fire services potentially forcing their way into burning premises). There may also be evidence that the premises had been ransacked, burgled or vandalised prior to the fire. The forensic fire examiners may also take into account information that they are provided with by the police and fire services. The forensic fire examiners cited evidence of forced entry or open access to the premises as a factor considered in reaching their conclusion in 44% of the cases. Evidence such as vandalism was considered to be a factor by the forensic fire investigators much less frequently (12.5% of all cases).

Figure 6.3 presents the factors that can typically provide support to the contention that a fire was not deliberately lit (i.e. accidental) and the frequency that the forensic fire examiners found these factors present in the cases in the dataset. The form of evidence that was most frequently cited by the forensic fire examiners as a factor considered in reaching their conclusion that the fire was not deliberately lit was evidence of smoking on the premises (cited in 9% of the cases).

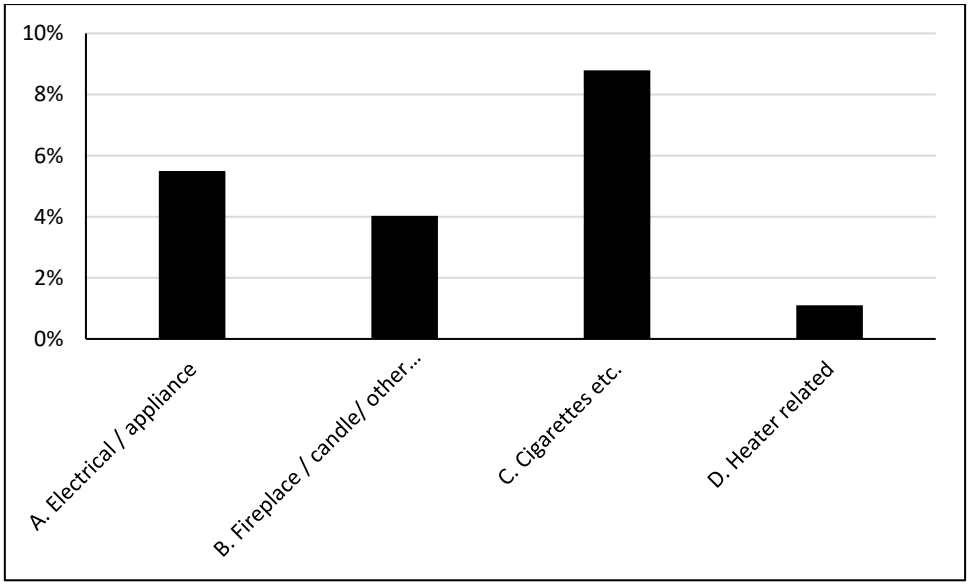

Figure 6. 3: Frequency that forensic fire investigators noted factors which typically contribute to reaching a finding of "not deliberately lit" (All cases, n=273).

Key

A. Electrical system / electrical appliance
B. Fireplace / candle / other naked flame
C. Cigarettes or other items relating to smoking
D. Heater related

The impact of forensic evidence in arson cases

An initial aim of this study was to quantify the judicial outcomes of arson cases that included forensic fire examination evidence and to explore the relationships between the forensic results with investigation outcomes (i.e. whether suspects were charged) and court outcomes (i.e. findings of guilt or otherwise in court). The dataset was heavily weighted to:

- cases which included forensic evidence that supported the prosecution case (86.1% of the 273 included cases);
- cases in which no charges were laid (78.4% of the 273 included cases); and
- cases in which guilt was not determined (83.5% of the 59 cases for which charges were laid).

The skewing of the forensic results that support the prosecution case is likely a consequence in part of the vetting process applied in this jurisdiction that occurs before cases are referred to the forensic laboratory. Via the vetting process, structural fires that have occurred as a result of accidental causes have been cleared of the need for criminal investigation and only fires deemed as suspicious are referred to the forensic laboratory. The exclusion of many accidental fires via the vetting process skews the data that has been obtained. The fact that arson is a difficult offence to prosecute and prove in court brings about the low frequency of charged suspects and convicted offenders. The vetting and referral process which caused the data to be highly skewed, in combination with the characteristics of arson prosecution that lead to low number of observations in the infrequent categories, meant that the planned quantitative case processing methodology and associated inferential statistics were not viable with this dataset and consequently were not conducted.

However, some quantitative results were obtained in relation to the impact of forensic fire examination evidence. A comparison of the frequency of charges being laid and guilt determined in cases which did, and did not, have forensic fire examination evidence that supported the prosecution of arson is presented in Figures 6.4 and 6.5. The figures do not suggest that there is a strong effect size and insufficient numbers of cases in some groups (e.g. cases which did not include forensic evidence supporting the prosecution of arson and charges were laid) precluded statistically testing the associations between the results of forensic examinations and whether changes are laid and guilt determined. However, the results obtained indicate that forensic fire examination evidence that supports the prosecution of arson may be associated with:

- a higher frequency of charging suspects (i.e. charges were laid in 23% of the cases that included supporting forensic evidence compared with 11% of the cases that did not) (refer Figure 6.4); and

- a higher frequency of guilty findings (i.e. guilty findings were reached in 18% of the cases that included supporting forensic evidence compared with 8% of the cases that did not) (refer Figure 6.5).

There was only one case (1.7% of charged cases) in which a suspect was charged despite the forensic report providing support for the defence hypothesis (i.e. the forensic fire examiner concluded that the fire was not deliberately lit). In this case, no samples were collected from the fire scene for analysis for the presence of ILR and the forensic fire investigator noted the presence of an electrical appliance (hair straightener). The accused in this case was charged with criminal damage by fire (arson) and the court reached a guilty finding with no conviction recorded but a community correction order applied. There were also three cases (5.1% of charged cases) in which suspects were charged when the forensic report was an inconclusive finding. In one of these cases the forensic fire examiner commented that the house had been totally destroyed (i.e. to the point of greatly reducing the presence of evidence) and the presence of electrical appliances was noted in the other two cases. One of these cases did not proceed to court. The other two cases resulted in guilty findings, one receiving a suspended sentence and the other sentenced to imprisonment.

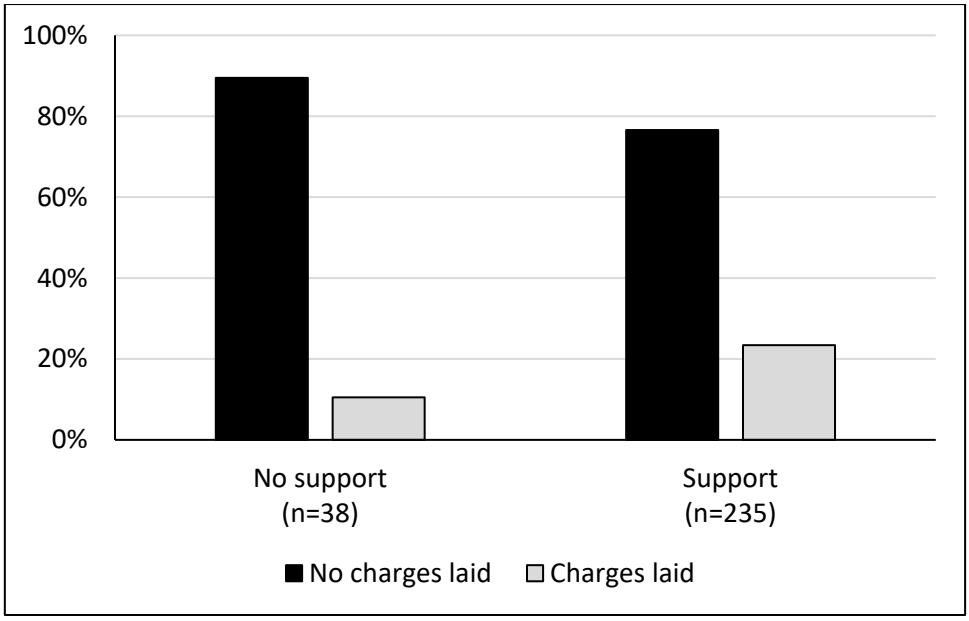

Figure 6. 4: Forensic evidence supporting the prosecution of arson by whether charges were laid. All cases (n=273).

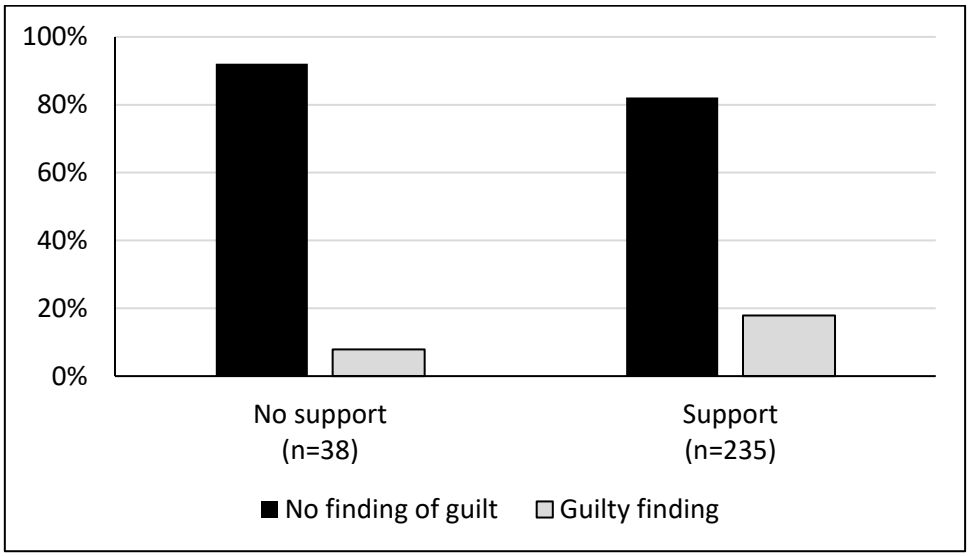

Figure 6. 5: Forensic evidence supporting the prosecution of arson by determination of guilt. All cases (n=273).

Identification of ILR at certain locations of a fire scene can provide evidence of the use of flammable liquid (accelerant) to fuel and accelerate the progression of the fire, and therefore provide support for the possibility that the fire had been deliberately lit. Samples were collected for laboratory analysis in 95 cases (35% of all cases). Of the cases in which samples were collected for laboratory analysis, ILR was identified in 69 cases (73% of cases in which samples were collected).

Comparisons of the frequency of charges being laid and guilt determined in cases which did, and did not, include ILR evidence are presented in Figures 6.6 and 6.7. Once again the figures do not suggest that there is a strong effect size and statistically testing the associations between ILR evidence and whether changes are laid or guilt determined was precluded due to insufficient numbers of cases in some groups. However, the results obtained indicate that the identification of ILR may be associated with:

- a higher frequency of charging suspects (i.e. charges were laid in 29% of the cases that included ILR evidence compared with 19% of the cases that did not include ILR evidence) (refer Figure 6.6); and
- a higher frequency of guilty findings (i.e. guilty findings were reached in 23% of the cases that included ILR evidence compared with 14% of the cases that did not include ILR evidence) (refer Figure 6.7).

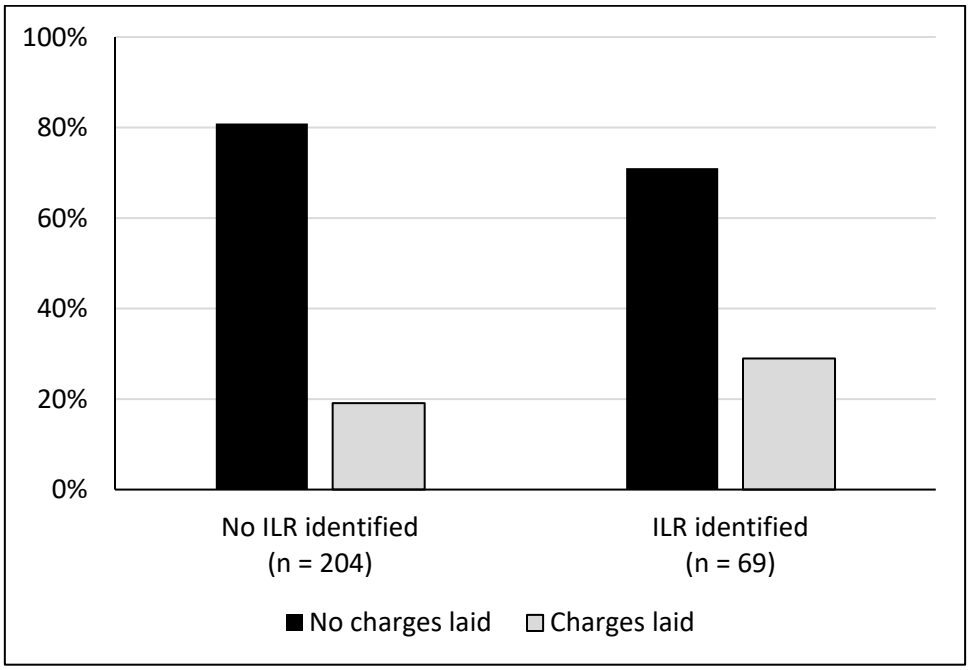

Figure 6. 6: Identification of ILR by whether charges were laid. All cases (n=273).

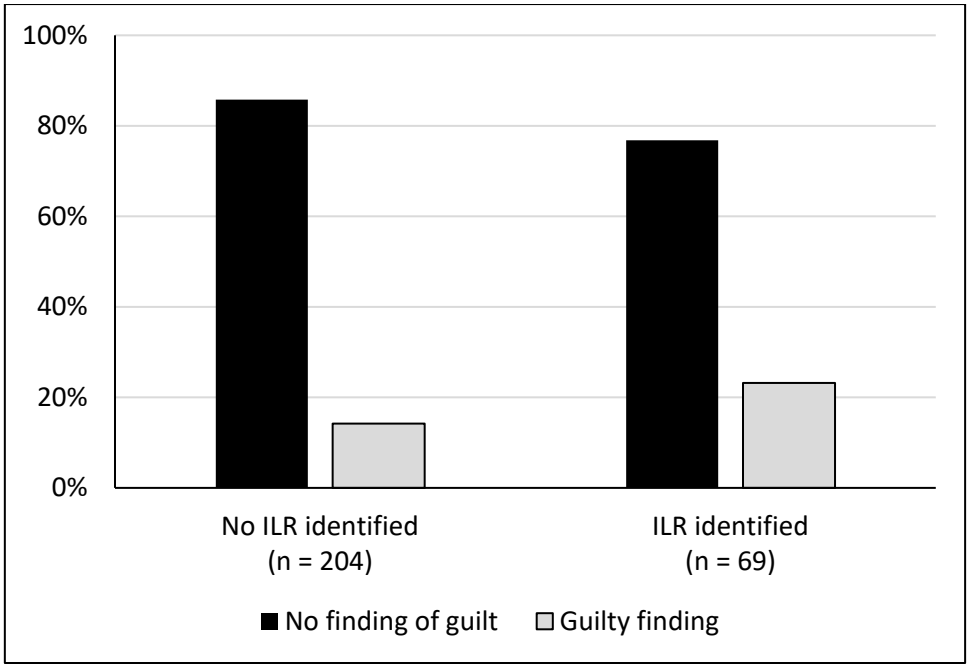

Figure 6. 7: Identification of ILR by determination of guilt. All cases (n=273).

A comparison of the interpretation factors between cases in which guilt was determined and cases in which guilt was not determined is presented in Figures 6.8 and 6.9. As would be expected, most of the evidence categories that can typically provide support for the possibility of fires being deliberately lit were cited more frequently in cases that resulted in findings of guilt (refer Figure 6.8). Similarly, most factors which typically contribute to reaching a finding of "not deliberately lit" were cited more frequently in cases which did not result in guilty findings (see Figure 6.9). As shown in Figure 6.9, evidence of smoking on the premises (e.g. identification of cigarettes, cigarette lighters and other related items) was cited with similar frequency in both groups (i.e. cases which resulted in guilty findings and cases which did not) suggesting this factor is not aligned with either judicial outcome.

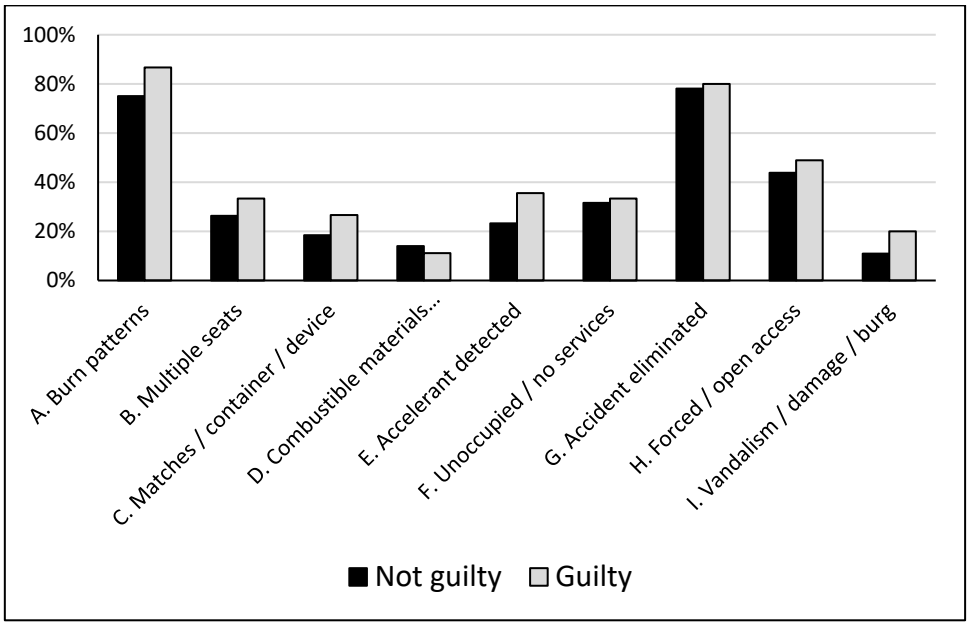

Figure 6. 8: Comparison between cases which resulted in a guilty finding and cases which did not, regarding the frequency that forensic fire examiners noted factors which typically contribute to reaching a finding of "deliberately lit" (Cases with no finding of guilt, n=228; Cases with guilty findings, n=45).

Key

A. Burn patterns
B. Multiple seats of fire
C. Matches / fuel container / incendiary device
D. Combustible materials amassed
E. Accelerant detected
F. Unoccupied / no services connected (i.e. electricity or gas)
G. Accident eliminated
H. Forced entry or open access to the premises
I. Vandalism / damage / burglary

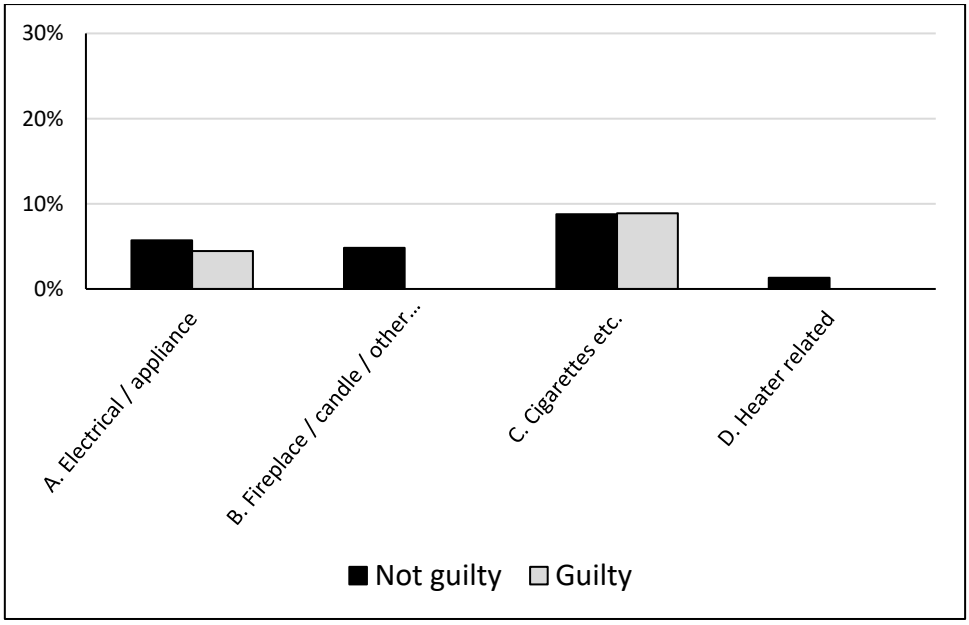

Figure 6. 9: Comparison between cases which resulted in a guilty finding and cases which did not, regarding the frequency that forensic fire examiners noted factors which typically contribute to reaching a finding of "not deliberately lit" (Cases with no finding of guilt, n=228; Cases with guilty findings, n=45).

Key

A. Electrical / appliance
B. Fireplace / candle / other naked flame
C. Cigarettes or other items relating to smoking
D. Heater related

Discussion

The results of this study indicate that in Victoria, Australia, the investigation of both domestic and commercial structural fires is conducted predominantly by detectives from local crime investigation units, with support provided by the forensic fire unit. Although it was not possible to capture data relating to fingerprint services or services provided by non-VPFSD forensic service providers (e.g. forensic medical services), the results obtained indicate forensic services additional to fire examination are rarely applied in the investigation of suspicious building fires. Arson is a crime that is characterised by low rates of prosecution and conviction of offenders. One problematic aspect of investigating arson is identifying and proving the involvement of the offender. DNA and fingerprints

are common forms of forensic evidence used to establish the involvement of individuals in many crime types, and other disciplines such as chemical trace evidence can also establish a link to individuals indirectly. However, the very nature of arson being property damage caused by fire, results in a crime scene in which many forms of forensic evidence are destroyed and the scope for forensic science to support the resolution of the crime greatly reduced. There are some incidents however, where structural fires can be connected with other offences such as homicide, and in these circumstances the forensic examination of a fire scene can become a component of a multidisciplinary forensic team response with the services of other forensic disciplines provided by the respective units.

Results were obtained which indicate that the decision to proceed with charging a suspect is a key step in processing arson offences relating to structural fires in Victoria, Australia. Although 86.1% of the cases included forensic fire examination evidence that supported the prosecution case, charges were laid in only 21.6% of all cases in the dataset. Additionally, a further proportion of cases were not presented in court after charges had been laid (20.3% of the cases in which charges were laid). This suggests that there is significant scrutiny of the prospect of securing a conviction that takes into account evidence that is additional to forensic evidence, before suspects are charged and before cases are presented in court. However, guilty findings were reached in the majority of cases in which suspects were charged (76.3% of cases with charges laid). For structural fires, where there is often a lack of physical evidence (Dehghani-Tafti & Bieber 2016) and DNA and fingerprint evidence is infrequently applicable, the inability to identify an offender can preclude the resolution of cases (Federal Emergency Management Agency 1988). The limited opportunity to apply forensic identification services to the investigation of structural fires may be a factor contributing to the low rates of arson prosecution.

In Victoria a fully integrated scene and laboratory forensic fire examination service is provided. This model brings specialised scientists to the fire scenes and provides continuity in the assessment of

the cause of the fire. Contextual bias is recognised as an issue applicable to fire investigation and this is one reason why it has been argued that the scientific examination of fires should be separated from the criminal arson investigations (Almirall et al. 2017; Lentini 2008). It has also been proposed that there should be separation of scene examinations and laboratory examinations as this can result in the "bias cascade effect" (Almazrouei et al. 2019). A counter consideration is the demand to bring science to the crime scene and, as stated by Roux et al (2012), the benefits for scientists to be engaged in the field and integrated with other actors. With the model of the scientist conducting the fire scene examination, the examiner has the opportunity to collect only the samples that are most appropriate to test theories that are being considered regarding the cause and origin of the fire (i.e. that are indicated by the physical evidence that is revealed during their scene examination). Benefits in optimising evidence collection via the participation of experts in scene examinations has been proposed with the application of other forensic disciplines (Cunningham et al. 2001). Deploying different scientific personnel for the scene and laboratory examinations is problematic in terms of resources and service delivery efficiency for small forensic fire units, such as the unit in this study which consisted of only four reporting scientists.

Despite adopting the same quantitative methodology as previously utilised by the authors to study chemical trace evidence (Woodman et al. 2020b), there were limitations of the data obtained in this study (highly skewed categorical data and small numbers of observations in infrequent categories) which did not permit inferential statistical testing to determine the impact of forensic evidence on judicial outcomes of arson cases. However, some results were obtained that indicate that fire examination evidence that supports the prosecution case may be associated with a higher frequency of suspects charged and guilty findings in court, although the significance of these relationships could not be statistically tested.

It was also found that only a very small proportion of investigations progressed to the stage of suspects being charged without having forensic evidence that supported the prosecution case (i.e.

6.8% of cases in which charges were laid did not have forensic evidence supporting the fire being deliberately lit), and the forensic results in all but one of these cases were inconclusive. This finding suggests that forensic evidence may be a component for building a case sufficiently strong to proceed to court. Results were also obtained that indicate that the inclusion of evidence of the use of flammable liquid in cases may be associated with a higher frequency of suspects being charged and guilty findings in court, although again the significance of these relationships could not be statistically tested.

Previous research has demonstrated that the value provided by some forensic disciplines cannot be fully captured by quantitative methods, which focus on the outcomes of specific steps in the criminal justice process (Bitzer et al. 2017; Williams & Weetman 2013). This study adds support to those findings. As previously stated, evidence revealed by the forensic fire examiner may support the possibility of the fire being a wilful act intended to destroy property, and therefore address some of the elements of establishing a case of arson. In such cases the forensic evidence has significant impact by establishing the need to investigate a crime that has been committed. Conversely, when forensic fire examiners reveal evidence to support a fire originating by accidental causes, the impact of the forensic evidence may be to close the incident from a police perspective without the need for further criminal investigation. As has been demonstrated in a previous study of chemical trace evidence (Woodman et al. 2020b), examining whether charges are laid in arson cases will also not provide a measure of the impact of forensic evidence on the decision making through the course of an investigation.

Evidence detected by the forensic fire examiners during their scene examinations can open avenues of inquiry for the police investigators to pursue. Once ILR have been detected at a scene, and the source product has been identified (e.g. petrol, kerosene, paint thinners), the investigating police officers may pursue purchase records at nearby suppliers. Similarly, items used in committing an arson that have been recovered during the scene examination (e.g. fuel containers, packaging of

sparklers that were used in the construction of incendiary device) may have distinctive features, such as labelling or product characteristics, that provide leads for the police investigators to pursue. These modes of impact provide an example of how previous research which is based on quantifying the progression of cases through specified stages in the judicial process (e.g. charging suspects, proceeding to court, court findings) fail to provide insight into many of the varied ways that police investigators use forensic evidence to support their investigations (Williams & Weetman 2013).

This study has shown that in this jurisdiction, the results of forensic fire examinations are provided in a very timely manner. Timely examinations of fire scenes are extremely important because of the short-lived nature of some forms of evidence (e.g. residues of flammable liquids can be lost due to evaporation). But timeliness is also extremely important in the provision of evidence to support early decision making by police investigators. Revealing evidence that supports the possibility that a fire was a criminal act of arson is fundamental to confirming the need for a police investigation. Further, evidence of how the crime was committed will likely impact on the course of the investigation and provide valuable information for investigators to use when interviewing persons of interest (Woodman et al. 2020a). Official reports of forensic fire examinations were found to be issued within relatively short time frames with a median value of 25 days (or 3.6 weeks) after the date of offence. This compares with the median reporting time frames of other disciplines at the same forensic laboratory during the same period of: ballistics/tool marks, median = 6.5 weeks; chemical trace evidence, median = 30 weeks; biology, median = 36.5 weeks (Woodman et al. 2020b). However, the preliminary reporting of forensic evidence via the routine briefing of the police investigators post scene examination ensures that important results are disseminated even earlier and is a factor that is critical to the effectiveness of the forensic support to the police investigations.

Forensic fire examiners use a variety of evidence forms to determine the cause and origin of structural fires. Burn patterns were found to be an important form of evidence in a clear majority of cases. This category actually consists of a variety of physical features that can be present at fire

damaged buildings, including V patterns, variable depth of charring, trailers resulting from flammable liquids and spalling of floor surfaces. However, errors can occur in the determination of the cause and origin of fires when conclusions are based solely on fire pattern analysis (Almirall et al. 2017) and other evidence forms must also be considered. Evidence of items used to ignite, fuel and accelerate fires are also considered, although the results obtained indicated that they were present less frequently. However, residues of flammable liquid were identified in approximately one third of the cases. Forensic examiners consider sources of naked flames (e.g. candles, fireplaces, gas stoves), electrical appliances and heating appliances as potential contributors to accidental fires. The forensic fire examiners use combinations of evidence types to eliminate the possibility of an accidental cause. An absence of evidence of accidental ignition, together with evidence that is indicative of the fire being deliberately lit, is used to conclude that a fire was not accidental. The elimination of accidental causes, as far as possible based on the evidence present, was frequently a step taken in reaching the conclusion that a fire may have been deliberately lit.

As previously stated, during the course of a scene examination it can be unavoidable that the forensic fire examiner detects evidence or receives information that is potentially biasing. There is however an important distinction between bias and relevance (Almirall et al. 2017). The detection of evidence of the disconnection of utilities such as electricity and gas, and the provision of information regarding the premises being unoccupied, may be relevant and legitimate factors to be considered (Almirall et al. 2017; Lentini 2008). As stated by Almazrouei et al (2019), forensic examiners should have access to all the evidence and information that is needed for the forensic task. However, the results obtained indicate that on some occasions the forensic fire examiners do encounter evidence and information that is not directly relevant to their determination of the cause and origin of the fire. In such cases where there is evidence that is not domain relevant (e.g. evidence of forced entry, open access to the premises, vandalism), the contextual information should be disclosed appropriately (Almazrouei et al. 2019).

A primary aim of this study was to statistically test the relationship between the results of the forensic fire examinations with the outcomes of criminal investigations and court processes. The data collated in this study were found to be unsuitable for this purpose, and although results were obtained that are indicative of the impact of forensic fire examination evidence, it was not possible to statistically test the observed effects. Repeating this research with a larger dataset may overcome the limitations encountered in this study that were due to the small numbers of observations for some of the infrequent categories of variables, however it may be impractical to achieve a sample size of cases adequately large for what appear to be small effect sizes. It would also be beneficial to capture the perspective of the police officers and fire services personnel who have conducted arson investigations and explore in greater depth points that have arisen from this study regarding how forensic fire evidence is utilised during the investigation phase.

This study has focused on structural fires, the most abundant form of arson in the state where this study was conducted. There are other types of fires, such as motor vehicle fires and bush fires that are also noteworthy due to their frequency and the impact they have on communities. There are differences in the forms of evidence that are associated with different types of fires and it cannot be assumed that findings reached in this study will be applicable to non-structural fires. The use of forensic fire examination evidence for intelligence purposes has also not been covered in this study. In this jurisdiction, arson intelligence services are provided by the police Arson and Explosion Squad and the results of forensic fire examinations are provided to this squad to support the pursuit of serial and recidivist arson offenders.

Conclusion

In the setting of this study (Victoria, Australia), a quantitative analysis of case level data and associated criminal justice outcomes was found to be unsuitable for evaluating the contribution of forensic fire examinations. However, results were obtained that indicate that forensic fire evidence may have influence in the judicial outcomes of arson cases. Of the cases that progressed to the stage of charges being laid, only a very small proportion did not have supporting forensic evidence (6.8% of charged cases compared to 15.9% of non-charged cases), which suggests that forensic evidence plays a role in the decision to charge and proceed to prosecution. The earliest point in a case where the forensic evidence has impact is soon after the incident has occurred, when the decision is made by the police investigator whether to proceed with an arson investigation. Evidence revealed via the forensic examination of the fire scene can shift the status of the incident from being a "suspicious fire" to an "apparent act of arson" which requires criminal investigation, or to an "accidental fire" that does not require further investigation. Evidence provided by the forensic fire examiner can also impact on the decision to charge a suspect. However, the contribution that forensic evidence can make to the determination of guilt or otherwise in court is tightly confined by the applicable criminal laws, as some of the elements that must be proved to establish a case of arson cannot be addressed by forensic evidence (e.g. that the accused had no lawful excuse for damaging or destroying the property).

Results were also obtained which indicate that forensic evidence of the presence or absence of flammable liquid, that may be used to initiate or accelerate a fire, may be associated with an increase, or decrease respectively, in the frequency of suspects being charged and defendants being found guilty, although these relationships were not statistically tested. However, the detection of traces of flammable liquids occurred in a minority of scene examinations, with samples collected for laboratory analysis in only a third of all cases. Although this provides some indication that arson is often committed without using flammable liquid, the frequency that this occurs is uncertain.

Situations can occur where flammable liquid may have been used in committing arson, but the remaining traces of the flammable liquid may be reduced to below detectable levels at the time of the scene examination due to being consumed in the fire and evaporated post-fire.

One reason why a quantitative case processing methodology may be unsuitable for assessing the support that forensic fire examination provides to criminal investigations and court processes is that this methodology focuses the evaluation on whether the forensic evidence has impacted the outcome of specific selected judicial steps (e.g. identification of suspects, charging of suspects, referral to court, court findings). This presents two problems. Firstly, forensic disciplines are applied in different ways and can have impact at different stages as cases progress through the criminal justice system. Secondly, crimes can be processed in different ways depending on the type of offence. In a quantitative study of chemical trace evidence, for which the majority of the cases in the dataset related to crimes against the person (e.g. homicide, rape and assault), charges had been laid in 67.6% of cases in the dataset on or before the date that the forensic case was created (Woodman et al. 2020b). This indicates that these cases had been processed via the provision of police to arrest suspected offenders, continue their investigation and then proceed to prosecution. In contrast, for the cases of potential arson in this study, charges had been laid in only 33.8% of cases on or before the date that the forensic case was created (i.e. the provision to arrest a suspect and then proceed with the investigation was applied less frequently than in the dataset of cases based predominantly on crimes against the person). A consequence of both these factors, relating to the forensic discipline and the offence type, is that some steps in the progress of cases through the justice system may not provide suitable points for assessing the impact of some forms of forensic evidence (see Chapter 4). Consequently, if the judicial steps that are selected for measurement in a quantitative case processing study are inappropriate for the subject forensic discipline, the results obtained will have little real world validity. It is therefore necessary to have substantial knowledge of the subject forensic discipline, of how it is applied to investigations and in court, and knowledge of

how the applicable crimes are processed, in advance of planning a quantitative case processing study.

The forensic fire services that were the subject of this study span across scene examination and laboratory analyses. The delivery of forensic fires services is aligned with the criminal investigation and the results of both the scene and laboratory services are formally reported within short timeframes. For the jurisdiction in this study, police investigators receive timely forensic evidence that can assist with the determination of whether an arson investigation is required. However, the forensic fire examiners can also provide the police investigators with information about how the incident occurred (e.g. locations within the building where the fire was started, whether flammable liquid was used, details of items such as incendiary devices that may have been used) which can support the investigation by illuminating avenues of inquiry and providing useful points to pursue when interviewing suspects. The investigative value of the evidence provided by the forensic fire examiners is tightly linked to the informal reporting of preliminary findings, which occurs routinely in this jurisdiction via post scene examination debriefs with the police investigator. Issuing official reports within short timeframes is also valuable as this can assist with making the decision to charge suspects and with the preparation of the brief of evidence for court.

Examination of the decision-making process of forensic fire examiners has provided insight into the variety of evidence that is considered by the forensic experts in reaching the important conclusion about the cause and origin of structural fires. Burn patterns are the primary form of evidence for determining the cause and origin of structural fires but other evidence is also considered in reaching a conclusion. As an example, the results of laboratory analyses are important in cases where flammable liquid has been used in committing arson. The forensic fire examiners do consider contextual information in reaching their conclusions. However, the contextual information is often domain relevant and directly related to considerations of hypotheses based on accidental ignition sources or activities that could accidentally result in creating a fire.

CHAPTER 7

Discussion and Conclusion

Introduction

This research originated from a desire to investigate the effectiveness of forensic science. Forensic science plays a role in the criminal justice system by applying science to physical evidence to produce findings that will assist police investigations and the courts, and ultimately contribute to achieving appropriate justice outcomes. There are other functions that are performed by forensic service providers including intelligence services, disaster victim identification and research and development, but the core function is to provide support to policing and the courts. In many cases and for many crime types, police investigators are reliant on forensic evidence to provide support to their investigation (Kelty et al. 2015). Forensic evidence is often a critical component of cases that are presented in court and jurors have come to expect that there will be forensic evidence that will assist with reaching their verdict (Dioso-Villa 2014; Eatley et al. 2016). Accordingly, the approach adopted in this research for assessing the effectiveness of forensic science was to examine the contribution of forensic science to police investigations and court processes, as this is the primary means by which forensic science provides support to the criminal justice system.

Existing relevant research

In Chapter Two the existing body of research that has examined the effectiveness of forensic science and the impact of forensic evidence on investigation and judicial outcomes was reviewed. This body of research has developed over recent decades, but further research is required to address limitations and deficiencies that exist in this collection of published research.

Reviews by government agencies on the effectiveness of forensic services have tended to focus on the delivery of forensic services, as opposed to its impact, with particular attention to the support provided to policing (ACPO/FSS 1995; McTavish 2003; Peterson & Hickman 2005). The methodology applied, and the criteria used in these reviews have included: the analysis of case attrition and the identification of leakage points in the case processing chain (Bradbury & Feist 2005; Home Office

2007); the timeliness and cost effectiveness of service delivery (Bourn 2003; Johns & Kahn 2004); and subjective assessments of the usefulness of forensic evidence by police and forensic personnel (ACPO/FSS 1995; Bourn 2003; McCulloch 1996).

Other research has produced empirical data regarding the relationships between forensic evidence and criminal justice outcomes (Antrobus & Pilotto 2016; Baskin & Sommers 2010; Baskin & Sommers 2011; Briody 2004; King et al. 2017; McEwen & Regoeczi 2015; Peterson et al. 2013; Peterson et al. 2010; Roman et al. 2009; Schroeder & White 2009). However, there are limitations to the findings of some of this research. Weaknesses are evident in the methodology that has been used in some of these studies that will likely have reduced the usefulness of the findings (e.g. studies that are based on the application of forensic services and which fail to incorporate the results of examinations into the analysis of the impact of the evidence). The approach in some of the studies has been to focus on offence types and different types of forensic evidence have been rolled up into a single entity. As a result, these studies have covered mixed groups of forensic disciplines without taking into account differences that may exist between the disciplines in how they add value to investigations and court processes. In general, there has been a focus on the identification disciplines of DNA and fingerprints and the contribution of many other disciplines of forensic science to support investigations and court processes have not been examined (Williams & Weetman 2013). There are conflicting findings in the published research and overall the picture of how effectively forensic science is fulfilling its role in the criminal justice system remains unclear.

This research and the research design

The approach to evaluating the impact of forensic evidence in the present research has been informed by a forensic science perspective. In other words, the research questions and methods employed have been conceptualised with an understanding of the application of and science behind forensic science. Forensic science consists of a diverse collection of scientific and technical services. There is variation in multiple aspects of these services including: whether the services are crime scene or laboratory based; the degree to which the evidence is based on expert, but subjective, assessment or the results of analytical testing; and the type of information that the evidence provides. The different types of information that forensic evidence can provide is of particular relevance to this research, as this may influence how the evidence relating to specific disciplines impacts on case outcomes. Categories of evidence, based on the information provided, that have been examined in this research include:

i. Evidence that can assist with establishing whether an incident that occurred was, or was not, a crime (e.g. fire examination evidence);
ii. Evidence that provides direct identification of individuals that may be connected with a crime (e.g. DNA evidence);
iii. Evidence that can indirectly connect an individual with a crime by establishing a nexus between items and a crime (e.g. chemical trace evidence, ballistics).

The overarching question of this research is "*What impact does forensic science have on criminal justice system processes and outcomes?*". The examination of diverse forms of forensic evidence using a mixed methods approach has facilitated a more holistic and nuanced understanding of the impact of forensic science on criminal justice system processes and outcomes. Separate studies consisting of quantitative case processing studies, an investigator survey and a forensic examination

Table 7. 1: Overarching question, research questions, hypotheses and the studies conducted.

What impact does forensic science have on criminal justice system processes and outcomes?				**S1 Chem Trace Quantitative**	**S2 Chem Trace Survey**	**S3 Fire exam Quantitative**	**S3 Fire exam Process study**
RQ 1	Is forensic science impacting on police investigations and influencing whether suspects are charged with criminal offences?	**H1**	... more likely that suspects will be charged if the case includes forensic evidence which connects the suspect to the offence	✓	✓	✓	
RQ 2	Is forensic science impacting on court processes and the determination of the guilt or innocence of those who are charged with criminal offences?	**H2**	... more likely to be found guilty if the case includes forensic evidence which connects the accused to that offence	✓	✓	✓	
RQ 3	Do multiple pieces of forensic evidence in a case increase the probable impact of forensic science on police investigations and court trials?	**H3**	The probable impact on the outcomes of police investigations and criminal trials will be increased when cases include multiple pieces of forensic evidence	✓			
RQ 4	Does the type of information provided by different forensic disciplines influence how the evidence impacts police investigations and court processes?	**H4**	The impact of forensic evidence… will vary between disciplines… depending on the information that the evidence provides	✓	✓		
RQ 5	In what ways, if at all, does forensic evidence influence the decision-making of investigators?				✓		✓

process study were used to test hypotheses and explore research questions that were drawn from the overarching research question (refer Table 7.1).

The research design included a focus on selected forensic disciplines, with data collected from cases which included the chosen type of forensic evidence. This contrasts with some other research where the approach has focused on the type of crime (i.e. data was collected from cases of a selected crime type). The selection of forensic disciplines in the present research (i.e. chemical trace evidence, biology (DNA), ballistics / tool marks and forensic fire examination) took into account forensic disciplines that are not well represented in existing published research and disciplines that would diversify the type of evidential information examined.

Chemical trace evidence was selected as the forensic discipline of primary focus for this research. The impact of this discipline on criminal justice outcomes has not been well studied and unlike the identification disciplines that have been studied frequently, this discipline can be used to establish a nexus based on the transfer of traces of materials such as paint, glass, fibres and gunshot residues. The viability of chemical trace evidence has also come under scrutiny (Roux et al. 2015). Trace evidence has been considered a challenging capability for forensic laboratories to maintain. Chemical trace evidence, or criminalistics as it is sometimes known, actually consists of several sub-disciplines based on the items from which the traces originate (e.g. paint, glass, fibres, gunshot residues) (National Association of Testing Authorities (NATA) 2013) and laboratories may need to employ multiple specialised experts to cover the full range of examination types. Trace evidence services are also considered resource intensive (i.e. reliant on skilled personnel and a range of expensive specialised instrumentation) and the benefits predominantly confined to having impact in court (e.g. due to lengthy laboratory examinations) (Roux et al. 2015). In this research, the impact of chemical trace evidence was examined in a way that also considered the potential unique and additive impact of biology (DNA) and ballistics/tool marks evidence, two forensic disciplines which were found to be commonly present in cases that included chemical trace evidence.

In the first study (Chapter 4), a database was constructed which brought together information relating to forensic examinations, police investigations and court outcomes for a sample of cases that included chemical trace evidence. Quantitative case processing methodology was applied to produce empirical data which described the relationships between the results of forensic examinations, the decision to charge suspects and the findings reached in court. This study also explored potentially influential factors such as timeliness of services and relationships that could exist between chemical trace and other forensic evidence that is present in some cases.

Chemical trace evidence was explored further in a second study in which police investigators were surveyed (Chapter 5). The survey was used to triangulate findings from the quantitative analysis of administrative data, build on the findings of the quantitative study by exploring more deeply trends that were revealed in the quantitative study and also by exploring aspects of the use and impact of forensic evidence that could not be addressed via the quantitative analysis of case processing data. The lead police investigators from a sub-sample of cases in the quantitative database were questioned about:

- Their purpose for using chemical trace evidence and other forensic services;
- Their expectation of what value the forensic services would provide;
- The actual impact of evidence in specified cases;
- Their general perceptions of forensic science more broadly.

Although there was emphasis on the impact of chemical trace evidence during the investigation phase of cases, the survey study was also inclusive of other forensic disciplines and examined the value that forensic evidence could provide at any point as cases are processed through the criminal justice system.

The subject discipline in the third study was forensic fire examination, which was examined specifically in relation to the investigation of structural fires (Chapter 6). This discipline differs to

many others. In a large majority of the structural fires that are investigated, forensic fire examination is the only forensic discipline applied. The forensic examination of structural fires can include both scene and laboratory examinations. The results of these examinations assist with the determination of whether a crime has been committed (i.e. was the fire potentially an act of arson) and the discipline is intrinsically connected with the crime of arson, an offence type that is considered to be difficult to investigate and prosecute (Anderson 2016; Federal Emergency Management Agency 1988; Weisberg et al. 1984). Again, a database of forensic fire examination cases was constructed so that quantitative analysis of case processing data could be used to explore the impact of the forensic evidence on criminal justice outcomes. Studying forensic fire examination also provided an opportunity to explore how the services of a forensic discipline that are crucial for establishing whether a crime has occurred, can be delivered to effectively meet the needs of the associated police investigation. In this study, data were also captured from forensic fire examiners that was used to examine the important decision-making process followed by the forensic fire examiners. To reach a finding regarding the cause and origin of structural fires, the forensic fire examiners use multiple forms of evidence that can be present at the fire scene and also the results of laboratory examinations of exhibits collected from the fire scene. The frequency and impact of these different forms of evidence was examined in this study.

What this research contributes

The impact and utilisation of forensic evidence on criminal justice system processes and outcomes

As demonstrated in Table 7.1, the in-depth study of a selection of forensic disciplines in this research provides an evaluation of the impact of forensic evidence relating to chemical trace evidence, forensic fire examination, biology (DNA) and ballistics/tool marks evidence.

The findings from the quantitative case processing studies in this research have been subject to some limitations. In Study 1, the quantitative case processing study of chemical trace evidence, it was found that the decision to charge suspects was not a suitable case processing step for measuring the outcome of police investigations, due to the high frequency of suspects being charged before the investigation was completed in this dataset of cases. In study 3, the quantitative case processing study of forensic fire examination, the highly skewed categorical data and small numbers of observations in infrequent categories in the dataset did not permit inferential statistical testing to determine the impact of forensic evidence on judicial outcomes of arson cases.

A consequence of these limitations was that in Study 1, the quantitative case processing study of chemical trace evidence, it was not possible to test Hypothesis 1, the impact of forensic evidence on criminal investigations. However, in Study 2 responses from police investigators indicated that they believe that chemical trace evidence can have valuable impact on criminal investigations. Additionally, results were obtained in the quantitative component of Study 3 that indicate that fire examination evidence that supports the prosecution case may be associated with a higher frequency of suspects charged, although the significance of these relationships could not be statistically tested. Further, only a very small proportion of arson investigations progressed to the stage of suspects being charged without having forensic evidence that supported the prosecution case. Consequently, this research provides some support for Hypothesis 1 that "*suspects are more likely to be charged if the case includes forensic evidence which connects the suspect to the offence*".

Forensic practitioners have some awareness of how cases progress through the criminal justice system, but they are not involved in the investigative processes which are conducted by police investigators. They are therefore unlikely to be aware that suspects are charged before forensic results are produced in a large proportion of cases. As discussed in the literature review, this limited understanding of criminal justice processes by forensic practitioners and forensic managers has been identified as one of the factors that contributes to laboratory processes that may not meet the

needs of police investigators effectively. Furthermore, in response to concerns about the potential for context bias, forensic scientists are discouraged from knowing about the investigation and prosecution of cases as they progress through the criminal justice system. This lack of integration between the laboratory and investigative processes, and thus lack of knowledge in relation to the laying of charges, was a major rationale for conducting this research.

Results were obtained that demonstrated variable impact of forensic evidence on court processes. In Study 1, the results of biology examinations were found to be significantly related to the determination of guilt (or otherwise) in court. However, for chemical trace evidence and ballistics evidence their relationships with court outcomes was only significant when these forms of evidence were in combination. Survey results (Study 2) were also obtained that demonstrated that police investigators believe that chemical trace evidence does impact on court outcomes. And in Study 3, results were obtained that indicate that fire examination evidence that supports the prosecution case may be associated with a higher frequency of guilty findings in court (again not statistically tested). This research therefore provides some support for Hypothesis 2 that "*defendants are more likely to be found guilty if the case includes forensic evidence which connects the accused to that offence*".

The significance of the combination of chemical trace evidence with ballistics evidence that align in terms of whether they support the prosecution case (Study 1) provides support for Hypothesis 3, that "*the probable impact of forensic evidence on criminal justice outcomes will be increased when cases include multiple pieces of forensic evidence that align in terms of implicating or exculpating suspects*".

Hypothesis 4, the "use and impact of forensic evidence during police investigation and criminal trial processes will vary between disciplines and will depend on the information that the evidence provides" was tested in Studies 1, 2 and 3 (refer Table 7.1). In regard to the impact of forensic disciplines on court processes, differences were demonstrated between the impact of chemical trace

evidence, biology and ballistics in Study 1. The biology evidence, which consisted almost entirely of DNA evidence, can establish a direct connection between an individual and a crime, and was found to be significantly related to court outcomes. In contrast, chemical trace and ballistics evidence, two disciplines that can establish an indirect connection between an individual and a crime, were significant only when in combination. In the survey of police investigators (Study 2) results were obtained which built on the observation that chemical trace evidence can achieve impact through connections with other evidence. Qualitative data collected from the surveys indicated that chemical trace evidence was used in combination with other forensic and non-forensic evidence by police investigators in multiple ways, with responses indicating that the ability of chemical trace evidence to provide information about "what" and "how" events occurred as being an important contributing factor. Forensic fire examination, which can assist with the determination of whether an incident was a criminal offence, was the subject of Study 3. The results of forensic fire examinations can be crucial in determining whether arson investigations are warranted. It was found that the results of both the scene and laboratory services are formally reported within short timeframes indicating that delivery of forensic fires services are closely aligned with the criminal investigation process. This research has produced findings which support Hypothesis 4, although further research which explores the relationship between evidential information and the impact of evidence is still required.

Study 2, the survey of police investigators explored Research Question 5, "*in what ways, if at all, does forensic evidence influence the decision-making of investigators?"* (refer Table 7.1). Quantitative and qualitative information was captured regarding the expectation and utilisation of chemical trace evidence and other forensic services by police investigators. The survey findings indicate that when the police investigators utilise chemical trace evidence services they do so with multiple purposes in mind. Although building a case for court could be considered the primary purpose, the investigators frequently sought chemical trace evidence to also support their investigation. Investigators utilised the ability of chemical trace evidence to contribute to the understanding of "what has happened" to corroborate other evidence (e.g. to assess the truth and

accuracy of witness accounts). Chemical trace evidence was also utilised by investigators to guide what might be described as the management of the investigation with scope to influence decisions on whether the investigation is still required, the level of urgency and the appropriate resourcing.

The second part of Study 3 consisted of a study of the fire examination process. This study explored Research Question 5 and how forensic evidence impacts the decision-making processes during forensic fire examinations (refer Table 7.1). Forensic fire examiners utilise a variety of evidence forms in their determination of the cause and origin of structural fires, including physical features of the fire scene, the results of laboratory analyses and information about the circumstances of the premises. Evaluation of the possibility that the fire was ignited accidentally was found to be a core component of their decision making process with alternative hypotheses not being reached without first eliminating accidental causes.

The overarching question of this research was *"What impact does forensic science have on criminal justice system processes and outcomes?"*. In this research, mixed methods were applied to explore the utilisation and impact of a sample of forensic disciplines during the investigation and court processes. Within these confines it has been demonstrated that forensic evidence is utilised in a multitude of ways and can add value to both investigation and court processes. However, within the selected forensic disciplines that were studied, which varied in the type of evidential information that they provide, there was variation in the use and impact of the evidence. Additionally, the methodologies applied in the examinations revealed different aspects of the value provided by the forensic disciplines. Consequently, the answer to the overarching question is that forensic science can impact on the criminal justice system but how it impacts depends on the forensic discipline, the stage within the criminal justice system in question and how the impact is measured.

This research both extends and deepens the existing body of literature on the impact of forensic evidence on criminal justice outcomes and the effectiveness of forensic science. Through the inclusion of disciplines that have not been studied in detail in previous research (e.g. chemical trace

evidence, forensic fire examination), the quantitative studies in this research have increased diversity in the range of forensic disciplines that have been examined using case processing methodology. This research, which has compared a selection of forensic disciplines, introduces the concept that there are categories of evidential information that influence the use and impact of different forensic evidence types. A further addition to the existing knowledge in this field is the demonstration of the potential for synergistic relationships to exist between forensic disciplines (i.e. chemical trace and ballistics evidence in combination). The mixed methods approach of this research led to the capture of qualitative information that provided a detailed understanding of multiple and varied ways that chemical trace evidence is utilised through investigative and judicial processes. This information builds on the existing literature by describing how forensic science impacts on investigative and judicial processes. The study of the forensic fire examination process and the use of multiple forms of evidence by the forensic scientists to reach their conclusion, is a new addition to the literature that has examined the importance of decision making processes.

Measuring the value of forensic evidence

In addition to developing knowledge of the contribution of forensic science to criminal justice system processes and outcomes, this research has led to a greater understanding of the task of evaluating the contribution of forensic science.

The capabilities and limitations of quantitative case processing methodology

Quantitative case processing methodology can be used to establish whether there are significant relationships between forensic evidence and criminal justice outcomes, and it can produce empirical data which illustrates the impact of evidence. However, this research has demonstrated that to obtain meaningful information about the impact of forensic evidence, it is essential to have significant knowledge of the forensic disciplines to be studied (e.g. how they are used, whether

preliminary results are regularly reported, whether synergies with other disciplines are likely) and the way the applicable cases are investigated and progressed through the criminal justice system (e.g. which criminal justice points will be suitable for measurement) before commencing a quantitative case processing study.

To measure accurately and in a valid manner the contribution forensic science makes through quantitative analysis of case processing data, a diverse spectrum of knowledge and skill is required. Sufficient foundational knowledge across the three fields of forensic science, policing and the legal system is required to understand the meaning and implications of information collected from and pertaining to each field. More specialised knowledge, that is specific to the particular forensic service provider and specific to the subject forensic discipline, is required for understanding and interpreting the content of case files and case management records. Technical skills are required to support data extraction from case management systems and the data processing involved in the construction of case databases (this includes knowledge of bespoke or locally customised computer-based case management systems). Competency in the statistical analysis of the collated quantitative data and interpretation of the results is also required.

Mixed methods is suited to the examination of the multifaceted and complex contribution of forensic science

In this research, a thorough and detailed understanding of how chemical trace evidence can add value to investigations and court processes was obtained by employing a combination of quantitative case processing data analysis and a survey of police investigators. A research design based on mixed methods, which employs different yet complementary methodologies, can provide a means for verifying the findings obtained via the separate methods (i.e. triangulation). In addition, by employing a combination of methods, it can be possible to fill information gaps that occur as a

result of limitations associated with some methodologies. In this research the impact of chemical trace evidence on the outcome of court trials was examined via the quantitative analysis of case processing data, but it was not possible to use the same methodology to examine the impact on police investigations. However, quantitative and qualitative data captured in the following survey study not only demonstrated that chemical trace evidence does impact on police investigations but also revealed how the evidence can have impact in a variety of ways. This demonstrates how mixed methods research can capitalise on strengths and overcome weaknesses of a single method approach (Maruna 2010; Shorten & Smith 2017).

Some of the impact associated with forensic disciplines can be measured using quantitative methodologies based on the analysis of administrative data. However, forensic evidence can provide value to the resolution of cases via means that may not be directly associated with a key outcome (i.e. decision to charge a suspect, court finding of guilt) at a specific point of case processing (i.e. police investigation, court hearing/verdict) in the criminal justice system. As an example, it was found using survey methodology that chemical trace evidence can be utilised by police investigators when interviewing witnesses and other persons of interest and also used to guide the management of investigations (e.g. clarifying that an investigation is required, assigning urgency to the investigation and guiding the allocation of resources to the investigation). This highlights the importance of probing the nuanced applications and benefits that can be associated with forensic evidence, to achieve a more complete appreciation of the value provided by forensic disciplines.

In the setting of this research, quantitative case processing methodology does not provide a practical means for monitoring the impact of forensic services

Evaluating the contribution forensic science makes to criminal justice system outcomes uses administrative data that, at least in this point of time in Australia, resides in disconnected sources

and systems. The data required for the quantitative study was originally collected and maintained for purposes that are very different to the requirements of quantitative research. Little or no provision had been made for the data to be extracted and utilised for purposes beyond case record management. Quantitative analysis of data on forensic science results requires the sample of cases to be categorised as to whether they do, or do not, support the prosecution case. The categorisation of cases involves the interpretation of examination results by forensic discipline experts, which is a process particularly unsuited for automation. Some of the current obstacles relating to the access and extraction of the required administrative data maybe be overcome in the not too distant future. An example which illustrates this point is that a system has been developed and trialled in the UK for providing secure access to personal criminal justice administrative data for evaluation purposes and it has been suggested that access to administrative data may become more readily available in the future (Lyon et al. 2015). However, the conclusion from this research is that under the current circumstances in Australia, the task of conducting quantitative analyses of administrative data on forensic science services and criminal justice system outcomes is extremely resource demanding and time consuming. It is therefore not practical that quantitative analysis of administrative data be used routinely and on a large-scale to monitor the impact of forensic evidence in a meaningful way.

Implications of the research findings

The findings of this research, together with related published articles, bring to light some important points for forensic service providers to consider when reflecting on the services that they deliver and whether improvements can be made to the value provided to criminal investigations and the courts. Some of the results obtained in this research will be linked to the specific forensic disciplines, the offence types and the characteristics of the criminal justice processes in the jurisdiction where these studies are based, and consequently it may not be valid to extrapolate some findings to other settings. However, it is likely that there will be parallels between like forensic disciplines across other

jurisdictions, and the higher-level findings of this research are likely to have broader relevance and provide some guidance for forensic laboratories to identify opportunities to strengthen the alignment of their service delivery with investigations and court processes.

One implication of this research is that forensic service providers are managing the delivery of their services without having empirical evidence that describes the impact of their services, and which could be used to guide the development of effective case management policies and operating procedures. Forensic service providers have systems embedded in their organisations for monitoring their service delivery and scientific quality. Additionally, research and development programs assist laboratories to keep pace with advancing technologies and to respond to emerging issues in the field of forensic science (e.g. contamination minimisation, contextual bias, discipline error rates). However, forensic service providers lack equivalent systems to provide supporting information on the impact of their evidence and they lack empirical data to facilitate an evidence-based approach to the development of operating procedures (Ludwig & Fraser 2014).

Forensic laboratories should have a sound and up to date understanding of the use and impact of each discipline, so that they can effectively align the delivery of their various services with investigation and court requirements. If the impact of their services was continually monitored, it may enable the early detection of shifts in the effectiveness of their services. It is relevant to consider the dynamic nature of crime, forensic science and the criminal justice system. The capabilities of forensic science are subject to change, often based on technical advancements. Crime trends vary over time and the changes that occur can relate to the emergence of new opportunities for offenders (e.g. “e-crime”) and adoption of alternative modus operandi to counter policing methods. Legislative changes can also occur that impact on the provision of forensic services (e.g. legal capacity to obtain personal samples and how the results of analysis can be used). It follows that the way forensic services are used by policing and the courts, and what impact the forensic evidence is having, may also be subject to change. It is inadequate to use perceptions of the value of forensic

evidence that are based on anecdote, limited personal past experiences and the impact seen in small samples of specific cases, to guide the development of procedures and polices relating to service delivery. Internationally there is a growing recognition of the need for providers of various service types to have access to administrative data on outcomes so that they may evaluate the effectiveness of their services (Lyon et al. 2015). It would be beneficial for forensic service providers to have access to information about how their services are being used, and access to data that describes the impact of their evidence, which is contemporary and can reveal emerging trends.

One of the findings of this research is that there are a number of limitations in examining the contribution of forensic science to criminal justice system outcomes by quantitative analysis of administrative data, which would need to be overcome before such an approach could be adapted as a basis for a monitoring system. Whilst it may be possible to overcome some limitations that relate to the resources for completing the task (e.g. such as data access and connectivity) it is less conceivable that limitations that are directly connected with the forensic services themselves can be addressed (e.g. the feasibility of forensic service providers to routinely collect and record essential data such as whether the results of examinations do or do not support the prosecution case). However, this research has demonstrated that mixed and complementary methods used in combination can reveal an array of modes of impact of forensic evidence and provide insight into how forensic disciplines add value to criminal investigations and court processes. Hence, as anticipated, the use of mixed methods in this research counteracted the limitations of reliance on a single method (i.e. quantitative analysis of administrative data) and provided a rich and more comprehensive understanding of the contribution forensic science makes to criminal justice system outcomes.

The way ahead (limitations and recommendations)

In exploring the overarching question of "*What impact does forensic science have on criminal justice system processes and outcomes?*", findings have emerged from the different study components of this research which collectively provide a picture of the contribution of forensic evidence that is varied and multifaceted. However, the results relating to each of the tested hypotheses also prompt questions that could be pursued in further research.

In the quantitative case processing studies relating to Hypothesis 1 (i.e. the impact of forensic evidence on police investigations) some limitations were encountered due to the justice process points that were selected for measurement. For the dataset of cases which included chemical trace evidence, the decision to charge suspects proved not to be a suitable criminal justice step for assessing the outcome of police investigations. However, this limitation was not applicable to fire examination cases. It would be valuable to establish whether the outcomes of other case processing steps, such as the referral of cases to court, might be more suitable for a wider range of forensic disciplines for assessing the impact on justice outcomes. This research did not explore the relationship between forensic evidence and the pleas entered by defendants, or changes in plea. Anecdotally, forensic practitioners hold the belief that their evidence can cause defendants to change their plea, but this belief has not been tested.

A quantitative case processing study was used successfully to test whether guilty findings will be reached more frequently when cases include chemical trace evidence, biology and ballistics evidence that support the prosecution case (i.e. Hypothesis 2). It would be valuable to apply this methodology to other forensic disciplines and broaden the range of evidence types that have been examined (e.g. hand writing examinations, digital evidence, etc.). The inclusion of multiple forensic disciplines within a quantitative case processing study provided a means to test for additive or synergistic effects between the disciplines (Hypothesis 3), which in this research revealed a significant

connection between the results of gunshot residue and ballistics examination, both of which provide information relating to firearms. This approach could be used to examine potential interactions between other forensic disciplines that are regularly applied as a combination in multidisciplinary cases.

In this research the impact of a selection of disciplines, which differ in terms of the evidential information that they provide have been compared (Hypothesis 4). The results that were obtained demonstrated that there are differences in the impact of different categories of evidence. There is however scope to explore more deeply whether the differences in impact are related to difference in the evidential information, and if so how. In this research, a deep understanding of the use of chemical trace evidence by police investigators and the impact of this evidence form on justice outcomes in specified cases was obtained via a survey of investigators. Conducting similar surveys of police investigators, in relation to cases that include different categories of evidence (i.e. evidence that can establish whether an incident was a crime, evidence that can directly identify individuals involved in a crime), would provide a means to examine the relationships between evidential information and evidence utility and impact. It may also be valuable to explore whether there is variation in the reporting formats that contributes to the observed difference of impact of the forensic disciplines.

The survey conducted to explore Research Question 5 ("*In what ways, if at all, does forensic evidence influence the decision-making of investigators?*") provided detailed information on the use of chemical trace evidence by police investigators. When combined with the results of the quantitative study of chemical trace evidence, a comprehensive understanding of utilisation and impact of this form of forensic evidence was achieved. This mixed methods approach could be applied to other forensic disciplines, which would enable a broader and more detailed comparison of the use and impact of forensic disciplines.

The overarching objective of this research was to examine how effectively forensic science is fulfilling its role in the criminal justice system. An underlining premise of this research is that if forensic science is being effective, it will have impact on criminal justice system processes and outcomes. This research sought to explore the effectiveness of forensic science from the perspective of forensic science service providers because they are intrinsically connected with the degree of effectiveness that forensic science achieves. Forensic science service providers are responsible for many important decisions (e.g. which crime scenes are attended, what samples are collected, which examinations are conducted and how the results are reported) that influence the effectiveness of the evidence that is ultimately reported to police investigators and presented in the courts. It is also important for forensic science service providers to be knowledgeable about the use and impact of forensic evidence so that they can strategically deliver their services. Consequently, information that has emerged from the quantitative studies, and the survey of police investigators regarding the use of forensic services and the impact of forensic evidence, is potentially valuable for guiding service providers in how they can optimise the deployment of their resources so that the benefits provided to the investigation process, and the criminal justice system more broadly, are maximised. However, other actors in the criminal justice system may have different perspectives of the effectiveness forensic science. Consequently, it would be valuable in the future to conduct research which captures the views of prosecutors, defence council, judges and jurors on the impact of forensic evidence and how forensic science can be effective. Additionally, this research has shown that currently it is not practical to use the quantitative analysis of administrative data to monitor the impact of forensic services in a meaningful way. Further research is also required to identify feasible methodology for producing data which supports service monitoring, and which can be used to guide the strategic delivery of forensic services.

In the present circumstances, there is inadequate empirical evidence of the impact of many forensic evidence types that is available to forensic service providers to guide the strategic delivery of their services. It would be valuable to conduct research with service delivery managers at forensic

laboratories to learn what knowledge they currently have of the use and impact of individual forensic disciplines, and what their knowledge is based upon. Questions could be pursued such as "at what organisational levels in forensic laboratories are policies and strategies set to align services to maximise support to criminal investigations and court processes", "how such strategies make allowances for the differences between forensic disciplines" and "how coordination is achieved across the range of disciplines provided by the laboratory".

Conclusion

Through the application of a combination of methodologies, a deep understanding of chemical trace evidence and its contribution to the criminal justice system has been developed. Quantitative case processing methodology, based on the analysis of administrative data, has been used to produce empirical data describing the important connection between chemical trace evidence and ballistics evidence and the significant relationship with court outcomes. Via a survey of police investigators that focused on specific cases, but also explored the value of chemical trace evidence in a more general sense, details were revealed of how investigators use this discipline during the investigation and through to the court process, in multiple and varied ways.

The study of forensic fire examination has provided insight into a forensic discipline that is frequently the only form of forensic science applied in arson cases, and which can reveal evidence that can be crucial for establishing whether a crime has actually occurred. This study has demonstrated how the delivery of forensic services can be aligned with the needs of police investigators and the critical early decision making of whether an arson investigation is required. The data collected from forensic fire investigators demonstrated the array of evidence forms that are used in the decision-making process for reaching their determination of the cause and origin of structural fires.

The quantitative analysis of administrative data has proven to be difficult to conduct and resource intensive, requiring a diverse range of specialised and domain relevant knowledge and skills. The contribution of forensic science to the criminal justice system is complex and multifaceted, and although quantitative analysis of administrative data can produce valuable empirical data on the relationships between forensic evidence and criminal justice outcomes, other methods must also be applied to capture qualitative information which can uncover the nuances of how forensic evidence is used and which must be recognised to fully evaluate the effectiveness of forensic science.

This research has shown chemical trace evidence to be a forensic discipline that is used and valued by police investigators to support their criminal investigations. This finding is in clear contrast to prevailing perceptions in the forensic community that the value of chemical trace evidence is limited to the court phase. This finding demonstrates the danger that forensic service providers are faced with when they lack a sound knowledge of the use and impact of their services. The unavailability of empirical research on the impact of many forensic evidence forms, which can be used to guide the strategic delivery of services, is currently a critical weakness in optimising the effectiveness of forensic science.

Appendices

Appendix A – Survey questions

Introduction

This survey is a component of a study which is aimed at examining the impact of forensic evidence on:

- criminal investigations; and
- court proceedings.

The project is being conducted by the Victoria Police Forensic Services Department (VPFSD) in partnership with the University of Tasmania and is part of a project that has been approved by the Victoria Police Research Coordinating Committee and the VPFSD Office of the Chief Forensic Scientist. It is anticipated that the surveys and the project in general will provide valuable information to support the strategic deployment of forensic services, with the potential to deliver benefits to policing, the courts and forensic services. Participation in this survey is voluntary. However, the support that you are providing by completing this questionnaire is greatly appreciated.

Regards

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Measuring the impact of Forensic Science on police investigations & court trials

Instructions

The survey consists of three parts with a total of 26 questions and is expected to take approximately 20 minutes to complete.

For Parts A and B, please answer the questions in relation to the case specified in the accompanying e-mail. For Part C, please answer the questions with regard to your opinions on forensic science services and chemical trace evidence in general.

When complete, please return the survey to peter.woodman@police.vic.gov.au

Should you experience difficulty in answering any of the questions, assistance can be obtained by telephoning Peter Woodman on 9450 9818 or 0400 687 401 or by email to peter.woodman@police.vic.gov.au.

PART **A**

The purpose of Part A of this survey is to capture information relating to:
(1) The particulars of a specific incident that was investigated; and
(2) The outcome of the related criminal justice processes.

This survey is specifically looking at investigations that inclu ded some form of chemical trace evidence. Note that chemical trace evidence includes the following examination types:

- Paint & other polymers
- Glass
- Fibres & textiles
- Gunshot residues
- Chemical irritants (e.g. capsicum spray)

1. Please enter the details provided in the email that identify the case on which you are basing your answers in this survey.

- VPFSD Case No.
- Survey file No.

2. Were you the lead investigator or a main investigator in this particular case?

Yes or No

• If **Yes**: **proceed to question 3** and complete the series of questions specifically in relation to this investigation.

• If **No**: please provide the following details of the lead investigator in this case (or another member familiar with the case);

- Name of lead/main investigator
- Registered No.

3. Has the investigation of this case been finalised?

Yes or No

4. Were any forensic services, in addition to chemical trace evidence, applied in this case?

Yes or No

If **Yes** indicate which (specify all):

- Audio Visual
- Ballistics or tool marks
- Biology (e.g. DNA)
- Botany
- Clandestine laboratories
- Crime scene (including shoe prints, tyre tracks, etc.)
- Document examination
- Drug analysis
- Fires or explosions
- Fingerprints
- Vehicle examination
- Other VPFSD services (please specify):
- Other non-VPFSD services – e.g. services provided by the VIFM (pathology, toxicology, etc.) or another forensic laboratory (please specify):

5. Were criminal charges laid as a result of this investigation?
Yes or No

If **No**, please **skip to PART B** *(do not answer any further questions in PART A)*

6. In this case, did any defendants plead guilty to the charges?
Yes or No

7. In this case, did any defendants plead not guilty to the charges?
Yes or No

8. Did any defendants change their plea at any stage?
Yes, from not guilty to guilty / No / Other (please specify)

9. Did the case proceed to court?
Yes or No

If **No**, what was the reason for the case not proceeding to court?

10. If the case did proceed to court, what was the outcome?
Note: *Please select the most applicable option.*

- Person(s) accused was/were acquitted
- Person(s) accused was/were found to be guilty
- Some person(s) accused was/were found to be guilty & others were acquitted
- The case went to court but no finding of guilt or innocence was reached
- Court hearings for this case are not yet finalised
- Not applicable – the case did not proceed to court
- Other (please specify)

PART **B**

The purpose of Part B of this survey is to capture information relating to:
(1) The intended purpose of utilising the forensic chemical trace evidence services; and
(2) The influence of chemical trace evidence in determining the final outcome of this case.

It is critical that Part B of this survey is completed and that accurate information is provided. Information captured in Part B will be used to evaluate the actual impact of chemical trace & other forensic evidence on the outcomes of specific cases. The information collected will also assist in assessing the alignment of forensic services with the needs of police investigators.

Please ensure that you answer all questions in Part B **in relation to the investigation specified in the accompanying e-mail.**

11. In this particular case, what was the purpose of lodging samples for chemical trace evidence examination? Did you expect the results may:
Note: *select all that apply.*

- Influence the course of the investigation (i.e. direct the focus towards or away from a particular line of inquiry): Yes or No
- Determine whether to charge a suspect: Yes or No
- Build the case for court: Yes or No

- Provide intelligence (e.g. link together a series of cases): Yes or No
- Other (please specify)

12. Did you anticipate that the chemical trace examinations may:

Note: *select all that apply.*

- Provide evidence that the matter under investigation was a criminal offence: Yes or No
- Identify individuals involved in the crime: Yes or No
- Establish a nexus between suspects and the crime: Yes or No
- Other (please specify)

13. In your opinion, did the results of the chemical trace evidence examinations influence:

- The course of the investigation: Yes or No
- The rate of progress of the investigation: Yes or No
- The decision to charge or not charge suspects: Yes or No
- The offence suspects were charged with: Yes or No
- Whether or not the case proceeded to court: Yes or No
- The plea entered by the accused: Yes or No
- The final outcome of the court proceedings (including the determination of guilt or otherwise): Yes or No
- Other (please specify)

14. In your opinion, how important were the following factors in determining the outcomes of this case?

Choose between a scale of 1 to 5 where **1 = not important at all, 5 = extremely important**

The chemical trace evidence: 1, 2, 3, 4, 5 or N/A

Other forensic evidence: 1, 2, 3, 4, 5 or N/A

- Audio Visual
- Ballistics or tool marks
- Biology (e.g. DNA)
- Botany
- Clandestine laboratories
- Crime scene (including footmarks, tyre tracks, etc.)
- Document examination
- Drug analysis
- Fires or explosions
- Fingerprints
- Vehicle examination
- Other VPFSD services (specify)
- Other non-VPFSD services – services provided by the VIFM (e.g. pathology, toxicology, etc.) (specify)
- Other non-forensic evidence (e.g. witness accounts, admissions by suspects, etc.) (specify)
- An overall lack of evidence
- Other (please specify)

15. With regard to receiving the formal written report in this case [i.e. statement(s) or certificate(s) of expert evidence], were the results of the chemical trace evidence examinations provided within the required turnaround time?

- Later than required
- Within the required time frame
- Sooner than required

16. What were the factors in this case that determined whether the turnaround time for the forensic results was appropriate?

Note: *select all that apply.*

- The results were required for support to an on-going investigation: Yes or No
- The results assisted with the decision of whether to charge a suspect: Yes No
- The results were relevant to an application for bail: Yes or No
- The results were required for service of the brief: Yes or No
- Other (please specify)

17. Did you receive *preliminary* results of the chemical trace evidence before receiving the *formal* written report(s) intended for use in court [i.e. statements o r certificates of expert evidence]?

Yes or No

If **Yes**, select all that apply:

- Yes, verbally (e.g. via telephone)
- Yes, via e-mail
- Yes, in the form of a laboratory report (stating "not to be used in court")
- Yes, other (please specify)

• If you answered **No** to question 17, go to **question 19**.

18. If you answered Yes to question 17, was it useful for the investigation to receive the preliminary results and if so how?

(please specify)

19. Was the value that the chemical trace evidence provided to this case influenced by the timeliness of receiving the results? Did the time taken to receive the results:

- Increase the usefulness of the evidence in this case
- Have no influence on the usefulness of the evidence in this case
- Decrease the usefulness of the evidence in this case

20. Are there any comments that you would like to make regarding this investigation, the forensic evidence involved &/or the criminal justice outcomes of this case?

(please specify)

21. Please complete the following details of this incident.

LEAP incident number
&/or
LEAP sub-incident number

PART C

The purpose of Part C of this survey is to capture information relating to **your opinions about forensic science services & chemical trace evidence in general.**

In answering the questions in this part please consider all your experiences with utilising forensic services and chemical trace evidence.

The questions in Part C **do not relate to a specific investigation.**

Note that chemical trace evidence includes the following examination types:

- Paint & other polymers
- Glass
- Fibres & textiles
- Gunshot residues
- Chemical irritants (e.g. capsicum spray)

22. In general, how do you rate the usefulness of chemical trace evidence for assisting with the following:

Choose between a scale of 1 to 5 where **1 = not important at all, 5 = extremely important**

- Determining the course of investigations
- The rate of progress of investigations
- The decision to charge or not charge suspects
- Determining the offence that suspects are charged with
- Whether or not cases proceeded to court
- The plea entered by accused parties
- The outcome of the court proceedings (including the determination of guilt or otherwise)

23. What do you believe constitutes a suitable turnaround time for the provision of chemical trace evidence results (i.e. sufficiently timely for most cases)?

- Within 2 weeks
- Within 1 month
- Within 3 months
- Within 6 months
- Within 12 months
- Other

24. What are the factors that in most cases determine whether the turnaround time for the chemical trace evidence results is suitable?

Rank the following options from 5-1, in terms of which apply most often **(5 being most often and 1 being least often**).

- Provided in time to support to an on-going investigation
- Provided in time to assist with the decision of whether to charge a suspect
- Provided in time for consideration of an application for bail
- Provided in time for service of the brief
- Other (please specify)

25. As a police investigator, how useful is it to receive *preliminary* results of chemical trace evidence examinations ahead of receiving the *formal* written report intended for use in court (i.e. statements or certificates of expert evidence)?

Choose between a scale of 1 to 5 where **1 = not important at all, 5 = extremely important**

- Verbally (e.g. via telephone)
- Via e-mail

- In the form of a laboratory report (stating “not to be used in court”)
- In the form of an intelligence report (stating “not to be used in court”)

26. Are there any comments that you would like to make regarding forensic science in general and how it can impact on police investigations and court trials?

(please specify)

Thank you for completing this survey.

Appendix B – Survey participant information sheet

THE EFFECTIVENESS OF FORENSIC SCIENCE IN THE CRIMINAL JUSTICE SYSTEM:

"MEASURING THE IMPACT OF CHEMICAL TRACE EVIDENCE ON POLICE INVESTIGATIONS & COURT TRIALS"

This information sheet is for members of the Victoria Police who have been identified as main investigators in cases that are the subject of this study.

1. Invitation

You are invited to participate in a research study that is being conducted by the Victoria Police Forensic Services Department (VPFSD) and the University of Tasmania. The study is examining the impact of forensic evidence on criminal investigations and court proceedings.

In this round of the project, data is being collected for a sample of cases that have utilised the services provided by the Chemical Evidence Branch (i.e. examinations relating to paint, glass, fibres, gunshot residue, etc.). Forensic case records indicate that you are listed as the lead investigator in a case which included an examination for chemical trace evidence. As such it is anticipated that you will able to provide us with valuable information about the use of forensic services and the impact of chemical trace evidence.

The research is being conducted by Mr Peter Woodman (manager of the Chemical & Physical Sciences Group of the VPFSD) and by co-investigators Associate Professor Roberta Julian (Tasmanian Institute of Law Enforcement Studies) and Dr Caroline Spiranovic (Faculty of Law) both from the University of Tasmania. This study is being conducted in partial fulfillment of a PhD for Peter Woodman under the supervision of the co-investigators.

Participation in this survey is voluntary. However, the support that you are providing by completing this survey is greatly appreciated.

2. What is the purpose of this study?

The purpose of this study is to build a better understanding of the use of forensic services by police investigators, the benefits forensic evidence can provide to criminal investigations and the impact that the forensic evidence can have at various stages of the criminal justice system. Having a better understanding of the impact of forensic evidence will potentially lead to improved strategic deployment of forensic services and an increased alignment with criminal investigations and court processes.

3. Why have I been invited to participate?

In this round of the study, data is being collected for a sample of cases that have included use of the services provided by the Chemical Evidence Branch (i.e. examinations relating to paint, glass, fibres, gunshot residue, etc.). Forensic case records indicate that you are listed as the lead investigator in a case which included an examination for chemical trace evidence. As such it is anticipated that you will able to provide us with valuable information about the use of forensic services and the impact of chemical trace evidence.

4. What will I be asked to do?

We would like you to complete a survey which aims to capture information in relation to a specific case for which you were a main investigator and information with regard to your overall perception and opinion of forensic science. The survey is in three parts:

> Part A – questions are directed at the details of a specific criminal investigation and the final criminal justice outcomes for that case.
>
> Part B – questions are directed at the intended purpose of utilising forensic science in the specific case and what influence the forensic (chemical trace) evidence had on the investigation process and the criminal justice outcomes.
>
> Part C – questions are directed towards your opinions on forensic science and the value that it can be provide to criminal investigations and court processes.

5. What will happen to the information that I provide?

All information that you provide will be confidential, including your identity. The information you give will be used for the purposes of the PhD thesis and any publications that may be associated with the thesis itself. Over the course of the study, the survey data will be maintained in hard copy and/or digital form on site at the Victoria Police Forensic Sciences Centre. The Forensic Services Centre is a facility with multiple levels of security including controlled access to the Centre's grounds, 24 hour security guarding and controlled access into & through out the buildings based on electronic key card. The only people that will have access to the information will be myself and my supervisors.

Unique codes will be used to identify survey responses. Completed surveys will not include any original identifying information. Data entry will be conducted by myself, Peter Woodman.

Data will be stored for a maximum of five years and then archived with your permission. If you do not provide approval, your data will either be erased (if virtual) or shredded (if in paper format).

6. Are there any possible risks from participation in this study?

There are no specific risks anticipated with participation in this study.

7. What if I have questions about this study?

If you would like to discuss any aspect of this study please feel free to contact myself, Peter Woodman on (bus) 94509 9818 or (mob) 0400 687 401 or Associate Professor Roberta Julian on (bus) 6226 2217.

This study has been approved by the Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number **H0016013**.

This information sheet is for you to keep. You are asked to sign a consent form. This can be done by typing your name into the consent form and then returning the form by email.

Appendix C – Survey participant consent form

THE EFFECTIVENESS OF FORENSIC SCIENCE IN THE CRIMINAL JUSTICE SYSTEM: "MEASURING THE IMPACT OF CHEMICAL TRACE EVIDENCE ON POLICE INVESTIGATIONS & COURT TRIALS"

This consent form is for members of the Victoria Police who are eligible for this survey because they have been an investigator in a case which has involved the use of forensic services in the form of chemical trace evidence.

1. I agree to take part in the research study named above.
2. I have read and understood the Information Sheet for this study.
3. The nature and possible effects of the study have been explained to me.
4. I understand that the study involves completing a survey in relation to a case for which I was a main investigator. Questions in the survey are aimed at capturing information about the impact of forensic evidence in a specific case and also my general opinions on forensic evidence and the value it can add to criminal investigations.
5. I understand that no risks have been identified for participants in this survey.
6. I understand that all research data will be securely stored on site at the Victoria Police Forensic Services Centre for five years from the publication of the study results, and will then be destroyed unless I give permission for my data to be stored in an archive.

   I agree to have my study data archived.

   Yes ☐ No ☐
7. Any questions that I have asked have been answered to my satisfaction.
8. I understand that the researcher(s) will maintain confidentiality and that any information I supply to the researcher(s) will be used only for the purposes of the research.
9. I understand that the results of the study will only be published in a form such that I cannot be identified as a participant.
10. I understand that my participation is voluntary and that I may withdraw at any time without any effect.

    If I so wish, I may request that any data I have supplied to date may be withdrawn from the research.

VicPol participant's name: _____

VicPol participant's signature: _____

Date: _____

NOTE: **Participants may type in the above information (i.e. name and date) and return the form via email. This will be considered equivalent to signing this consent form.**

Statement by Research investigator

☐ The participant has received the Information Sheet where my details have been provided so participants have had the opportunity to contact me prior to consenting to participate in this project.

Research investigator's name: _____

Research investigator's signature: _____

Date: _____

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