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"*The effective use of forensic science in the investigation of volume crimes in Scotland*"

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Abstract

The use of forensic science in the investigation of volume crimes has grown significantly in recent years. Nevertheless, a number of key reports published in England and Wales have identified important factors which affect the use of forensic science. A review of this literature has evidenced a set of common recurring themes which are shown to hinder the effectiveness of its use. No research of this kind has been carried out in Scotland.

This research investigated the knowledge and perception of the use of forensic science in the investigation of volume crimes in Scotland. A self-administered survey was designed and distributed to the two largest police forces in Scotland (Strathclyde Police and Lothian and Borders Police) and the Scottish Police Services Authority Forensic Services (SPSA FS) units situated in Edinburgh, Glasgow, Dundee and Aberdeen. Approximately 400 surveys were distributed and a return rate of 68% was achieved.

This research has identified that the effective use of forensic science in Scotland is affected by number of important factors. Factors such as a lack of communication and poor information exchange, timeliness, limited forensic training and poor forensic knowledge, inadequate interagency relationships and poor use and deployment of resources hinder criminal investigations. The varied perception of crime scene examiners (CSEs) was also found to be important. Better understanding of the role of forensic science as well as how the interactions – the communication, the collaboration, and the mutual exchange of knowledge and information – between investigative organisations affect its use are considered by this research.

Declaration

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree. The copyright of this thesis belongs to the author under the terms of the United Kingdom Copyright Acts as qualified by the University of Strathclyde Regulation 3.51. Due Acknowledgement must always be made of the use of any material contained in, or derived from, this thesis.

Signed: *Date:*

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Publications and Presentations Related to this Research

Publications

Ludwig, A & Hill, L. (2009) *Forensic Science Research & Practice*, Joint meeting of the Scottish Institute for Policing Research and the Centre for Forensic Science, Strathclyde University, Glasgow, Science & Justice, Vol. 49, pg. 230–5

Fraser, J. & Ludwig, A. "*Forensic Science in Scotland*" in Policing Scotland (2nd Ed), D. Donnelly and K. Scott (Eds), Willan Publishing. (2010)

Oral Presentations

Ludwig, A. "*Exploring the use of forensic science in Scotland*", 5th European Academy of Forensic Science Conference (EAFS), Strathclyde University, Glasgow, 8-11th September 2009

Poster Presentations

Ludwig, A & Fraser, J. "*The Integration of Investigation and Forensic Science in Volume Crime*" Scottish Institute for Policing (SIPR) Research Second Annual Conference, Murrayfield Stadium, Edinburgh, 2nd September 2008

Ludwig, A & Fraser, J. "*The Integration of Investigation and Forensic Science in Volume Crime*", Research Evaluation & Interpretation – Forensic Science Society (FSS), AGM & Annual Conference, Wyboston Conference Centre, Wyboston, 31st October 2008

Ludwig, A & Fraser, J. "*Effective use of forensic science: Preliminary survey results*", 5th European Academy of Forensic Science Conference (EAFS), Strathclyde University, Glasgow, 8-11th September 2009

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Abbreviations

ACPO	Association of Chief Police Officers
ACPOS	Association of Chief Police Officers Scotland
AFR	Automated Fingerprint Recognition System
BCU	Basic Command Unit
CAST	Centre for Applied Science and Technology (*formerly known as HOSDB*)
CHS	Criminal History System
CJS	Criminal Justice Service
COPFS	Crown Office and Procurator Fiscal Service
CRFP	Council for the Registration of Forensic Practitioners
C/S	Coaching/Shadowing
CSEs/CSIs	Crime Scene Examiners/Investigators (*see also VCSE & SCI*)
CSMs	Crime Scene Managers (*see also SSM*)
CTM	Contact Trace Material
DC/DS	Detective Constable/Detective Sergeant
EAFS	European Academy of Forensic Science
EC	Evidence Collectors
FI	Forensic Investigators
ENFSI	European Network of Forensic Science Institutes
FIND	Facial Imaging Database
FOA	First Officer Attending

FP Examiner	Fingerprint Examiner
FSS	Forensic Science Service
FSSoc	Forensic Science Society
FT	Formal Training
HB	Housebreaking (*theft by housebreaking*)
HMIC/S	Her Majesty's Inspectorate of Constabulary/for Scotland
HO	Home Office
HoCSCST	House of Commons Select Committee on Science & Technology
HOLAB	Home Office Laboratory Submission Form
HOSDB	Home Office Scientific Development Branch (*see also CAST*)
IO	Investigating Officers
KS-TEST	Kolmogorov-Smirnov test
LCN DNA	Low-copy number DNA analysis
MV	Motor Vehicle
NAFIS	National Automated Fingerprint Identification System
NAS	National Academy of Sciences
NDNAD	National DNA Database
NFRC	National Footwear Reference Collection
NIFL	Northern Ireland Forensic Laboratory
NIJ	National Institute of Justice
NPIA	National Policing Improvement Agency
OTJ/OJ	On-the-job
OLP	Opening-lockfast-place

PC/PS	Police Constable/Police Sergeant
PF	Procurator Fiscal
PI/PM	Performance Indicator/Performance Management
PoW	Place of Work
SA	Specialist Advisor
SCDEA	Scottish Crime and Drugs Enforcement Agency
SCI	Serious Crime Investigator
SCRO	Scottish Criminal Records Office
SFSLG	Scottish Forensic Science Liaison Group
SLT	Submission Lead Time
SIO	Senior Investigating Officer
SIPR	Scottish Institute for Policing Research
SOCA	Serious and Organised Crime Agency
SOCIMS	Scenes of Crimes Information Management System
SOP	Standard Operating Procedure
SPC	Scottish Police College
SPSA	Scottish Police Services Authority
SPSA FS	Scottish Police Services Authority Forensic Services
SSMs	Scientific Support Managers
SSA	Scientific Support Advisor
SWGMAT/ TREAD	Scientific Working Group for Material Analysis/Shoeprint and Tire Tread Evidence
SWIM	Scientific Working Improvement Model
TWOC	Taking-without-owners-consent

UFSE	"Using Forensic Science Effectively"
UTM	"Under the Microscope"
VCSE	Volume Crime Scene Examiner
YoS	Years of Service

Glossary

Attrition	The gradual loss of activity or output at different stages in a process. More crimes are committed than are effectively disposed of (via a variety of methods) and this is caused by the loss of valuable data or evidence at specific stages of the investigation.
Blanket attendance	The attendance, by an investigating office or CSE, of every crime reported. Blanket attendance policies do not use screening mechanisms to assess the value of attending the scene.
Crime desk	An information centre which contains resources with a mix of administrative and investigative duties: e.g. taking incoming calls, recording information regarding an incident as reported by the public, investigate crime when police presence at scene is not needed.
Crime of dishonesty	A category of crime types used in Scotland which include all thefts including theft by housebreaking, theft by Opening Lockfast Places (OLP), Thefts of and from motor vehicles, shoplifting, fraud and so on (*see also Volume Crimes*).
CSE	An individual responsible for the examination of incidents and the recovery of forensic evidence in police investigations. CSEs are also known as Scenes of Crimes Officers (SOCO), Crime Scene Investigators (CSI) or Scientific Support Assistant (SSA)

Culture	A pattern of shared ideals (traditions, values, symbols, beliefs, meanings, etc.) within a group of individuals which affect the actions and perceptions of those individuals.
Detection rates	Cases where police determine a crime has occurred, evidence is collected, suspect is charged.
Deterrence	A disincentive towards committing crime for the increased fear of getting caught.
Discretionary attendance	The attendance of scenes which has been evaluated (screened) by a tasking officer or call centre operator and determined to be valuable or which meets specific criteria. Not every incident is necessarily attended (immediately or at all). Can be a means of managing resources.
Effectiveness	"Doing the right thing". The extent and quality of the match between specifically defined objectives (actions, goal, procedure, service, etc) and their achievement.
Efficiency	"Doing things right" The ability to achieve the desired outcome without wasting (or minimal expenditure of) resources, energy, time or money.
Explicit knowledge	Information which can be recorded, expressed, shared and communication with relative ease and is often contained within documents, manuals, standard operating procedures or other direct instructional documents.

Fingermarks	Impressions recovered from the scene of an incident. Often fingermarks are invisible (latent) or deposited in another substrate (e.g. blood).
Fingerprints	Impression of the ridges (prints) of the fingers of known individuals. Previously, fingerprints were collected using ink and paper, however modern technology now allows the capture of prints using electronic terminals
Forensic Awareness	A basic understanding that a form of evidence (may or may not be of value) is present, useable or important to an investigation.
Forensic Knowledge	A thorough understanding of the potential contribution of something (e.g. evidence) as well as an ability to conceptualise and explain important aspects (e.g. limitations). Forensic knowledge is gained by experience and training, and should provide a true understanding of the value and use of evidence
Forensic intelligence	The collection, analysis and evaluation of forensic evidence and information about offenders and crimes, which can be used in an investigation. Intelligence is often used to link crime scene or offenders as well as providing knowledge which can be used for future activities or investigations.
IDENT1	A national software program which contains several police biometric databases, including the national fingerprint database, the PALMS database and FIND (facial imaging database).

Identification	The classification of evidence which determines a common source – e.g. the stain present at a crime scene was identified to be blood. (*Identification can also be used to describe the process of establishing and confirmation of the identify of an offender*)
Individualisation	The identification of evidence to a local source – individual, object or substance, (e.g. the DNA profile from the bloodstain recovered from the scene was matched to the DNA profile of an individual).
Livescan	Technological equipment used to electronically capture fingerprints and palm prints. Livescan terminals are used to electronically transfer of prints to the IDENT1 database for comparison.
Mutual Knowledge	Knowledge that is held and shared (or communicated) between different individuals which is known to be accurate and necessary by both parties to fulfil their roles effectively.
NPIA	A UK non-departmental body which provides support to the police in areas such as information technology, professional development, operational standards, recruitment and training.
Perception	The process by which individuals give meanings to the environment and form views or opinions on a specific subject or person (which can determine their behaviour) based on impressions and information collected (or lack of).
Proactive investigations	Proactive investigations are targeted actions prior to the occurrence of an event. Often involves the use of intelligence and can target crime hot spots.

Reactive investigations	Reactive investigations typically occur in response to an event. For example a member of the public brings an offence to the attention of the police).
Tacit knowledge	Knowledge which is obtained from experience, observation or direct action, which is often shared (communicated) verbally and directly between individuals. It is knowledge which cannot easily be articulated and is often used in conjunction with explicit knowledge. Remembering how to ride a bike is an example of the use of tacit knowledge.
Theft by housebreaking	The illegal entering into the property of another, with the intention to commit theft.
Utility	The importance of the contribution of forensic evidence and the extent to which it accurately meets the needs of an investigation (its progression and outcome).
Volume crimes	Crimes of a less serious nature which occur frequently and consequently make up the majority of offences recorded in official crime statistics. They most commonly include domestic burglaries, vehicle thefts and thefts from vehicles, and are categorised as crimes of dishonesty in Scotland.

Chapter 1: Introduction

The reliance on forensic science in police investigations has become increasingly important over the last century [1-5]. Police use forensic science as investigative support and it is routinely employed in the investigation of many crime types. Forensic science often involves the recovery and analysis of evidential material available in connection with a crime from a scene and forensic scientists interpret the results from an analysis to provide intelligence and information to the police and to a case in general [6]. Forensic evidence "*attempts to uncover the actions or happenings of an event* [...] *by way of (1) identification (categorization), (2) individualization, (3) association, and (4) reconstruction*" [7]. Therefore, forensic evidence has the potential to help to identify and prosecute individuals responsible for criminal activities as well as eliminate victims, witnesses and other innocent individuals [5, 6, 8].

Forensic material can not only identify an individual (e.g. fingerprints, DNA), it can provide intelligence (e.g. footwear marks, toolmarks) to link separate crimes to the same offender(s) and it can link a suspect to a particular scene (e.g. fibres, hairs, glass) [5, 9, 10]. Evidence from a crime scene can also confirm or refute intelligence already obtained, reconstruct events, corroborate other evidence or provide further intelligence for investigations to follow (e.g. identifying alternative lines of inquiry, providing secondary evidence for convictions) [8, 11]. Where such evidence is missed, overlooked or absent, the identification of an individual becomes more difficult and police officers use traditional means of police work to achieve the identification of suspects [12].

Undoubtedly, the "*significance, influence and visibility*" of forensic science has grown significantly [13]. Forensic science is no longer limited to the use in serious crime investigations, but is also used in less serious (high-volume) crimes [5, 14-19]. The introduction of intelligence databases (e.g. the National DNA Database, the

Scottish DNA database, the National Automated Fingerprint Identification System, and IDENT1) as well as many other technological advances have meant that availability of forensic science is no longer restricted to local areas only [9]. However, forensic science continues to be used in different ways by police forces [12].

The investigation and prosecution of a crime requires the effective collaboration of several interdependent criminal justice organisations. Investigations are inherently complex and the extent of the involvement of different organisations may vary [20, 21]. The separate elements (e.g. roles and responsibilities) of each agency must be recognised and incorporated effectively into the criminal justice system [5, 14, 15]. Knowledge and understanding of each individual role, as well as the processes involved in the investigation, is also required [16-19, 22]. The three main organisations involved include the police, forensic service providers and the prosecuting authorities in Scotland. The interconnected nature of this tripartite relationship is shown in figure 1.

At each stage of an investigation a number of interactions occur which can have an effect on the process and on the outcome. Variations in the levels and quality of knowledge, understanding, collaboration and communication have been shown to influence the investigation [21]. The effective use of forensic science is also affected by a number of other factors which include resource availability, training and timeliness at each stage of the system [16, 18, 23]. This is further complicated by a widespread and varied understanding of the roles of particular members of the investigative team and the different perceptions of their responsibilities [24].

This research will consider forensic science as a specific part (or stage) of the larger system that is the investigation and prosecution of crimes (the criminal justice system). Early management theorists determined that for a system to be effective a complex task must be broken down to "*optimise performance of the subtasks*" [25]. A system was described as the collection of a number of different (or separate) parts which should work together collectively to achieve an overall goal [26-29]. Any

activity at one part of the system can have an effect on the other parts [30]. However, the extent to which this happens may vary as some parts may be more influential than others. The systems approach to management recognises the involvement of a complex mix of people, processes, tasks, technology, as well as organisational and cultural elements which are interconnected and form part of a larger environment [30-33].

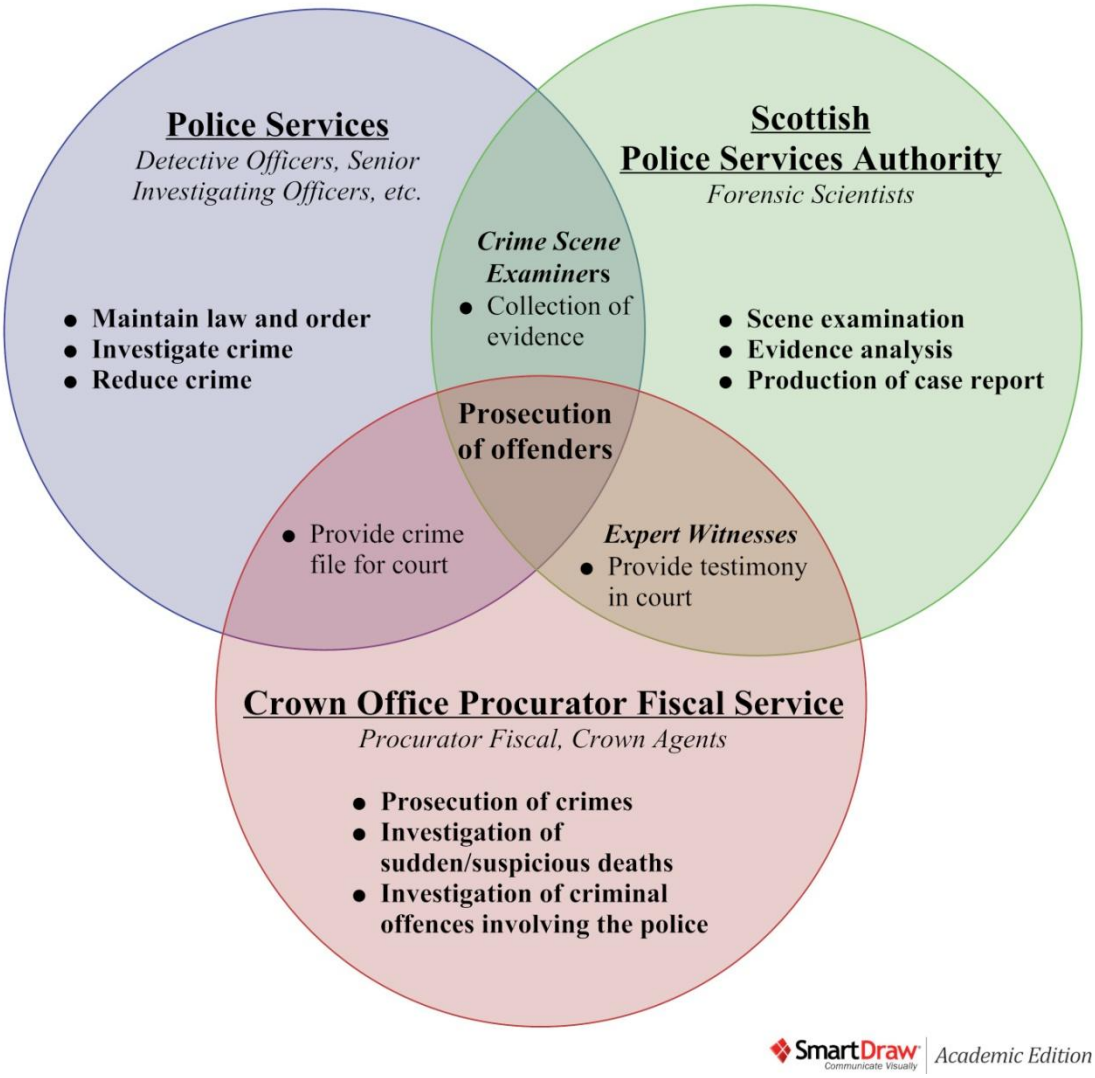

Figure 1: **The relationship between police, forensic service providers and prosecuting authorities.**

The Criminal Justice System (CJS) involves a number of different organisations and is split into various parts (or stages). At each stage of the investigation a number of processes occur. These can be described as a set of activities or events which are designed to produce a specified output (or result) and often occur in a specific sequence (e.g. the analysis of surfaces for latent fingermarks) [34, 35]. The analysis of the different stages and the processes involved can be used to understand the effectiveness and efficiency of the system as a whole [25].

Using the systems approach to evaluate the use of forensic science, specific processes can be analysed which allow a sequence of steps to be established. This also allows the relationships between individuals involved to be illustrated as well as analysing the relationships between internal and external roles and responsibilities [29, 36]. Other factors which reduce the efficiency and effectiveness can also be highlighted, including resource bottlenecks, ineffective policies, poor information management systems, limited knowledge of practices, etc. [37]. "*The significance and influence individual roles, in supporting or inhibiting effective outcomes, is also more evident following process analysis*" [11].

Organisations ought to be able to "*set and achieve their objectives by planning, organising and controlling their resources"* as well as optimising their relationships with partners and stakeholder [31]. For forensic science to have maximum impact on the contribution towards an investigation, Touche Ross [18] stated that investigative needs must be identified and competent staff must be deployed to achieve specific objectives at appropriate times. Process flowcharts were used in this research to analyse the various stages, task and sub tasks involved in investigations of volume crimes using forensic science. Although the system as a whole is interconnected, each agency has its own responsibilities, working practices and management [38]. At each stage of the investigation, where decisions are made, information is exchanged or communicated, when there is a requirement for collaboration and a demand for knowledge [39] – the effectiveness and efficiency of the different stages of the investigation are affected [30]. The impact of these themes (or barriers) will be considered in more detail in chapter 2.

1.1. Project Aims

The aims of this research were:

1) To review the current use of forensic science in volume crime in the UK by analysing the current academic literature, government reviews and other relevant reports. From this review, to identify factors that enable the investigative use of forensic science and understand the barriers to effective use of forensic science in volume crime.

2) To assess the previous recommendations stated by the literature to improve the effective use of forensic science and to determine if these have been implemented or been successful in facilitating change.

3) To explore the use and value of forensic science in Scotland for the investigation of crimes of theft by housebreaking including:
    a. The extent of use and the evidence types involved in an investigation
    b. The level of knowledge and understanding of forensic science by investigative staff
    c. Role perceptions of CSEs
    d. The sources of advice used by investigative personnel.
    e. Amount and type of training received by all individuals involved in an investigation
    f. Level of collaboration amongst investigative staff in investigations

4) To identify areas where improvements could be made to the use of scientific support services in criminal investigations by police, forensic scientists and the legal community in Scotland.

This will provide an evidence base for developments of polices and working practices, identify mechanisms for more effective use of forensic science in crime investigation, and inform the training of all investigative staff (police, scientists and CSEs).

1.2. The investigation of crimes

That forensic science plays a critical role in investigations has been recognised for some time [12, 16, 19, 23, 40]. Since the 1980s, studies into the use of forensic science have focused attention on specific aspects or stages of the process [12, 14]. This has resulted in a "*phase specific*" (or patchy) interpretation of the information available and have failed to address effects on the system as a whole [23, 41]. The literature that is available is diverse; and each publication has different aims and assessment criteria. The investigation of a crime (whether serious or volume) includes a number of well established (often sequential) steps. It also requires the participation and collaboration of a number of different individuals, roles and organisations at various stages that necessitate effective management and control [41, 42].

Figure 2 provides a simple schematic of the sequential nature of a small part of an investigation using forensic science (which is described in more detail in Appendix 1). It highlights the potential outcomes at different stages and indicates some of the interactions between organisations. It is the analysis of the barriers or themes (e.g. timeliness, resourcing) which affect the efficient use of forensic science which are considered in this research [14, 16, 18, 43].

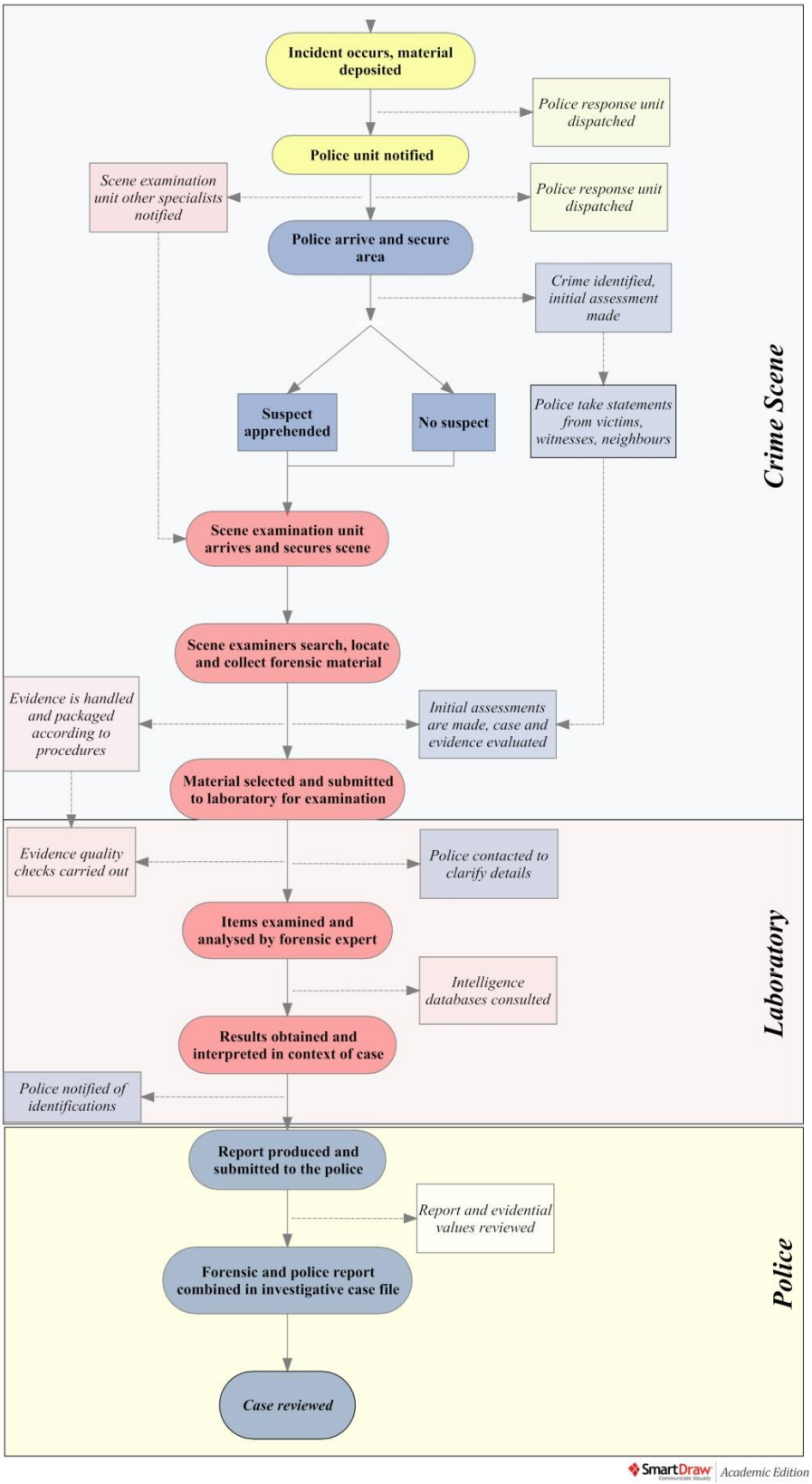

Figure 2: Schematic of parts of the investigation of volume crimes involving forensic science.

The management of the investigative and prosecution process (from criminal incident to case disposal) has previously been discussed in England and Wales, which consider the role of forensic science [14, 37, 44]. Bottlenecks and barriers were identified hindering the use of forensic science and a number of recommendations for improvements were made (and some implemented) [37]. Similar work evaluating the effects of forensic science has not been carried out in a Scottish context. Forensic evidence is frequently collected and analysed for a wide range of crimes, however the effects this has on the overall outcome of an investigation is unknown [45]. This work aims to begin to address this issue in Scotland.

1.2.1. Effectiveness and efficiency

The management literature states that effectiveness is 'doing the right thing' and efficiency is 'doing things right' [46]. "*Effectiveness*" is defined as the extent and quality of the match between specifically defined objectives (e.g. actions, goals, procedures, services) and achieving the expected outcome or requirements [47, 48]. The ease (degree of accuracy, speed, etc) with which an action achieves the desired result cannot be assessed without exploring 'efficiency' [49-51]. "*Efficiency*" measures the volume of inputs against outputs in terms of amount of resources, energy, time or money required to complete the task (results achieved versus resources used) [47-49]. Therefore, better efficiency is achieved when unnecessary actions are eliminated [48, 49, 52].

1.2.2. Attrition

Effectiveness and efficiency are also closely linked to attrition. Attrition can be defined as the gradual loss of activity or output at different stages in a process [42, 53, 54]. Figure 3 is a simple schematic of an investigation which gives examples of where attrition can occur. Attrition can be used as means of measuring the effectiveness and efficiency of the CJS by calculating the proportion of cases which fail to proceed to the next stage [55, 56]. There are a large number of crimes which are committed, however the number of cases which progress through the system become fewer and fewer until a fraction of the original number of crimes committed end up in court [53, 54]. Attrition is therefore "*the shortfall between the number of crimes reported and offenders subsequently prosecuted*" [57]. The concept of attrition has become increasingly important over the past decade, and the definitions and measures have been standardised [56].

The importance of attrition has been discussed in the past [9, 42, 54] and areas where attrition occurs include:

- The crime response system – the call centre or crime desk[1] which receives the initial notification from a member of the public of an incident must be appropriately resourced with knowledgeable and well trained staff who determine the urgency of the call (or crime) and make decisions about deployment of resources [20, 37].

- Crime Scene Examiner (CSE) workload – increased demand on resources results in CSEs spending a limited amount of time at each scene before being called to the next one [9, 12, 15].

[1] An information centre that has mix of administrative and investigative duties, including taking incoming calls, recording information regarding an incident as they get reported by the public, investigate a crime when police presence is not needed at the scene.

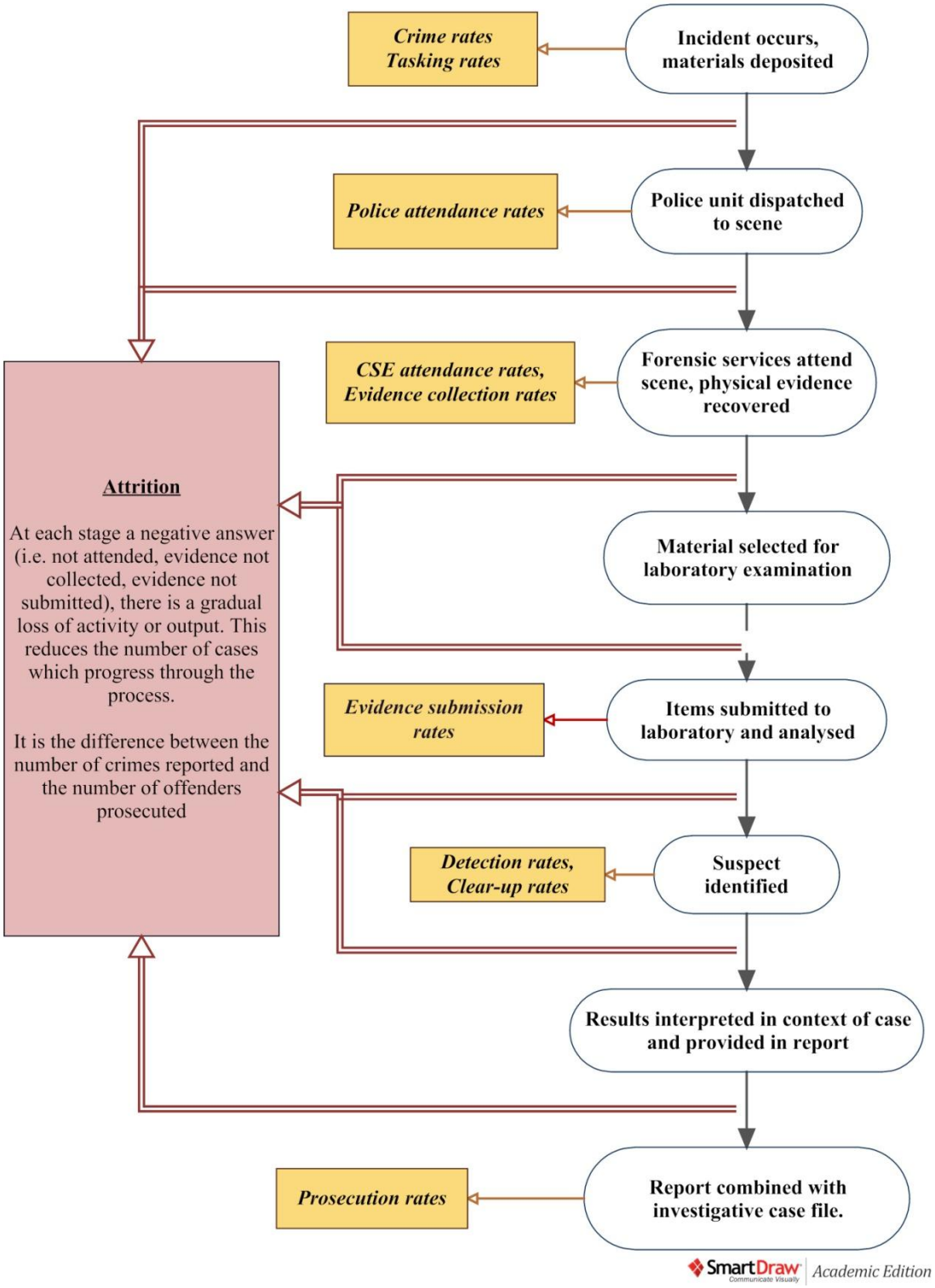

Figure 3**: An example of the attrition of forensic science**

- Application of technology – poor utilisation and adoption of new technologies, techniques or innovations by investigative staff (e.g. LiveScan[2]), potentially resulting in delays.

- Timeliness – the failure to act in a timely manner at specific stages of the investigation can affect whether specific processes can achieve desired results. For example, the likelihood of the recovery of stolen goods is reduced or the results of the forensic analysis are no longer required as the case has been solved via other (often traditional) methods [42].

- Evidence submission procedures – limited training results in poor forensic science awareness in terms of the capabilities and limitations of specific evidence types [42, 54]. The utility of forensic evidence is not sufficiently understood to be able to determine the optimum evidence to submit for analysis in the given circumstances [14].

- Evidence conversion – intelligence attained from forensic services are often not utilised effectively by police forces to further the investigation [40, 54].

1.3. Forensic Science in the UK

Many of the studies from England and Wales reviewed in this thesis were published at a time where the provision of forensic services reflected more closely the current situation in Scotland (i.e. prior to the privatisation of the Forensic Science Service). With this similarity in mind, a comparison of the results of the literature from England and Wales can be made which can be useful for evaluating the emerging environment in Scotland. More current models of forensic science delivery in

[2] An electronic platform which allows the inkless collection of fingerprints from a crime scene which are uploaded and compared to the database in real time.

England and Wales and other jurisdictions are significantly different from Scotland and must also be considered [58, 59].

1.3.1. England & Wales

Developments in forensic science have differed between England and Wales and the rest of the UK terms of the provision, demand and financial support. England and Wales remains the only jurisdiction where forensic services are largely supplied by private sector organisations [58, 59]. The provision of forensic services has undergone a number of changes, from the sole service provision via the Forensic Science Service (FSS) to all forty-three police forces in England and Wales (except the Metropolitan Police Force who had their own Forensic Science Laboratory), to an Executive Agency of the Home Office and then a privatised government owned company, to a free market situation [59-61]. This increased the competition from other private forensic providers giving all forty-three police forces a range of service providers and a negotiable price market [19].

A recent review (2011) of the FSS stated that it held approximately 60% of "*market share in forensic science provisions*" in England and Wales (approximately 120,000 cases a year) and assists a large number of countries around the world with specialist services which include "*consultancy, training services, systems and databasing technology and casework*" [59]. However, most recently, the Home Office announced the closure of the FSS at the end of 2012, which undoubtedly will cause further changes to the provision of forensic services in England and Wales with knock-on effects on the rest of the UK and possibly Europe [59]. However, the direct impact of the closure of the FSS on how forensic science will continue to play a role in an investigation is difficult to predict and will need to be assessed in future research.

In England & Wales, the UK government has implemented a body in charge of setting quality standards (termed the 'Forensic Science Regulator[3]'). The Regulator has established specific quality standards for the supply of forensic science in the "*investigation, prosecution, and conviction of offenders*" [62]. It is recognised that the absence of a system of quality checks (or standards) has added to the complicated interaction between police and forensic service providers. It is expected that the regulation of national quality standards in forensic science will enhance the quality of service of the justice system to ensure confidence is maintained in the reliability of forensic science in court [62]. Although the Regulator only has direct jurisdiction in England and Wales, the authorities in Northern Ireland and Scotland have agreed that national UK wide standards relating to forensic science quality assurance are "*highly desirable*" and will be supportive of changes implemented [62].

1.3.2. Scotland

The Crown Office and Procurator Fiscal Service (COPFS), as the independent prosecution authority, is responsible for the investigation of suspicious, sudden or unexplained deaths, as well as investigating criminal offences [63]. COPFS works in cooperation with the Association of Chief Police Officers in Scotland (ACPOS) and the local police forces. In Scotland, the eight police forces carry out initial crime investigations on behalf of the Procurator Fiscal (PF) [63]. The PF receives the report of the investigative findings, and on the basis of the evidence, determines whether to take further action and prosecute or otherwise. Only in very serious crimes does the PF attend the scene of the incident. It is the PFs responsibility to review all evidence (forensic or otherwise) prior to case going to court to ensure sufficient evidence is available [11]. Before 2000, service provisions were focused on local requirements (e.g. individual Forces, and PF offices) causing a large degree of variation in prosecution policies and practices. However, as a single national

[3] From herein referred to as the Regulator

organisation, a level of consistency is intended via stronger relationships and closer management of all organisations involved [11].

1.3.2.1. The Scottish Police Services Authority

The provision of forensic services underwent a major change in 2007 with the creation of the Scottish Police Services Authority (SPSA). SPSA is an organisation which is independent of the police, although it works closely with forces in the investigation of crimes. It is also responsible for the provision of IT services [64]. Under the Police, Public Order and Criminal Justice (Scotland) Act 2006, SPSA gained the responsibility of the national provision of forensic services in Scotland. The implementation of SPSA Forensic Services (SPSA FS) removed the operational delivery of forensic science from police organisations and has essentially resulted in a single provider, multiple customer environment [65]. The aim of the implementation of SPSA FS was to integrate services which were operating in numerous locations across Scotland into one national service [65].

This has resulted in four forensic laboratories and fingerprint bureaux and eight scenes of crime examination units making up SPSA FS. Each individual SPSA FS unit retained the responsibility for the provision of some forensic services (e.g. scene examination, fingerprint examination) to the surrounding police forces. More specialist service (e.g. toxicology, firearms) were restricted to specific laboratories throughout the country providing a national service for specific (or specialised) forensic evidence examinations [65]. The particular service provided by each of these labs is shown in table 1 and includes the local police forces for which they are primarily responsible.

Table 1 also illustrates the percentage of national scientific case loads each of the four main units in Edinburgh, Glasgow, Dundee and Aberdeen deal with [24]. Recent changes to the management structure and service provision of forensic services within SPSA FS has involved deliberations to provide a national service for all forensic evidence from a dedicated SPSA FS location (e.g. all DNA work to be carried out by SPSA Forensic Services in Dundee for all eight Scottish police forces, fingerprint analysis only occurring at SPSA Forensic Services in Glasgow) [24, 64].

Table 1: Location of the four major SPSA units, the local police forces they provide services for and the specialist services which they supply nationally.

SPSA FS location	Local forces provided for	Specialist national services	% Scientific Caseload *
Glasgow	• Strathclyde Police • Dumfries & Galloway Constabulary	• Document & Handwriting Comparisons • Firearm & Firearm Discharge Residue Analysis	50%
Edinburgh	• Lothian & Borders	• Toxicology	25%
Dundee	• Tayside Police • Fife Constabulary • Central Scotland	• DNA (databasing, criminal paternity and human remains identification)	15%
Aberdeen	• Grampian Police • Northern Constabulary	• Mark Development • Photography • Drugs Analysis	10%

**Figures received by SPSA Forensic Services for calendar year 2008-2009 [24]*

The development of the SPSA established a service which encompasses provision from crime scene to court resulting in a streamlined process. It was hoped the implementation of SPSA could help to improve effectiveness by faster "*timescales*, [better] *use of electronic submissions, better communication regarding case progress and greater use of dedicated points of contact within fiscal offices*" [64]. As well as improving the effectiveness of current cases requiring forensic analysis via a '*one-stop-shop*' [66], SPSA FS was expected to reduce the size of the backlog of cases still requiring analysis [65]. How well SPSA has been in achieving some of these aims has recently been questioned [67-69].

Prior to the implementation of SPSA, the forensic laboratories, fingerprint bureaux and scenes of crimes unit mainly worked independently of one another, with limited collaboration. A number of different procedures, working practices, professional guidelines were evident between labs, bureaux and SoC units. The implementation of SPSA aimed to standardise the management of all forensic service provisions in terms of nationally agreed policies and practices [65].

However, variations in resources, crime levels, experience, etc. continue to exist due to previous connections with specific police forces [11]. Local priorities previously determined resources levels available at each laboratory and lack of management from a single authority has resulted *ad hoc* developments driven by individual organisations' desires and aspirations with limited cooperation between investigative organisations (e.g. police and laboratories) [11]. Previous attempts to develop national standards by the Scottish Forensic Science Liaison Group (SFSLG) in Scotland had failed due to these reasons [65].

The investigation of a crime is often complex and dynamic [5, 41]. It has been suggested that by placing all of the established forensic science units under one umbrella organisation, and implementing standardising policies and practices throughout Scotland, more unified investigations involving forensic science could occur [65].

1.3.2.2. The Forensic Science Gateway

As well as the introduction of SPSA, the Forensic Science Gateway[4] was developed in Scotland. The Forensic Gateway is a functional unit within each of the eight police forces[5] working together with the COPFS and the SPSA forensic units. As the access point for all cases requiring forensic examination submitted to SPSA by the police, the Gateway's main purpose is to provide a "*system for the assessment and delivery of forensic services within the criminal justice system*" [70].

The Gateway seeks to manage the caseloads of laboratories by restricting the number of productions submitted for analysis. This was to be achieved by evaluating the evidence of a case and "*screen*[ing] *irrelevant submissions out of the system before presentation to the relevant laboratory*" [71]. Consequently, only cases which warrant continuation for forensic examination are recommended for analysis. The Gateway aims to consider all requests from police in accordance with the case and force priorities in relation to all other evidence submitted and determine a realistic timescale in which results can be obtained to meet the resource availability of the laboratory as well as the time requirements stipulated by the police or PF [70].

Primarily driven to enhance Scottish forensic service efficiency, the Gateway was developed to promote the working relationship within the criminal justice community and it was proposed to be used to monitor agency compliance [70]. The relationship between the Forensic Gateway, the police and the SPSA units is shown in figure 4.

[4] From here-on in the Forensic Science Gateway will be referred to as the Gateway.

[5] A 9th Gateway was set up for the Scottish Crime & Drugs Enforcement Agency (SCDEA).

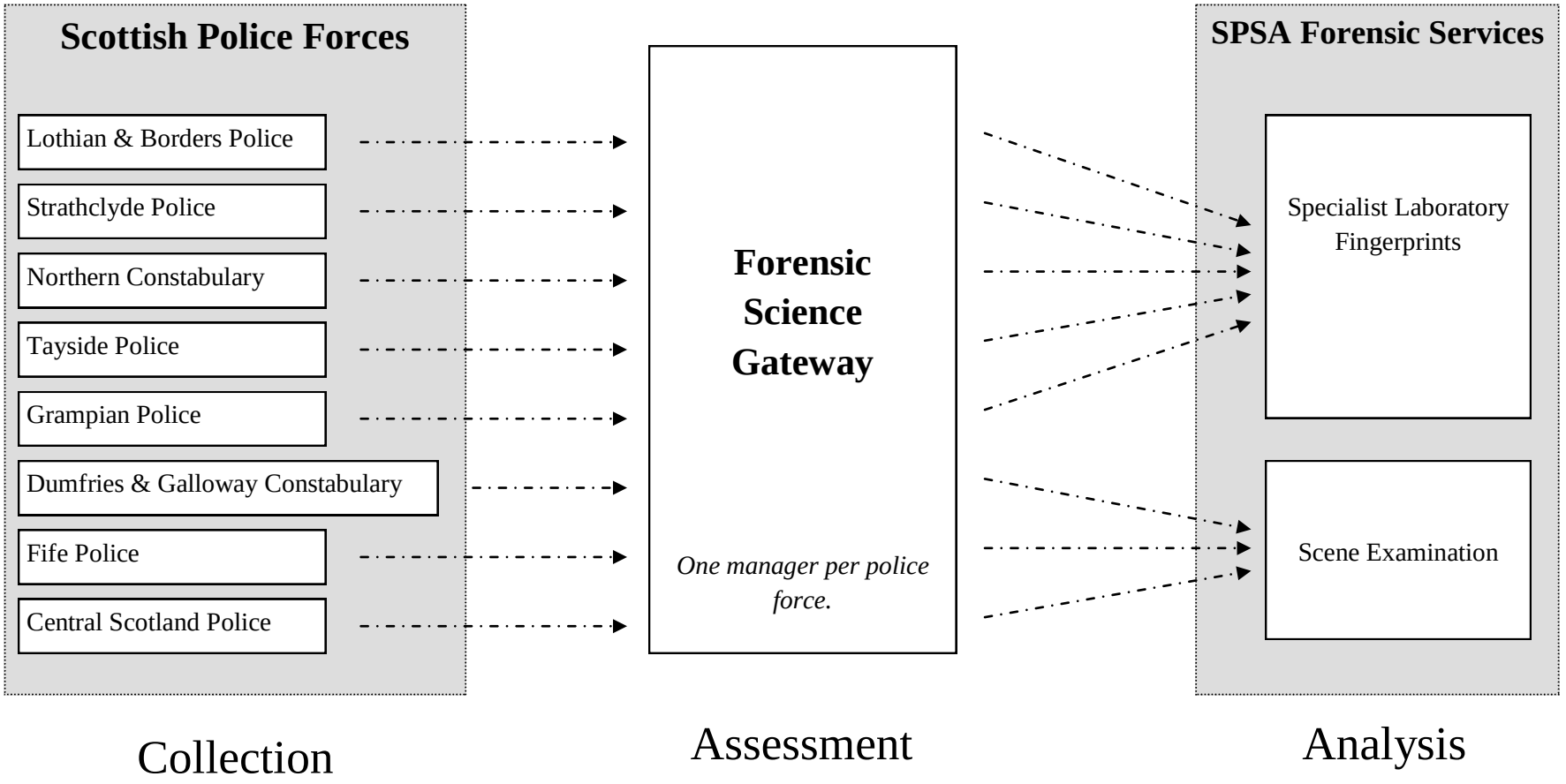

Figure 4: The relationship between police forces and the SPSA forensic services which tracks evidence from collection to analysis.

The implementation of the Gateway system and the redistribution of the national responsibilities for evidence examination to specific SPSA units was hoped to benefit Scottish police forces by encouraging the provision of flexible services which meet the needs of police and forensic service providers [70]. However, it has emerged that the Gateway is not being utilised in the way it was expected and that a number of different types of systems have developed across the country [24]. This research aims to evaluate whether the Forensic Gateway is being utilised effectively by investigative personnel.

1.4. Crime classification

A crime is defined as "*an act* [or omission] *punishable by law*" [72]. Scots Law allows crimes and offences to be divided into separate categories, where crime is used for more serious criminal acts and offences refers to less serious criminal infringements. This is mainly for statistical recording purposes and the Scottish Executive has implemented a detailed classification code of all crimes and offences, which totals about 360 codes for the collection and analysis of criminal statistics [73, 74].

When analysing crime statistics, consideration must also be given to the fact that not every incident which occurs is reported to the police [75]. The Scottish Crime and Justice Survey suggests that 64% of incidents are reported to the police, following a steady increase of crime reporting throughout the past decade [75]. There may be a number of reasons why victims will not report an incident to the police, including that they feel it is too trivial for the police to take any action [75]. Although all UK forces now use computerised crime logging systems, variations in procedures and practice for recording offences may still be evident between different forces and different areas [73].

Table 2: Criminal offence classification and crime types included in each class

Classification	Crimes included in category
Crimes of Violence	(Culpable) Murder/homicide (attempted) Causing death by dangerous driving Serious assault Assaults with intent to rob Child neglect Robbery
Crimes of Dishonesty	(Attempted) Theft by house-breaking (with intent) Theft from a motor vehicle (MV) Theft by opening-lockfast-place (with intent) –MV/non MV (Attempted) Theft of motor vehicle and contents Fraud, Forgery Theft
Public Order Offences	Breach of peace Vandalism Perverting/defeating/hindering the cause of justice Giving false information to the authorities False accusation Resisting arrest Obstruction of police officer Treason, Perjury

Crimes will first be classified when they are reported to the police call handler, where they will be recorded onto the central force management system [76]. This often includes basic descriptions of the proposed sequence of events surrounding the incident as well as all other actions taken since (e.g. police unit deployed). At this early stage, the initial decisions are taken whether the circumstances described should be recorded as a crime or some other type of incident and whether specialist services (e.g. forensic services) should be called to attend [44].

For historic reasons criminal offences tend to be split into two categories: serious (or major) crimes and volume crimes. Previously, forensic science was used predominantly only in serious criminal offences. Such cases tended to have better clear-up rates than all other crime categories [77]. Scots law classifies offences in relation to their distinct criminal procedure: either 'solemn' or 'summary' procedures. Solemn cases involve more serious offences, are governed by procedure and trials are heard before a jury in the High Court. Summary offences involve less serious crimes and are heard without a jury.

No formal classification system exists which group crimes according to type in Scotland; however some divisions have been established based on common features and organised under headings such as "*Crimes of Violence*", "*Crimes of Dishonesty*", "*Public Order Offences*" and so on. Table 2 lists some of the offences connected to each heading [78].

1.4.1. Crimes of Violence

Crimes of violence (also known as non-sexual crimes of violence in Scotland) include the most serious of offences (i.e. murder, attempted murder, and serious assault). The grave nature of these crimes means police dedicate more time to the investigation and can deploy more resource [79]. In their study, Tilley and Ford [14] found that "*the use of forensic science in the investigation of major crimes appears*

to be relatively well informed and takes place efficiently, the investigative process in volume crime appears [...] *to be less well thought through*". The approximate proportion of crimes of violence has remained consistent over the past decade in Scotland, around 5% of all crimes recorded [79] and there has been an increased focus on improving major crime investigation [80].

1.4.2. Crimes of Dishonesty

Crimes of dishonesty occur more frequently than other crimes types, therefore they are commonly labelled as volume crimes. Limited resources often mean that all these crimes cannot individually benefit from the same level of forensic services as applied to the investigation of more serious crimes [40]. Volume crime investigations must therefore maximise "*the benefits from the limited resources available*" [81]. The categorisation and definition of certain volume crime offences varies slightly between England and Wales and Scotland. Scotland uses different terminology and table 3 compares offences as classified under Scots Common Law to their English statutory equivalent. This study has focused on volume crimes because: they offer a potentially large data sample with a variety of forensic evidence; they are the most common offences; they are typically recidivist offences whereby any improvements could affect crime levels as well as reducing police work-loads; and finally the low conviction rate currently experienced in this data group should persuade the police and the PF of the mutual benefits of the work [82].

Volume crimes currently have a clear-up rate of less than 50% in Scotland [83, 84]. Research published in England and Wales has identified that the percentage of crimes cleared up significantly increased (particularly for burglary cases) when trace evidence was collected and analysed [5, 41]. Therefore, a more effective use of forensic science has the potential to positively affect the investigation of a large number of volume crimes per year. The large numbers of volume crime offences which occur have been shown to have an accumulated effect on a community and the

perceptions of individuals by increasing their fear of crime [75, 85, 86]. Crime such as theft-by-housebreaking (theft HB) are regarded as some of the most serious crimes in this category due to their effects on the victims as it involves an intrusion into their private spaces [87, 88]. Volume crimes, such as theft HB, increase the fear of crime experienced by victims of this offence, and studies have shown that often they can become victims of repeat offences [87, 88].

Table 3: Criminal offences in Scotland and their equivalent for the rest of the UK.

Volume crime offences	
Scotland	**England & Wales**
(*Attempted)* Theft by housebreaking of a dwelling, non-dwelling or business premises (*with intent*)	(*Attempted)* Burglary in a dwelling (*with intent*)
(*Attempted)* Theft by opening-lockfast-place (*with intent*)	(*Attempted)* Burglary of a building other than a dwelling (*with intent)*
(*Attempted)* Theft by opening-lockfast-place of a motor vehicle	(*Attempted)* Theft from a motor vehicle
(*Attempted)* Theft of/from motor vehicle	(*Attempted)* Theft of a motor vehicle/ Taking Without Owners Consent (TWOC)

Improved processing and prosecution of volume crime incidents has a bearing on crime deterrence by increasing the fear of getting caught which may in turn affect the number of volume crimes committed [89, 90]. Langan and Levin [91] identified that often a small number of individuals are responsible for a large amount of crime.

They discussed issues such as recidivism as well as the possible progression from volume to more serious crimes over time [91]. In this sense, they determined that the effective use of evidence such DNA and fingerprint can be used in the investigation of crimes to help identify repeat offenders [91] as well possibly deterring others from committing (further) offences [92].

Touche Ross [18] suggested that for forensic science to have maximum contribution towards an investigation, the investigative needs must be recognised. They also found that in order to achieve specific investigative objectives at appropriate times, dedicated and competently skilled staff are required [18]. The fact that only as little as 20% of an officers' daily time is spent actively investigating volume crimes highlights the necessity to manage that time productively by concentrating on system outcomes, not just process outputs [40, 43].

There has been limited research which addresses the situation in Scotland and it is therefore unsurprising that a recent review found a lack of reliable data on how forensic science is used [93]. This means that the effectiveness of current practice cannot be determined "*on the basis of systematic evidence*" [11]. The research carried out in this project aims to address these issues in a Scottish context. Two factors make this research particularly timely: the changing nature of forensic services in England and Wales, and the restructuring of forensic service provisions in Scotland since 2007. The nationalisation of forensic services and the removal of the operational delivery of forensic science from police organisations was hoped to integrate forensic science better into investigations, improving relationships and communication. Whether this has occurred will be evaluated by this research.

Chapter 2: Literature Review

Numerous reviews, audits, inspections and studies carried out in England and Wales over the past 40 years have identified common themes which have been shown to hinder the effective use of forensic science and some of the specific processes associated with the investigation of crimes [5, 12, 14-19, 23, 37, 38, 40, 41, 76, 87, 94-97]. These studies[6] have examined and evaluated all of these themes repeatedly and have highlighted the suboptimal use of forensic science in the investigation of crimes. It has been shown that for an effective investigation, all work undertaken must be focused and fit-for-purpose as the failure in any part has the potential to lead to missed opportunities, a prolonged investigation wasting resources and at worst the loss of a prosecution and conviction [14, 16, 23].

An analysis has been carried out of the current literature available on the investigation of crimes and the use of forensic science. Most of the literature has been based in England and Wales. Similar work which has been carried out – mainly the United States of America, Australia and the limited amount from Scotland – has also been considered in this analysis. These studies suggest that the themes found in England and Wales were also found elsewhere [6, 98, 99].

Twenty-four studies were reviewed as part of this research. Although a large amount of literature has been published addressing the use of forensic science or the investigation of crimes, these publications are not systematic research studies with robust experimental designs. Strict inclusion and exclusion criteria were not applied [100], however, a number of detailed search terms were chosen to identify literature

[6] For the purposes of ease, the generic term 'studies' will be utilised from here on in as a collective term for all the previously mentioned types of literature (i.e. audits, reports, inspection, consultations). However, when referring to specific types of work (i.e. research studies) the appropriate term will used to describe this particular kind of work.

which could help to address the research aims. An outline of the search strategy (key terms and resources) can be found in Appendix 2.

The themes identified as part of this research are based on the findings from studies published which have a number of different aims, purposes, formats, methodological approaches and samples sizes. Many of the studies focus on short snap-shots in time and lack analysis and rigorous interpretation. The investigation of crimes involves a number of interlinked organisations (and individuals), and this complexity makes it difficult to carry out methodologically robust studies which address a number of different research aims or encompass the system as a whole [5]. A brief review of the main works used in this research can be found in Appendix 3 and Appendix 4 which outlines the aims, methodology, sample sizes, and outcomes of each. Limitations of the studies are also highlighted in the tables in the appendices and detailed throughout this next section.

2.1. Assessment of the previous work – some considerations

The studies used as part of this review were found to contain a number of limitations which required consideration: limited scientific methodological approaches, lack of statistical analysis which evaluates the significance of the findings, analysis of case file data from a limited period of time and location (i.e. sample restricted to a small number of forces). Many of these studies also focus on specific stages of an investigation and fail to address how this impacts the criminal justice system as a whole [38, 76, 87]. This is limiting in that it restricts their applicability, however the information which is contributed for analysis in this research helps to illustrate the range and diversity of issues which are associated with investigations.

One of the main limitations identified from the previous studies published is the restricted availability and access to the appropriate information or data. Much of the data utilised by these studies has been collected for other purposes (e.g. annual

reports, performance reviews). This is less than ideal for research purposes as data needs ought to be defined to meet the specific research criteria prior to collection. Consequently, many of the studies that have been carried out are often restricted by a specific time frame (e.g. a single year) [37, 55, 87, 101] or by the geographical distribution (e.g. a single police force) [9, 15, 38, 55, 76, 97]. The number of methodological approaches with which to collect data is also limited (e.g. questionnaire, case file analysis) [12, 16, 96, 97]. This type of work often means these restrictions cannot easily be avoided.

Many of the studies used interviews (structured, semi-structured, unstructured) in order to obtain data [16, 96, 97, 102]. For example, the Byford report [96] used interviews with police officers to assess the errors made by the investigative staff, the weaknesses in procedures, and the limitations of knowledge of various investigative personnel throughout the 'Yorkshire Ripper' inquiry. Burrows [97] utilised semi-structured interviews to investigate the factors identified which affect case outcomes and Ramsay [16] used the combination of interviews and questionnaires to assess the perceptions of the effectiveness of the FSS (the main forensic service provider in England and Wales at the time of the study). Interviewing allows specific targeting of participants in order to explore general views or opinions of a specific topic [103]. When used in combination with questionnaires, it provides a strong methodological approach as areas of interest arising from a questionnaire can be discussed in detail during the interviews [104].

Other studies reviewed case files, original documentation or crime reports [16, 21, 96, 97]. Burrows *et al*. [42] for example, assessed the policies applied during an investigation by tracking 3,000 volume crime cases from committal to disposal, to calculate the rates of attrition. There are a number of advantages and disadvantages to using case study data. Statistically, the sample selected for analysis should be representative of the population from which it is taken [105-107]. However, as many of the studies are inspections, or audits and not academic research studies, the importance of the statistical robustness, although desirable, is not critical.

Sample sizes varied in many of the studies utilised in this review. Ramsay [16] had by far the biggest collection, analysis and assessment of data at the time of the study. He analysed approximately 600 case files and examined 900 questionnaire responses from police and scientist [16]. However, as random sampling and data normalisation is unlikely to have occurred, the results obtained require careful consideration not to over-emphasise the meaning of results [105-107]. Although limiting some of the findings (in terms of their representativeness), the information available is useful for identifying some of the issues encountered in investigations involving forensic science which partly build the basis for the research carried out as part of this project.

McCulloch [12] assessed how police forces and forensic service providers used technology (the SOCIMS[7] database) to import, search and use data from case files. Looking to identify the method of best practice for collecting statistics (the importance of which had been recognised since the early 1980s [16, 18]), she sampled eleven forces (plus two forces which did not use the database) to determine how they recorded data [12]. The results identified that many forces had incomplete data inputs (a fundamental issue when analysing statistics in terms of measuring performance), and consequently any assertions made from this work must be considered with care as any gaps in data must be taken into consideration. Jacobson et al. [38] determined that the complexity of burglary investigations requires the adoption of systematic procedures. However, their conclusions and recommendations hinged on the level of completion of the paperwork in the case files as well as the degree of accuracy provided in the interviews and focus groups [38].

Stockdale and Gresham [102] evaluated police operations when tackling burglary offences for three forces by assessing the perceptions of respondents via interviews. However, variations in collection of data by different police forces again affected the comprehensiveness of the results and therefore their applicability [102]. Thematic Inspections by Her Majesty's Inspectorate of Constabulary (HMIC) in 2000 [40] and 2002 [108], attempted to evaluate the scientific support received by all the police

[7] Scenes of Crimes Information Management System

forces in England and Wales. The inspections collected data via checklists and self-assessment questionnaires which were complemented with interviews and focus groups. Both studies encountered problems relating to the "*absence of rigorous data*" [40]. A number of recommendations were made in 2000 to address this, however little change was found in the follow up inspection in 2002 [40, 108].

Reviews are a good way of reflecting on the literature published in a particular area and outlining current knowledge [5, 8, 41, 61]. The systematic literature review of 50 studies by Bradbury and Feist [5], collated work to indentify how forensic science is used and how it contributes to the detection and conviction of volume crimes. They highlighted areas of improvement from previous research and made a number of recommendations for the future (e.g. to identify how the application of particular forensic techniques can improve forensic processes) [5]. Burrows and Tarling [9] analysed CSE scene attendance rates for specific crime types. A lack of data meant that the researchers had to compare their estimates of these figures from two police forces against national statistics. Due to the nature of their study the effects on the significance of the trends identified were not assessed [9].

Focus on specific stages of investigations also occurs in many of the studies. Burrows and Tarling [101] focused on the police investigation (as opposed to the forensic investigation). Their study set out to address whether the level of police resources had an effect on detection rates and whether these rates were an accurate method for measuring performance [101]. They found that overall the mix of the type of criminal activity ('the crime mix') had the biggest impact on clear up rates compared to many other factors, although resources and investigator workload were also shown to be important [101].

Although the study does comment briefly on the use of forensic science to help in the police investigation it does not recognise the importance of forensic evidence in achieving effective outcomes [101]. The evaluation of police use of forensic science by Tilley and Ford [14] also only addressed the provision of forensic science from an investigative perspective and did not consider its impact on the outcomes of the

criminal justice process. It provided good insight into police perceptions although it is limited to the initial stage of the investigation and does not provide analysis of how police attitudes (and subsequent actions) affect the other stages of the investigation [14].

Gill *et al*. [76] examined the crime recording systems in place at nine police forces in order to assess performance contribution to achieving successful outcomes. Despite the large sample size (nine forces, 655 interviews) the study made no attempt to link investigative actions with its results – they did not look at cause and effect [76]. The joint study by the FSS and the Association of Chief Police Officers (ACPO) [23] addressed investigative procedures and identified a number of models for improvement. Documentary evidence, semi-structured interviews and workshops assessed attitudes of practitioners and suppliers, and the use of forensic science for police investigations. The study identified variations in levels of communication and issues of inter-agency relationships [23].

The Scientific Working Improvement Model (SWIM) [37] is one of the most comprehensive studies of the investigative process and assesses systems and force performance levels in forty-one police forces to identify performance gaps and bottle necks. SWIM [37] mapped various activities involved in investigations and identified means of improving police performance. Although the effects of the implementation of the recommendations from this study have not yet been addressed in any systematic review, several recommendations were implemented successfully in the pilot sites. Recommendations from the SWIM project [37] have also encouraged similar initiatives elsewhere to "*add value to the forensic science services delivered*" [109]. The SWIM project [37] highlighted how and why problems could (and do) occur at various stages of the investigation of crimes.

Bond [55] addressed whether blanket attendance procedures for scenes affected the timeliness of evidence processing and the effectiveness of the investigation. Bond [55] manipulated the variables as the prioritisations of attendance rates were changed specifically to test his assumptions. This is therefore not reflective of actual

procedures and requires a much broader (national) implementation in order to assess the validity of his results [55]. He also identified that limited resources meant this prioritisation could not be carried out indefinitely. Once the study was completed crime and detection levels returned to roughly their pre-assessment levels [55]. Therefore, this cannot feasibly be considered an effective long-term solution without appropriate availability of resources; however he argued that focused attention can improve timeliness and detection levels [55].

The lack of systematic and robust research studies using valid and reliable data continue to hinder assessments of the effectiveness of many aspects of an investigation and prosecution [45, 110]. Although the studies utilised as part of this review do provide information which is of value for outlining the barriers involved, the limitations in their applicability and reliability has been considered in this section.

2.2. Themes previously identified affecting investigations

That forensic science is one part (albeit an important one) in the larger environment that is the CJS has already been explained. How this works in connection with other parts of the CJS has been little explored in the UK. As has already been explained the majority of the literature on the investigation of volume crimes used for this research has come from government publications (audit, reports, inspections, consultations, etc.) and research studies predominantly carried out by the Home Office or the Police Research Group in England and Wales. Examination of twenty-four publications identified that several specific or themes affect the investigation and the use of forensic science.

All of the studies utilised in this review identified several themes which have been repeatedly identified throughout the last 40 years:

- Fourteen studies emphasised limited forensic knowledge (the value of evidence and uncertainty of the capabilities of forensic science [9, 16-19, 21, 23, 37, 40, 41, 57, 76, 79, 96],

- Thirteen studies identified limited training [5, 9, 15-17, 19, 23, 40, 42, 76, 94, 96, 97],

- Seventeen studies identified a lack of communication [5, 12, 14-17, 21, 23, 38, 41, 42, 57, 76, 79, 87, 94, 96],

- Twelve studies emphasised poor interagency collaboration and inadequate relationships [14-19, 21, 38, 40, 79, 87, 94],

- Six studies identified a confused perception of the roles and responsibilities of scene examination personnel [5, 15, 17, 40, 41, 96],

- Eighteen studies commented on poor use and deployment of resources [5, 12, 14, 15, 18, 19, 21, 37, 38, 40-42, 57, 76, 79, 94, 96, 97], and

- Thirteen studies identified factors of poor timeliness and slow turn-around times [15, 16, 21, 37, 38, 40-42, 57, 76, 87, 96, 97].

Many of these themes, as well as the recommendations for improvements, were identified in some of the first reviews undertaken in the 1980s [16, 18, 96]. However, table 4 clearly demonstrates that these themes are still found in current literature, therefore remain relevant, and appear largely unchanged today. The aims of the previous studies have been to examine the investigation of crimes from a number of different approaches [15, 38, 40, 42, 76, 87, 94, 96, 97], to assess the use of forensic science [12, 14, 16-19, 21, 23, 37, 55] and to review the literature to gain a better understanding of how to achieve a more efficient and effective approach to investigating volume crimes [5, 8, 41].

Table 4: A selection of recurring themes identified in the past four decades which have been broken down into a number of categories

Year	Report	Repeated themes						
		Education		Inter-relational themes			Management	
		Knowledge	Training	Communication	Collaboration	Role perceptions	Resources	Timeliness
1981	Byford Report [96]	√	√	√		√	√	√
1986	Burrows [97]		√				√	√
1987	Ramsay [16]	√	√	√	√			√
1987	Touche Ross [18]	√			√		√	
1993	Roberts & Willmore [21]	√		√	√		√	√
1994	Saulsbury *et al*. [17]	√	√	√	√	√		
1996	Amey *et al.* [94]		√	√	√		√	
1996	Coupe & Griffiths [87]			√	√			√
1996	FSS & ACPO [23]	√	√	√				
1996	Gill *et al.* [76]	√	√	√			√	√
1996	Tilley & Ford [14]			√	√		√	
1996	McCulloch [12]			√			√	

Year	Report	Repeated themes						
		Education		Inter-relational themes			Management	
		Knowledge	Training	Communication	Collaboration	Role perceptions	Resources	Timeliness
2000	HMIC [40]	√	√		√	√	√	√
2003	Jacobson et al. [38]			√	√		√	√
2004	Burrows & Tarling [9]	√	√					
2004	Nicol *et al*. [79]	√		√	√		√	
2004	Williams [15]		√	√	√	√	√	√
2005	Bradbury & Feist [5]		√	√		√	√	
2005	Burrows *et al*. [42]		√	√			√	√
2005	Burrows *et al*. [57]	√		√			√	√
2005	House of Commons [19]	√	√		√		√	
2005	Jansson [41]	√		√		√	√	√
2006	Bond [55]			√			√	√
2007	SWIM [37]	√					√	√

One of the first attempts to measure the 'effectiveness' and 'efficiency' of forensic support within the police forces of England and Wales resulted in the Home Office commissioning an external company, Touche Ross Management Consultants, to review how forensic science was being utilised and implemented by police forces [18]**.** Regarded by many as the pioneering report, a number of subsequent publications referred to it extensively and supported its recommendations and reasoning [5, 41, 111, 112].

2.2.1. Collaboration

> "*Sharing, exchanging and managing knowledge efficiently to overcome barriers and create joint benefits*" [113]

The availability of scientific support [18] and the effectiveness of the FSS [16] were investigated in the late 1980s by two landmark studies. Both of these reports were highly critical of the poor relationship and quality of collaboration between police forces and forensic service providers [16, 18]. The first of these two reports assessed the management and use of scientific support [18]. It declared that " [forensic] *laboratories and police* [forces] *must* […] *ensure that each is aware of the problems and requirements of the other*" [18]. The second complementary study by Ramsay [16] in the same year also recommended a need for the improvement of relationships between police and forensic service providers, in order to best meet investigative needs. Knowledge of the role and use of forensic science was shown to be limited in police officers [16, 18]. Therefore, in order "*to make informed judgements about* [the] *value*" of forensic science a cohesive relationship and collaboration between investigative staff is necessary [114].

Further work in the 1990s proposed a much closer partnership between investigators, CSEs, and police officers to aid the effectiveness of the investigation [17]. It has been suggested that in order to obtain the maximum impact from forensic science, relationships between investigative organisations as well as the degree of integration and collaboration must reflect the objectives and aims of all of the parties involved [22]. If several individuals (or organisations) are to work together effectively, each must have a clear understanding of the responsibilities, accountability and authority of the roles involved to achieve their common goal [115]. For systems and processes to work effectively, the individuals involved must have an understanding of the interconnected nature of their activities as well as how their actions can affect the system as a whole [30].

The thematic inspection by HMIC in 2000 entitled "*Under the Microscope*" identified that case turn-around-times, the efficiency of case progression to court and the accurate interpretation of forensic evidence can be considerably improved when the different organisations involved in the investigation of crimes work cohesively [40]. As well as a stable and effective partnership, this requires a shared commitment and mutual ownership between participating groups involved in a complex interconnected system [116]. Collaboration between users and suppliers of forensic services are based on the assumption that both are working together to achieve effective outcomes [16, 17]. Efficient criminal investigations work not only towards identifying (and consequently prosecuting) offenders but also to aid in the rapid elimination of witnesses and other innocent individuals [23, 117].

Effective use of forensic science is also dependent on the collaboration of all of the stakeholders and organisations involved in the investigation. "*Without a detailed understanding of their mutual roles, processes, epistemologies and expertise, the hope of developing a productive relationship seems unachievable*" [118]. Collaborative work is required to allow the most benefit to be obtained [119]. However, collaboration and relationships are also affected by poor communication and cultural differences observed between different organisations and individuals [16, 18].

2.2.2. Organisational Cultures

> *"The customs and traditions of* [an organisation] *are a powerful way of influencing behaviours. They are the natural products of social interaction* [which] *evolve and emerge over time"* [120].

The police service are predominantly interested in the outcome (end-means) of an investigation (e.g. the arrest and charging) [121]. Forensic service providers on the other hand, are much more focused on the way something is done; that is they are interested in the steps required to accurately analyse evidence (the process) [112, 122, 123]. These differences are part of the fundamental tension between the organizational cultures associated with each agency [124]. In order to understand this tension better a more detailed assessment of what organisational cultures are, how they are formed and how they affect working practices must be made.

Organisational culture has been defined as a pattern of shared basic assumptions that are learned and founded in "*traditions, beliefs, values, norms, symbols and meanings*" which determine how individuals within that particular organisations behave [125-128]. Cultures are communicated and transmitted to new recruits by the teaching of the "*correct*" way to "*act, perceive and think*" through everyday interactions [125, 128]. Often, cultures are so formalised that they can be identified by the mission or vision statements which are often part of large organisations [126]. "*All organisations must develop a degree of coherence in their culture for them to be able to function effectively*" [129]. Some organisational cultures can be very influential (e.g. military, police) and strengthened by uniforms [127, 130], compared to others.

Often organisations are also affected by the mix of formal and informal rules which govern activities and shape cultures [127]. Formal rules are "*expectations and requirements* [...] *that are routinely associated with the pursuit of organisational purposes, activities or goals*" [131]. Informal rules are based in the interactions and

associations (norms of behaviour) between individuals which are not necessarily confined to the aims or activities of the organisation [131]. Aspects of individual's behaviours are governed by the collective norms generated in informal groups based on the development of various associations or friendships [127]. A sense of inclusiveness occurs as people are drawn together by sharing similarities in role expectations, work pressures and career structures [132]. This sense of "*belonging*" can affect the views of the individual of the "*outside world*" and consequently affect their relationships with others outside of their group or culture [127, 132, 133].

The four main types of culture identified – power, role, task and person - are described in table 5. These have previously been connected with organisational structures and form the basis for many modern theories [120, 134].

Table 5: Description of the four types of organisational cultures based on work by Roger Harrison [134] and Charles Handy [120].

Type of culture	Descriptions
Power culture	This culture has a single, central (charismatic) power source (an individual or corporate group) that radiates control and influence to a limited number of key individuals with entrepreneurial values [120, 128, 134, 135].
Role culture	Characterised by specialist, interdependent functions, sections, departments or sub-groups which are able to operate independently. The work and interaction of these sections is controlled by: roles or job descriptions, and procedures for communication. [120, 128, 134, 135].

Type of culture	Descriptions
Task culture	Based on expert power, it seeks to draw together the appropriate resources and the most appropriate people who have the right experience or training. It is characterised as highly flexible, adaptive, group oriented and responsive to change [120, 128, 134, 135].
Person culture	Based with the individual at the centre, this type of culture is formed by seeking people with mutual interests to help assist the individual. Not often found in business, person cultures are formed in partnerships, relationships and family settings [120, 128, 134, 135].

Modern organisations do not neatly fit into one type of culture alone [128, 135]. Organisational cultures are often more difficult to change than people individually, therefore cultures can remain unchanged in organisations for a long time [136-140]. It has already been stated that police and forensic service providers work differently and part of this is due to the differences in cultures. How these affect the investigation of crimes requires a more detailed analysis of both organisational cultures.

2.2.2.1. Role and power - police culture

Police culture has been studied for a number of years [122, 141-144]. Police cultures are most often associated with "*machismo*", sense of mission, hero status, isolation, and suspicion [118, 130, 141-152]. Police cultures contain two principal variables:

danger and authority, and have been found to show an unusually high degree of occupational solidarity [132, 143, 153]. Police officers, in fulfilling their mandate for investigation of criminal events often find themselves in hostile, dangerous and isolating environments. Herbert [145] asserted that traditionally policing is often regarded as narrow-minded, masculine, too focused on taking risk and glory hunting.

The strong subculture controlled by traditions and customs identified in police forces has previously been characterised as rigid and inflexible, providing a rigid platform resistant to change [147, 154-156]. Current work indicates that the strong subculture remains largely unchanged; however, it is not permanent or largely negative. It is a necessity needed for the "*functional to the survival of police officers in an occupation considered to be dangerous, unpredictable, and alienating*" [143]. Furthermore, recent debates regarding police culture indicate changes will need to occur in line with modern policing which is much more focused on interagency collaboration [157].

Complex bureaucratic professions (e.g. police, military) have been shown to struggle to accept new ideas, processes or systems into their daily routine [147]. That uniformed officers felt uncomfortable accepting recommendation from non-uniform personnel[8] was suggested by Cope [118], Reuss-Ianni [147] and Guyot [154]. Non-uniform personnel, including scientific support, were found to be under resourced and had a "*low status*" amongst police officers irrespective of the importance of their job [20]. The Audit Commission found that the "*effects of under-resourcing and low status* [were] *reinforced by organisational structures"* and organisational cultures [20]. Detectives rarely liaised with scientific support.

[8] 'Non-uniform' police staff is used here to mean a police employee who does not have these specific powers of a uniform officer, but contributes to general police functions through specialisation of skills (e.g. CSEs). This can also be called non-sworn, civilian or police staff. 'Uniform' means a police employee who is under oath and has full police powers (i.e. powers of arrest criminals).

Uniformed officer's perceptions of non-uniform individuals (police or non-police) were shown to affect the degree willingness to cooperate, to communicate and to collaborate, which could hindering the effectiveness of an investigation [118, 147]. For example, the introduction of new scientific techniques (e.g. DNA analysis), meant that new skills and knowledge had to be learned and that the method of identifying offenders was partly removed from police control [123, 158, 159]. Scientific support staff would give advice on its significance. Advances in technology "*destabilize the power balance between organizational segments by altering communication patterns, roles relationships, the division of labor, established formats for organizational communication, and taken-for-granted routines*" [158]. Seeking help was seen to 'encroach' on police authority and position, fundamental aspects of their role [118].

Like many other organisations, police forces wish to keep up with current technological developments [11, 123], however *"the impact of technology is dependent on how* [it] *interacts with existing cultural values, management styles,* [and] *work practices"* [160]. Police use of technology has increased over recent years and this has affected the cultural divisions experienced within police forces [158, 160]. The division between "*management cop*" and "*street cop*" culture has recently become more apparent in police organisations partly due to the introduction of information technology and the employment of non-uniform police staff as technology workers [141, 147, 150, 160]. Perceptions and attitudes of specific administrative roles – those predominantly office based with a responsibility to support "*real*" policing – affect investigating officers acceptance and recognition of the expert intelligence they can provide [160-162].

The Winsor Review [163], recently called for a change in police cultures so that "*forces operate as a single organisation with a single culture*", and that the value and importance of non-uniform police staff equals that of uniformed police officers [164]. Organisational cultures are often complex in nature [124]. Manning [165] argued that organisations (such as police) do not "*possess a common culture when viewed from the inside*" and differences were detected between individuals "*holding*

different functional responsibilities" [166]. Investigations therefore must work towards unifying the various disciplines and organisations involved in the system taking into consideration the different cultures involved in order to be maximally effective [161].

That police officers' perceptions of "*administrative*" roles involved in an investigation affects the acceptance and recognition of expert intelligence was argued by Miller [161]. Organisational cultures influences "*police expectations and uses of the products of forensic scientific activity in general*" [111, 112]. Cultures can affect how well individuals communicate with one another within and between different organisations when seeking information or advice. The integration of forensic science (and its capabilities) in terms of collaboration, communication and awareness may be limited due to police culture [118].

2.2.2.2. Task and role - forensic science culture

Forensic service providers also demonstrate organisational cultures, although much less research has carried out into this field. From the table 5 forensic science culture can be classed as a role and task culture [120, 128, 134, 135]. Role and responsibilities of individuals working in various areas of forensic science can often be classified into specialist departments (e.g. biology unit, chemistry unit, crime scene unit). Specific role descriptions determine the responsibilities of these individuals and results in a fixed division of labour [167, 168]. Each separate department is able to work independently of the others to carry out their job, but is sometimes required to work together effectively (e.g. the analysis of one evidential item submitted to the laboratory for two separate types of evidence may require the communication between two separate departments to determine the sequence of analyses).

The task culture of forensic science works on the basis that there are a number of "*experts*" with specialised knowledge in individual fields who work together to discern information from evidential material recovered and interpret the findings in context of the case [115]. Working in collaboration with one another, each set of experts is aware of the limitations of their work, however they are in control of the processes that relate to their field [115, 169]. Decisions made relating to their work, and interpretations or judgements resulting from their analysis are respected by other individuals involved [115].

Experienced individuals have significant knowledge of daily procedures and practices, which are shared with new recruits in order for them to fully engage in the task, job or profession [170, 171]. Individuals at different levels of an organisation (in terms of hierarchy or expertise for example) may not only have different skill levels (or lack certain skills completely) but may not have any knowledge of a particular procedure compared to more experienced colleagues [172]. "*Individual competence was a reflection of the culture and quality management approach of the practitioner's organisation* [173]". Set routines are often established which may differ slightly from clearly defined operating procedures [167, 174-176].

Forensic science culture utilises a hierarchical order of power and systematic control in day to day work (much like policing). However, qualification, training and experience are often required before and during employment [22, 177, 178]. The nature of forensic science work requires detailed analysis of evidence and meticulous recording of results. That individuals in different cultures communicate differently was stated by Treven *et al*. [124]. The use of language, jargon, verbal style as well as non-verbal communications can be very distinct between cultures and affect the level of interaction between individuals [124]. That this has previously been identified as an issue affecting the use of forensic science in the investigation will be shown in the next section.

The use of expertise is important in the investigation of crimes, as individuals with detailed knowledge provide the means of relaying often technical and complex information which is otherwise not available to other members of the investigation or to lay members of the public (e.g. members of a jury) [179, 180]. They can provide evidence that may not be available by other means. However, irrespective of their levels of expertise, Lawless [181] found that forensic science can be perceived as "*providing an adjunctive contribution to police* [...] *who are seen to retain overall ownership*" and influence of an investigation. Cultural difference between police and forensic service providers [115], differences in perceptions of the importance of investigative roles [15], as well as limited understanding of the value and role of forensic science in aiding police investigations can affect the effectiveness of investigations [181].

2.2.3. Communication

> "*The communication of the facts of the case* […] *is important if an investigator wants a full interpretation of the findings*" [182].

Communication and the sharing of information between individuals involved in the investigation of crimes is important to the criminal justice system as a whole, not just to specific stages such as the effective use of forensic science [14, 16, 23, 38, 42, 76, 94]. Communication is defined as the production, sharing and analysis of information (e.g. thoughts, opinions, facts), which is exchanged between people or organizations via a variety of different mechanisms (e.g. written, visual, oral) [31, 183-185]. That the communication (in terms of the exchange of information) between investigating officers and the FSS is limited was shown by Ramsay [16]. He found that the poor flow of information had a negative effect on the number of criminal cases referred for forensic analysis by police forces [16].

Touche Ross [18] found that direct communication between forensic scientists and police officers in the form of case reports did not contain clear evaluations of evidential strengths which investigating officers could understand. That reports produced by the FSS were "*vague or obscure*" with officers having to "*read between the lines*" and that "*the style of reports led to a blunting of their impact*" due to technical jargon was highlighted by Ramsay [16]. Direct communication between police officers and forensic scientists was found to be limited also [18]. Roberts and Willmore [21] found that that often investigative officers did not update forensic laboratory staff with any changes of circumstances occurring in the case under investigation, consequently affecting the relevance or significance of the work being carried out.

Effective communication involves the mutual understanding of the roles, responsibilities and procedures; knowledge of the investigation, information sources and formal lines of enquiry as well as close collaboration and cohesive relationships [16, 186]. In order to successfully locate, identify and prosecute an individual, police, forensic scientists, CSEs need to work together [40, 187, 188]. The 1996 review by the ACPO and the FSS [23] highlighted that formal lines of communication between investigating officers, crime scene staff and forensic scientists were strained consequently affecting the effectiveness of the investigation. That smaller police units were more effective at communication than larger ones was shown by the review [23], and Saulsbury *et al*. [17] showed that strong relationships between police and scientists provide the means for sharing information and intelligence proactively.

One of the major recommendations made by HMIC in 2000 [40] was for improved communication and relationships between investigative staff and police officers. It was found that not only does communication ensure the most up to date information is available and passed onto the relevant personnel, it can also affect more proactive[9]

[9] There are two types of investigations – proactive and reactive. Proactive investigations involve targeted actions prior to the occurrence of an event. They often involve the use of

investigative procedures such as crime pattern analysis and the targeting of specific repeat offenders [40, 108]. If intelligence that has been identified by any member of the investigative team is not communicated to the relevant individual (or organisation) that may utilise it, the effectiveness of the investigation is reduced [40, 41]. For example, crime trends or specific evidential items could easily be missed.

The follow-up report by the HMIC in 2002 "*Under the Microscope – Refocused*" [108], identified that some of its recommendations in relation to communication had been implemented. Many forces had recognised the importance of communication on the impact of the potential use of forensic science to crime investigation. Effective communication can share the intelligence required by police to catch those few individuals who can be the cause of a large number of volume crime incidents within one area [41].

The report by Roberts and Willmore [21] also found that "*the efficiency and effectiveness of the prosecution process might be improved by more effective liaison between the FSS and prosecution organisations*". That forensic scientists had very little communication with legal representatives regarding forensic casework was also recognised by Tilley and Ford [14]. Communication appears to be problematic within and between organisations at various stages of the investigation and prosecution.

2.2.3.1. Feedback

> "*Feedback from the various parts of the criminal justice system is at best uncoordinated and at worst confusing or duplicative, with the consequential risk of communication failure*" [189].

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intelligence and can target crime hot spots. Reactive investigations are typically in response to an event (e.g. an offence is brought to the attention of the police).

As well as the transfer of information, an important aspect of communication is giving and receiving feedback [19, 190]. However, Ramsay [16] found that this simple form of communication has been inadequately employed within and between investigative organisations, and feedback on the value of forensic evidence for example was given in only 5% of cases. Current research indicates this has remained broadly unchanged [8, 42]. At its worse, it has been shown that poor feedback can reduce motivation, increase feelings of isolation [23], and result in substandard scenes of crime work (in terms of quality) [5, 14]. If feedback is not given to forensic providers, the contribution of their work and the value of their input may not be recognised towards the outcomes of an investigation or to the criminal justice system overall [184, 185]. In order to best meet investigative needs, individuals must have some understanding of what they can contribute towards an investigation [12].

Feedback is a fundamental aspect of communication and by encouraging discussions, clarification, and interaction between individuals can help to build effective relationships and encourage a more effective investigation [184, 185, 190]. Tilley and Ford [14] found that feedback is predominantly given in cases where forensic evidence has had a positive effect on the investigation, identified the offender or provided intelligence for furthering the investigation for example. In cases where forensic evidence has been less useful (for a number of reason which include the offender was identified using traditional investigative techniques), they found that giving and receiving feedback was more limited [14]. This means that factors surrounding the use of forensic evidence are not addressed as they are not recognised (or not recorded) and explanations identifying factors affecting the effectiveness of the system cannot be established [189, 191].

The quality and type of feedback is dependent on the overall experiences of police officers. where "*good experiences with laboratories induced a positive feedback approach; negative experiences generated scepticism about forensics and a preference for other sources of information*" [5]. Both types of feedback are required to assess the effectiveness of the investigation; positive feedback to identify areas which worked well for a given scenario and constructive feedback in order to

identify areas of weaknesses and to implement changes in future to improve the effectiveness [192]. Assessments of areas of good and poor practice can be identified using feedback mechanisms and can influence future actions in similar scenarios [189].

HMIC [40] suggested that arrangements should be made to ensure an efficient communication process which facilitates professional information exchange and provides effective and accessible opportunities to receive guidance from the most knowledgeable source. This requires some knowledge of how investigations work; scientists need to adequately understand the police role and police need to have some forensic knowledge [5, 14, 15, 38, 94].

2.2.4. Forensic Knowledge and Awareness

> "*Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information.*" [193]

Although the use of forensic science has increased in recent years, the understanding of the use and value of commonly encountered forensic evidence types which influences police officers decisions whether to submit evidence for forensic examination has been shown to be limited [16-18]. By testing respondent's knowledge about the uses of evidence, Saulsbury *et al*. [17] identified that the importance of DNA was understood and it was perceived highly in terms of ability to conclusively identify an individual. However, other evidence types were undervalued and less frequently collected [17, 19]. "*Using Forensic Science Effectively*" [23] reported that forensic evidence is significant to the successful detection of crimes but many investigators fail to collect or adequately exploit the physical evidence present at a crime scene due to limited understanding of its potential.

HMIC [40] found that there were evidence types which have been deemed to provide little value towards an investigation by police officers. The limited training and forensic knowledge of most officers can reduce the effectiveness of investigations [18]. Limited awareness of the capabilities of forensic science can prevent the optimal use of resources [12, 18, 40]. HMIC [40] examined the use of forensic science by the police service to detect volume crime. It specifically looked at how particular evidence types (DNA, fingerprint, footwear marks) were managed, and how intelligence, identifications and technical support sources affected the investigation of crimes [40]. Knowledge of forensic science was still found to be limited and large variations of instigative procedures were also present [40]. Previous recommendations proposed improvements to the utility and knowledge of forensic science, as well as establishing areas of good practice. The follow up inspection in 2002 [108], found that there was still poor awareness by police officers the utility of forensic evidence.

Along with many other studies [14, 16, 18, 23], HMIC also identified a number of concerns relating to the understanding of the evidential strength of forensic materials [40]. DNA and fingerprint evidence are known to have "*a substantial ability to identify an individual*" [194], as well as to provide a physical link between offenders, scenes and evidential material [9, 55, 195, 196]. However, the collection of footwear marks, toolmarks, and other trace evidence, appears to be poorly utilised [19, 197, 198]. That there is a preference for certain types of evidence was also demonstrated [18, 23]. Although investigating officers do not normally collect evidence from scenes, individuals have been shown to prefer evidence they feel comfortable with, have the greatest understanding of or believe most likely to provide a successful outcome [45]. The Pathfinder project demonstrated that increased awareness of the value of evidence can have a positive effect on collection rates [57]. It found that the "*<u>message</u> about the value of footwear spread well beyond the Pathfinder divisions*", with recovery rates rising by 18% in all areas (original emphasis) [57].

Limited understanding of the value of evidence could mean that other evidence types may be overlooked or not collected from scenes [199]. The practice of collecting as much evidence as possible just in case from a crime scene appears to have ceased [18]. However, without an understanding of the potential utility of forensic evidence, investigative opportunities may be missed [14, 18]. Bradbury and Feist [5] understood this issue and endeavoured to identify factors which contribute to the effective detection and conviction in volume crimes. They determined that although forensic science plays a small role in this, the proactive use of specific evidence types (such as DNA) have increased crime detections significantly [5]. The current lack of research on this topic will be discussed in section 2.4.

Without the knowledge of the value of specific evidence types, officers are unable to utilise this investigative tool to maximise the possible benefits available from it [14, 15, 200]. As well as knowledge of the utility[10] of specific forensic evidence types, the importance of the use of explicit and tacit knowledge by investigative personnel has also been considered in forensic science.

2.2.4.1. Explicit Knowledge

Explicit knowledge is knowledge that can be recorded, expressed, shared and communicated with relative ease [201]. It is often contained within documents, manuals, standard operating procedures (or other direct instructional documents), etc. [167, 202, 203]. It is often learned in formal settings and can be expressed in words or numbers [204]. Set frameworks such as SOPs contain explicit instructions which can be followed in order to arrive at a given outcome, operate a specific instrument or set out a specific procedure [167]. Such documents explicitly describe how a given operation should be performed, including which equipment to use, the purpose

[10] The importance of the contribution of forensic evidence, and the extent to which it accurately meets the needs of an investigation (its progression and outcome).

of the action, the materials required for the process, the physical operation of the device, as well as standardisation and calibration [167]. SOPs can help to develop workers that behave in a similar manner in order to obtain consistent and 'reliable' outputs [167]. However, as will be discussed later, the actual practices of daily routine within an organisation often differ from espoused practices [162, 175, 205, 206].

2.2.4.2. Tacit Knowledge

Knowledge is not only obtained via formalised systems, but is also developed via interactions between individuals within organisations [204]. Learned from observations, practice, or experience, tacit knowledge "*is entrained in action and involves more gut feeling and experience, and is therefore more difficult to articulate and express to others*" [207, 208]. Tacit knowledge requires different mechanisms to be shared or extracted as it is not normally written down [201, 207, 209-211]. Tacit knowledge can be most effectively shared via social interaction of individuals in specific circumstances – mentoring, learning on the job with supervisions, etc. [175, 202, 212-216]. Nonaka and Takeuchi [217] determined that not only does socialisation allow for tacit knowledge to be shared between individuals, it also provides an opportunity for the learner to quickly apply the new knowledge in a practical setting [218]. Tacit knowledge and explicit knowledge are not used separately; often it is the combination of the two types which determine the actions of the individual [204, 219]. Explicit knowledge builds the foundation of knowledge for practitioners when they begin their initial training, as individuals become more experienced the use of tacit knowledge increases [167, 220, 221].

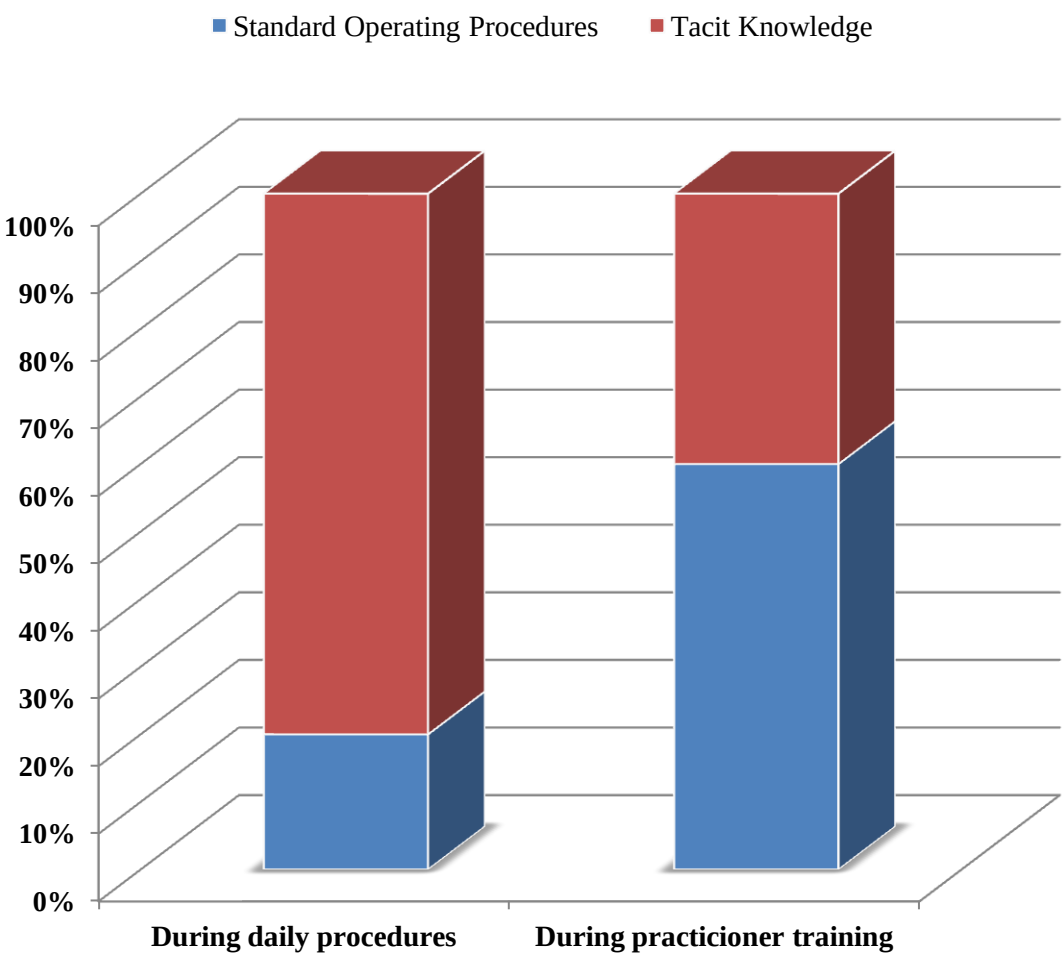


Figure 5: The use of Standard Operating Procedures (SOPs) and tacit knowledge (TK) by forensic scientists in specified circumstances *(figure taken from [167]).*

In his study, Doak [167] demonstrates that scientists require the use of tacit knowledge to supplement the explicit knowledge provided by SOPs on a frequent basis in their daily routines. Figure 5 illustrates that practitioners rely on a combination of their own experiences and tacit knowledge when faced with decisions that are not covered specifically in SOPs [167]. Knowledge gained from experience enables staff to provide context to the procedure they are carrying out and will often be used together with explicit instructions also [167]. Experience and practice can

allow individuals to determine a "*better*[11]" way of achieving the same outcome more efficiently [204, 219].

2.2.5. Training

> "*Training is fundamental to any organisation: ensuring that it's people have the skills and knowledge effectively to do their jobs for which they were recruited should be paramount*" [222].

Training has been identified as an issue in the investigation of crimes since the early work in the 1980s [16, 96, 97]. Much work is available highlighting that the forensic science training received by police officers is inadequate, resulting in limited knowledge of the potential of what forensic science can actually provide to an investigation [16, 19, 23, 40]. Forensic training was shown to be "*extremely limited*" and essentially non-existent for investigative staff, particularly police officers in a number of different fields (e.g. crime investigation, fire investigation) [50]. Training on how to best preserve forensic evidence, as well as how forensic science can be used to aid in an investigation was often found to be limited for police officers. HMIC [108] stated that there is a lack of awareness "*particularly* [at] *the operational level*" of what can be effectively achieved when using forensic science.

[11] 'Better' as used here is not meant to denote that the previous way is no longer valid, however it is simply used to define a difference between the actions in terms of achieving a result in a manner that may provide the same outcome in a slightly different manner. Changing the procedure from the standardised method may produce some (minor) benefit to the individual: reduction in time taken to perform procedure, etc.

In order for an investigation to be effective, Ramsay [16] stated that all investigative staff involved must be appropriately trained to carry out the task. It is required that the most suitable person for the job is available to carry out or complete a job [223]. Training involves the acquisition and facilitation of new knowledge, or skills [224]. As a means of communication and a learning process, training can change people's attitudes and raise their awareness of gaps in their existing knowledge or skills [160, 222]. Training is essential to carry out complex tasks and is often occupation specific, different roles require a different amount of training [223].

Since the early reports in the 1980s, basic training courses have generally improved forensic knowledge, however much of this complex process is still poorly understood by police officers [23, 40]. For training to be effective, it must be built around the needs of those who require training (e.g. police officers, forensic service providers) in order to change or improve understanding, attitudes and behaviour [222, 225]. Therefore, it is important that individuals have received specialist training for a given role (e.g. crime scene examiners) in order to fulfil their role requirements effectively [16, 23, 226].

Forensic science training courses appear to lack standardisation, and often course content and length is varied [19, 22]. HMIC [40] found that investigating officers primarily learned through trial and error from first-hand experiences with certain situations or via information passed on from colleagues. Currently, investigating officers are encouraged to learn using a combination of 'formal training' and 'practical experience' [227]. This allows the trainee to be exposed to theoretical aspects (the explicit or formal elements) which can then be actualised through practical implementation (the tacit or informal elements) [210].

The ACPO and FSS review in 1996 [23] identified that additional training packages as well as refresher courses should be made available to all investigative staff, particularly for CSEs. It was recommended that these training packages consider aspects such as: statement writing for court, report writing for investigating officers, oral presentations, as well as explaining new forensic analytical techniques and

describing the effects these may have on the utility of specific forensic evidence [23]. Considerable insight into this issue could be provided by detailed analysis of the number of different training programmes currently available.

Bradbury and Feist [5] indicated that knowledge of crime scene preservation and management appears to be stronger than general forensic evidence awareness. Effective and appropriate training, whether for newly appointed investigators and scientists or as continual or refresher training for experienced staff is necessary to ensure staff have the knowledge to carry out their roles [22, 169, 228]. Regular reassessments ensure forces are staffed with knowledgeable and accredited personnel who work effectively and to the best of their ability [8, 40]. The standardisation of training programmes requires the investment of the finite resources, time and money [5]. That "*the multiplicity of organisations involved in identifying and disseminating good practice in forensic science to the police is unhelpful and wasteful*" was recognised in 2004, and recommendations for a single organisation to control training were made by the House of Commons Select Committee on Science and Technology report "*Forensic Science on Trial*" [19].

The National Policing Improvement Agency (NPIA) has been the main body responsible for the majority of formalised training in England and Wales [229]. In their 2008-2011 Business Plan NPIA proposed to invest £10 million in the Forensics21 Programme[12] to improve forensic training for all forty-three police forces [230-232]. This funding was to be used for "*the effective use of forensic science in the investigation of crime* [... by focusing on] *all aspects of forensic science learning and competence*" [230]. After numerous reviews and recommendations, forensic training appeared to be a priority. However, not only did the current Business Plan (2010-2013) revoke this funding, choosing to concentrate on budget savings instead of training investments [233], a consultation document recently announced that "*NPIA will be phased out* [and] *its functions reviewed to*

[12] A support programme for police forces which aims to transform the delivery of forensic services.

determine whether they are still needed and, if so, where and how they might best be delivered"[234]. This will result in the end of over 60 years of service providing training and support to the police and it appears training will continue to be an issue [235].

Training is not only necessary for obtaining knowledge relating to the use of forensic science, but also affects the effective deployment of resources [5, 12, 15, 40]. Williams [15] discussed the benefits of the introduction of specialist Volume Crime Scene Examiners (VCSEs) in some forces in England and Wales. These are police staff specifically trained to attend vehicle or volume crime scenes [15]. Their training is not as extensive as standard CSEs undergo and subsequently their remuneration is lower, however their implementation has the potential to free up many resources for the investigation of other crimes [15].

Although the direct impact of VCSEs has not yet been reviewed, NPIA used their introductory Crime Science Investigator (CSI) course to train individuals specifically on the collection of evidence from recovered stolen vehicles. This suggests that the benefit of the potential of such a specialist role was recognised [226, 236]. Separating CSEs and VCSEs aimed to improve the availability of resources for attendance and investigation of volume crimes which may affect public perception and confidence of police work [37]. Better use of resources by dividing by crime types can improve the effectiveness of investigations as it ensures that all scenes can be attended in a timely manner and investigated by appropriately trained personnel [37].

2.2.6. Resources

> *"Unless proper resources are allocated to commensurate potential workload,* [the investigation] *will tend to degenerate into bureaucratic inefficiency"* [96].

The importance of the effective use of resources has been highlighted on several occasions over the past four decades [5, 12, 15, 18, 37, 40, 108]. Not only does there appear to be a wide variation in the number of specialist scene examination personnel compared to the force size and crime rate [14], financial and technological resources also appear to vary dependent on force forensic policies and systems [5, 40]. Variations in staffing levels and crime rates consequently affect scene attendance rates and CSE performance (timeliness, collection rates, etc.) [12, 15, 237].

Resource availability and geographical location have been shown to affect the rates of CSE scene visits, reflected partly in the variations of attendance rates between different forces [38, 87]. Tilley *et al*. [238] showed that no statistical relationship existed between differing attendance and evidence retrieval rates (per scene visited). They also found that increased resources did not correlate with higher retrieval rates (within/across similar crime types) either [238]. High attendance rates did not appear to hinder (negatively affect) evidence retrieval rates and factors such as scene attendance selectivity, timeliness of response, degree of communication, integration of police and scientific support personnel as well as resource deployment were shown to have a significant effect on determining retrieval rates [225, 238]. Noteworthy is that neither low attendance rates nor greater resources, guarantee higher retrieval rates [5, 57]. Therefore, blanket tasking of CSEs to every scene did not necessarily increase productivity or forensic outputs [238].

The most comprehensive and robust study addressing the increasing demands on resources has been the SWIM [37]. SWIM assessed performance gaps and bottlenecks identified within the investigative process and found variations in

detection rates between forces (irrespective of geography, force size or demographics), timeliness of investigation, and the conversion of identifications to detections [37]. They established that the skill levels and the work pressure on CSEs (such as the number of scenes attended) was directly linked to the level of variations, and that often the data required to measure performance was limited [37]. SWIM found that investigative agencies collected performance data on process outputs rather than overall outcomes [37]. This has resulted in a measure of CSE workload, rather than their skills and the outcomes of their productivity.

Investigating resource bottle-necks, SWIM [37] measured CSE productivity levels by focusing on the average number of scenes visited by each CSE per day (2.5 per CSE per day). Deviations from this estimated mean number of scenes per day was not necessarily found to be negatively significant, as resource demands varied between forces depending on the crime rates [37]. However, several factors must be considered when analysing CSE resources in this manner. A higher than average number of scenes visited per CSE per day may be due to more motivated staff or more efficient resource deployment procedures or a shorter travelling times to, from or between scenes [37]. A high number of scenes per day but a lower than average attendance rate may be indicative of an under-resourced force, poorly motivated staff or ineffective deployment of resources [37]. Conversely, high attendance rates to a lower than average number of scene visits per day may be indicative of a need to restructure resources deployment and staffing levels [37]. Better understanding of this variation could be provided by detailed analysis of the scene attendance rates, CSE workloads and evidence recovery rates.

SWIM identified that (at the time of publication) 25% of all crimes reported in England and Wales were volume crimes and of those 69% were attended by CSEs [37]. Therefore, volume crimes take up a large percentage of resources if each is investigated individually. If CSEs spend an average of 33 minutes per scene, and investigate approximately 2.5 scenes per day, only 17% of an average working day is spent at crime scenes [37]. Resource deployment and utilisation of CSEs was therefore found to be an essential aspect of an effective investigation. Planning and

managing CSE workload can help ensure CSEs have adequate time at each scene to carry out their investigations and collect evidence before being deployed to the next scene. Performance review of the ratio of identifications to detections can subsequently help determine whether the individual is focused on number of prints (outputs) or the quality of the prints (outcomes) [37].

SWIM [37] also identified that shift patterns were shown to vary from crime rates, where peak times for crime reporting did not reflect the peak availability of resources. The optimisation of shift patterns allows a more effective and efficient response and in light of previous research a better chance of recovering stolen property [38] or collecting evidence prior to contamination or loss [82]. The availability CSEs (well trained and skilled) has been shown to be of great importance to effective examination of scenes [37].

Ensuring critical resources are not unnecessarily wasted requires improvements in channels of communication, as it was found that scientists continue to work on cases where a suspect has pled guilty to a charge or the work is no longer required to build the case [18]. Work in the 1980s established that, at that time the circumstances of a case and consequently the purpose of the work carried out by the scientists changed approximately 10% of cases involving forensic evidence [16]. The dynamic nature of crime investigations means that investigative staff and forensic scientists must be updated of any changes in circumstances to avoid using valuable resources where they are no longer required.

It has been well documented that the use of forensic science has grown significantly since the 1980s; therefore, it must be considered that it possible (and likely) that this figure has increased. Therefore, it is increasingly important to provide continues feedback and updates relating to a case to ensure that the finite resources often available in an investigation are not unnecessarily wasted. That communication between police and forensic service providers continues to be an issue has been shown. Considerable insight into this issue could be provided by further analysis into the number of cases where changes in circumstances are not reported to laboratories.

2.2.6.1. Tasking

> "*Successful tasking involves utilising resources to the best effect in order to maximise recovery of forensically viable material from scenes as quickly as possible and provide a high quality of service to the public*" [239].

The lack of standardisation of the use of forensic science has been shown to affect the way police use forensic support during the investigation of particular crime types and the availability of resources [12]. Ensuring that the most appropriate resources are available to investigate the scenes which hold the most potential for providing useful evidence has been recommended by SWIM [37] and requires effective management and specific tasking procedures. However, when it comes to tasking officers and scene examination personnel to crime scenes, a large degree of variation and inconsistency has been shown [23, 240-242]. All investigative organisations strive to enable their staff to attend scene which are judged important [9, 76, 196]. However, when determining the worthiness of scene attendance, a variety of factors affecting the decision making process which include resources availability, geography and so on, have been shown to require consideration [14, 40, 239, 243].

Many police forces now implement mechanisms for managing resources and have case screening procedures and specific policies on attendance for specific crime types [239]. Firstly, in case screening procedures decisions are made very early in a case regarding the practicality and usefulness of continuing with further (or even beginning initial) investigations [76]. A call is often received by the crime desk (or equivalent) and assessments are made regarding the likelihood of obtaining valuable information or evidence from a scene to be able to provide leads or intelligence for further investigations [76]. Ideally, trained respondents should be able to quickly establish the likelihood of collecting useful evidence and correspondingly will dispatch the relevant personnel [244].

Tilley and Ford [14] found that cases where evidence is missing, contaminated or destroyed, or those cases which are unlikely to result in a detection, use up precious resources which could otherwise be utilised at more productive scenes. In order to ensure that cases are not dismissed randomly or unsystematically, the training and knowledge of tasking officers must be sufficient for them to carry out their roles effectively [41, 76]. In her review, Jansson [41] found that the selection of specific cases must be carefully managed and undergo regular assessment and performance management to ensure it remains effective.

However, whilst assessing the factors affecting how crimes are dealt with, Gill *et al.* [76] found a number of factors were considered important. Firstly, the coherence and emotional state of the caller can affect the clarity of information communicated to call handlers and may results in a delay. Secondly, the misinterpretation of the severity of the offence or the incorrect grading scale of the crime by crime desk staff can mean a slow response rate of investigators [76]. The time of day a call is made can also influence the rate and speed of response as crime rates fluctuate throughout the day and consequently affect workloads. Finally, when crimes are recognised to be part of series of linked incidents a call handler may again react differently in prioritising that incident over others [76].

Gill *et al*. [76] also found that officers interviewed as part of their study identified factors such as racial motivation, value of property, location and force priorities also affected the likelihood of officers and investigative staff being tasked to a scene [239]. Therefore, variations in the attendance of scenes identified previously can be partially linked to tasking procedures as well as the ratio of scene staff to police officers and crime rates [14, 37, 76]. Increased demand on resources means that tasking of scene personnel must maximise the detection and recovery of available forensic evidence as efficiently as possible [239]. Further analysis into the factors identified by Gill and his colleagues [76] which could affect tasking can identify whether such variations in procedures can be minimised using standardised call scripts.

Tilley and Ford [14] also found that scene attendance policies varied widely between and within police forces. In some forces, the first officer attending (FOA) has complete discretion of the scene and whether a CSE should be called. Others polices were in place for specific circumstances where a CSE should be called. Even when formal policies were in place which specified the offences which required a CSE to visit, they found that many respondents were unaware of a specific policy and junior officers tended to call CSEs just in case [14].

HMIC in 2000 and 2002 [40, 108] recommended that CSEs are deployed in a more standardised manner utilising either a blanket or discretionary scene attendance procedure for specific crime types. This means, that certain crime types which are believed to provide the biggest likelihood of collecting evidence which will further the investigation (and lead to a detection), are attended every time [42, 244]. Those cases which are more variable, are screened according to the first methods identified and CSEs dispatched on the evaluation of the tasking officer [23, 42, 76]. Discretionary attendance is dependent on the number of CSEs available for the level of crimes committed per force as well as the reliability of information given to call handlers located at crime desks and their skills and knowledge to interpret the value of evidence available [5].

The perceived importance and potential strength of evidence and its significant value in the criminal investigation is a decisive factor in determining attendance procedures of CSEs [239]. Screening policies can be used to decide whether a CSE is required to attend a scene. Information gathered (e.g. by the crime desk or FOA) during the initial stages of an investigation regarding the circumstances and possible evidence available from the scene can determine the necessity of CSE attendance. In order to attend scenes in a timely manner, and consequently maximise evidence potential as well as offender detection, tasking of resources must be well managed [23, 40]. A number of different methods for CSE tasking have been established in England and Wales [239].

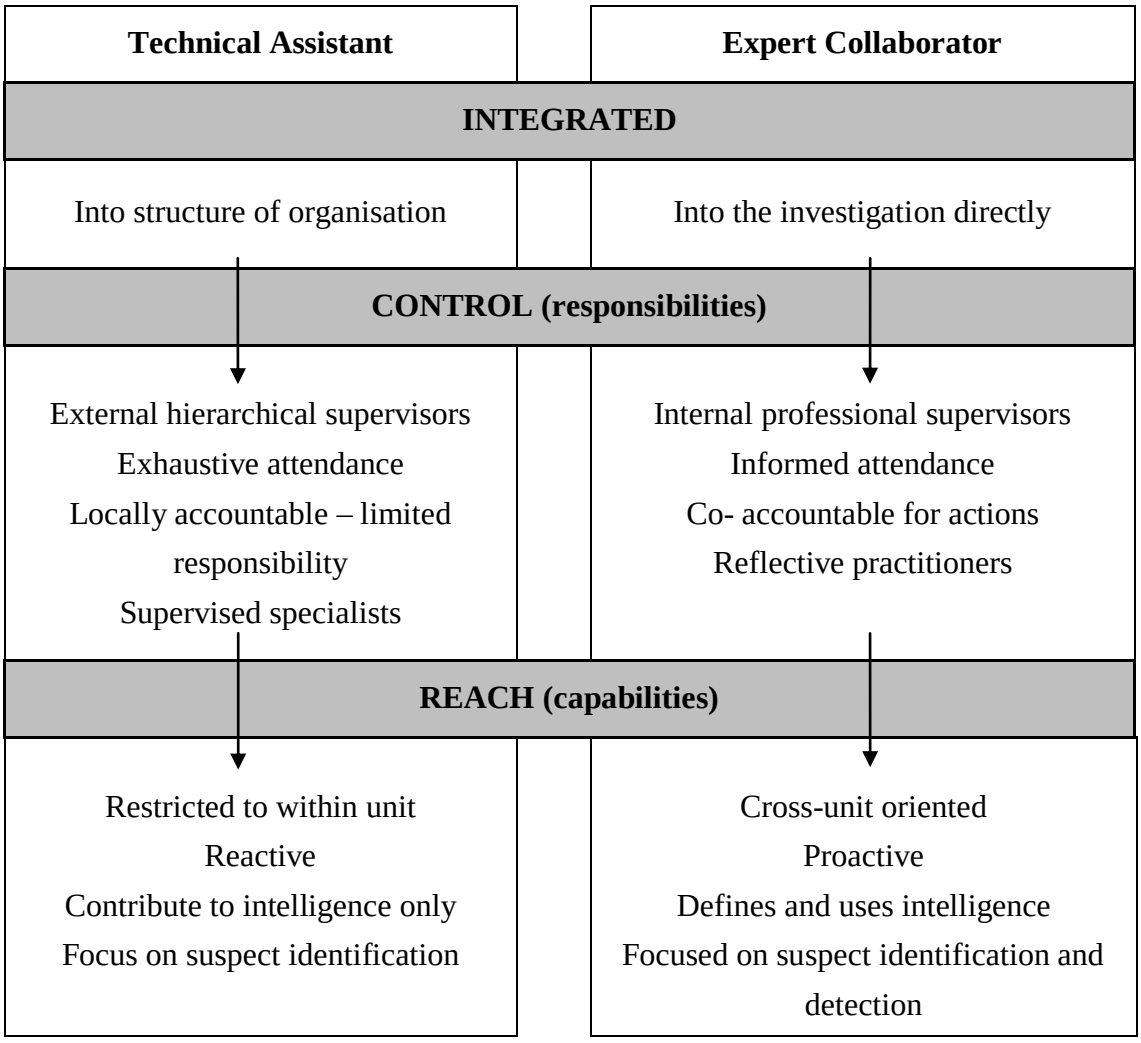
2.2.7. Expectations and role perceptions

The necessity to employ specialist scene investigation staff (or CSEs) to recover and collect evidence from crime scenes has been recognised by police forces throughout the UK [1, 15, 17, 96]. Over the years, the examination of crime scenes has evolved to become much more complex and CSEs are now required to have some understanding of the underlying knowledge of scientific process involved in evidence analysis in order to carry out their job [1, 17]. The acceptance of CSEs in the investigative team hinges on the perception of their role by others involved [5, 40, 242]. Williams [15] demonstrated that the understanding of the nature of the work of CSEs and their perceived role in terms of their responsibilities and placement within the investigative team varied greatly [5]. The differences in the perceived roles of CSEs and the understanding of the nature of their work were found to affect the efficiency and effectiveness of the investigation [5, 17, 23, 40].

In the study by Williams [15], CSE staff were perceived either as "*expert collaborators*" in an investigation or as "*technical assistants*" to real investigators [245]. The difference in the perception of these two roles affects their degree of integration or involvement in an investigation. Figure 6 illustrates the consequences of differences in perceptions of CSEs [15, 246]. It specifically identifies the "*type and degree of 'control' that CSE's are able to exercise over their own work*" and the "*extent of their 'reach' into (or involvement in)"* the investigation of crimes [15]. The difference between the two labels essentially indicates how well integrated into the investigation CSEs were found to be.

The label "*expert collaborator*" recognises the authority and specialist skills based on the relevance of distinctive knowledge-based experiences resulting in the routine application of these expertises in the investigation of crime scenes [15, 242]. Expert collaborators are valued as reflective professionals skilled at producing and interpreting forensic materials, and competently contribute their knowledge to an investigation [15]. Whether CSEs acknowledge themselves as 'experts' or not, the importance of the work performed by them continues to increase [247]. Expert

collaborators "*promotes an understanding of scientific support which acknowledges the distinctive knowledge-based expertise of forensic practitioners*" [112].



** Reproduced from Williams [15]*

Figure 6: A comparison of the role labels of CSEs either as expert collaborators or technical assistants

"*Technical assistants*" were seen to provide information which is valid and technically reliable which then needs to be assessed by more senior members of the investigative team [15, 242]. This implies that the level of expertise of the individual is less important as all of their work is performed under careful supervision due to their "*predominantly technological focus*" [248]. Consequently, this results in the competence and skill levels of CSEs being underrated and misperceived [15, 242].

Harrison [1] stated that CSEs valued their professional autonomy to regulate evidence collections and scene examinations. CSEs were previously seen to provide the means of bridging the knowledge gap relating to the "*potential discriminative powers*" of types of evidence as well as the improving the relationships between police officers and forensic scientists [5]. Considerable insight into the effects of this issue could be provided by a detailed assessment of CSE roles and the perceptions of CSEs (by others and themselves).

2.2.8. Timeliness

All aspects of the investigation are subject to time pressures – the police investigation, the scientific analysis of evidence, the production of the case reports for court – irrespective of any delays in the receipt, submission or collection of evidence, the identification of offenders, etc. [40, 87]. The interconnected nature of the work of these organisations means that often individuals are dependent on one another in order to carry out their work. The use of several different roles and jobs means that each must carry out the work they are required to effectively to produce efficient outcomes [40, 87].

The amount of time it takes for officers to respond to incidents has been shown by Jansson [41] to depend on: the amount of time between the incident occurring and it being reported to a call handler stationed at a response desk, the time it takes for a call handler to establish all the necessary information from the caller, the grade

allocated to the incident (an assessment of the severity of the crime as well as the likelihood of obtaining evidence), the availability of resources or workload of investigating officers and CSEs, as well as issues such as the time of day and the distance to the scene [41]. Variations have also been shown to be present between different forces in terms of the response times for priority grade calls, where some forces respond twice as fast to priority calls compared to others, this may be linked to some of the factors identified above [41].

Coupe and Griffiths [87] found it particularly important that scenes were attended quickly and evidence collected before they can become contaminated or lost. They observed that the speed of attendance at burglary scenes by police officers and crime scene examiners (which in their study on average took 30 minutes) directly affected the detection rate as well as the likelihood to collect evidence which may be important to the investigation [87].

It was also identified that the speed of scene attendance (the time between incident being committed, reported and attended) also affected the chances of offenders being caught at the scene [41, 87, 249]. Jacobson *et al*. [38] highlighted the need for timely response to reports of burglary crimes, as they found that most offenders have disposed of the incriminating evidence stolen from the property within 25 minutes of the incident. They stated that not only was this important for catching offenders in the act but it also affected the chances of the victims having their property returned to them [38].

Burrows [97] investigated the variations in clear-up rates for burglary offences in six forces in England and Wales. Although, he found no correlation between faster response times and higher detection rates, the study investigated how response times impacted all burglaries (not just those reported in progress) as well as the effects of cases detected through offences being taken into consideration. Burrows [97] argued that solely focusing on quick response times can only be beneficial if the offence is reported as in progress or immediately after it has occurred. In all other cases, where

some time has passed since the offence was committed, the speed of response did not necessarily affect detection rates [41, 97].

The importance of timeliness for the utility of forensic evidence and the value of the intelligence for police investigations has been repeatedly discussed [15, 16, 40, 42, 55, 96]. However, the linear model developed by the SWIM [37] in 2007 was the first comprehensive study to look at the correlation between timeliness factors (e.g. lead times, speed of attendance, case turn-around-times) and crime rates in a systematic manner to assess the effectiveness of forensic science as well as measuring performance of investigative staff [37].

They found that during their study, 73% of burglary (dwelling) incidents were attended within 24 hours and 98% within 48 hours. Different crimes demonstrated different initial lead times [37]. They defined a lead time as the time elapsed between the date/time that the incident was reported and the date/time the scene was attended (mean 1.3 days). SWIM also showed that the attendance of some other crimes took considerably longer [37]. Housebreaking crimes have been shown to produce a range of reactions from victims[13]; therefore the requirement to contain and process the scene quickly provides some reassurance and allows the victims to return to their normal lives as quickly as possible [97].

The variation in lead times reflects factors such as communication, travel time and CSE workload (availability) [37]. The volume crime scenes which CSEs attended within 8 hours often revealed that the first 2 hours were linked to travel time [37]. Irrespective of the 48 hour attendance rate, actual time spent at scenes does not reflect the quality of work produced nor can it assess the level of CSE performance [37]. However, resources must be available in the first place to provide the required level and quality of service to the public required to demonstrate the effectiveness and efficiency of the investigative system [37].

[13] E.g. anger, shock, embarrassment.

Arguably, the most routine evidence types collected from crime scenes are DNA and fingerprints [93, 250, 251]. Therefore, the success of the investigation is potentially linked to the rate at which these are processed and an identification is established. Bond [55] investigated the timeliness of fingerprint and DNA identification for a number of different crimes. He found that where DNA evidence was collected and analysed, a suspect was arrested within sixteen days (on average), whereas fingerprint evidence took nineteen days [55, 250, 252]. The need for improved timeliness has been identified repeatedly over the past 40 years, with the increased use of DNA and fingerprint evidence the focus has been on identifying whether they are being used effectively and efficiently in achieving investigative outcomes [55].

2.3. Work carried out other jurisdictions

> "*The situations faced by those tasked with the investigation of crime scenes reflect the demographic, geographic and law enforcement challenges of each jurisdiction*" [225].

Some work assessing the use of forensic science and the investigation of crime has been carried out in other jurisdictions [6, 8, 44, 50, 93, 98, 99, 253, 254]. A number of reports were analysed in order to assess whether similar issues to those identified to be present in England and Wales were also noticeable, and table 6 clearly demonstrates some similarities. Analysing all of the published literature available from elsewhere would not have been possible within the time frames of this research; therefore the following section provides a selection of studies available and does not claim to contain a comprehensive list.

Table 6: The recurring themes identified in the past four decades from work carried out in other jurisdictions outside of England and Wales.

Year	Report	Repeated themes						
		Education		Inter-relational themes			Management	
		Knowledge	Training	Communication	Collaboration	Role perceptions	Resources	Timeliness
1977	Greenwood *et al.* [255]		√	√			√	√
1984	Peterson *et al.* [253]	√	√	√	√	√	√	
1987	Peterson *et al.* [254]	√			√		√	
1996	Horvath & Meesig [8]	√	√	√	√			
2004	Briody [98]			√	√		√	√
2008	Roman *et al.* [99]	√	√	√	√		√	√
2009	NAS [6]		√	√	√		√	√
2011	Peterson *et al.* [45]	√		√			√	√
Scotland								
2003	HMICS [44]		√	√	√		√	√
2004	Jamieson [50]		√	√			√	
2007	SCRO [256]		√	√			√	
2009	Fraser [93]	√	√	√	√		√	√

The analysis of the use of forensic science began around the same time in the USA as it did in the UK, with research by Greenwood *et al*. [255] and Peterson *et al.* [253] assessing the clearance rates for volume crime offences (mainly burglaries) when forensic evidence was available. A significantly higher conviction rate of offenders was found for cases that utilised forensic science, than cases which did not [253, 254]. Further work carried out in the USA recommended that crimes should be targeted "*where the most progress could be made*" [255, 257, 258]. Focusing on crimes and evidence which provide the best opportunities to achieve effective investigative outcomes – the detection, identification and prosecution of an offender – has therefore been found to be important in other investigative communities in different jurisdictions [259].

In their review of US publications, Horvath and Meesig [8] also identified a lack of forensic evidence awareness where "*police investigations [...] consistently reveal that the use of physical evidence is limited by the knowledge and skills of investigators as well as the extent to which they are able to interpret it within the context of their investigations*". This clearly reflects the work of Ramsay [16] and Touche Ross [18] who also identified that general forensic knowledge and awareness appears to be limited in investigative staff, and that forensic science faces a similar suboptimal utilisation as experienced in the UK. Poor knowledge between investigative personnel was also found to be an issue by Fraser [200]. The level of understanding different investigative parties need to have of the processes and practices of other parties to work together effectively was found to be limited [200].

Exploring the role of crime scene examiners, Peterson *et al.* [253, 254] found that CSEs were disjointed members of the investigative team and did not fit easily into the rank-based culture experienced in policing. Work from Australia also stated there was a simplistic perception of the roles and jobs of CSEs; they had been viewed as "*pickers, packers and posters*" [225]. Difference in perceptions between investigative staff was also found. Laboratory-based personnel considered themselves as scientists and other ('field') personnel as technicians. This fails to recognise the complexity of the tasks and responsibilities and crime scene examiners

"*have not helped* [change this perception] *as they do not see <u>themselves</u> as scientists*" (original emphasis) [225]. It has also been determined that CSEs are not utilised in a uniform manner by different police departments causing further differences in their role expectations and responsibilities [6, 99]. Other similarities were expressed regarding the limited quality controls and performance measures of the work carried out by CSEs in the USA, mirroring findings from England and Wales [99].

Assessing the effects of evidence on the court process was investigated in the late 1980s and early 1990s [253, 254]. Peterson *et al*. [253] determined that "*cases with physical evidence tend to go to trial a greater percentage of the time*". In a subsequent study they also found that DNA evidence provides a certain confidence that the offender committed the offence and consequently results in the judges increasing the severity of the punishment by custodial sentences which were longer than if other evidence was available [254]. However, that the effects of evidence on custodial sentences is dependent on the jurisdictions was highlighted by Briody [98], as the results of his work carried out in Australia was affected by differences in legal procedures (e.g. lack of plea bargaining or where the jury have no say in recommending a sentence).

Briody [98] assessed the effects of evidence in cases of sexual offence, homicide, serious assault, and property offences. He compared cases which contained DNA evidence to cases which had other or no evidence in relation to their progression through court [98]. Stages of the system where the decision making was determined critical to the case progression were identified, and case numbers were measured at each point. As well as investigating the effects of evidence at specific stages of the investigation (e.g. the decision to prosecute, the number of guilty pleas, whether the evidence assisted judges in making decisions about guilt or innocence), the severity and length of custodial sentences were also assessed [98].

Table 7: The influence of DNA evidence on the progression and outcomes of cases going through court for four different crime types in Australia [98].

Case type	Case reaching court	Guilty pleas	Jury decisions	Sentencing
Sexual Assault	Positive predictor, although not significant	No significant effect on inducing guilty please	Positive, crucial predictor	Not significant variable on degree of sentencing
Homicide	Significant, a higher proportion reached court.	No significant effect on inducing guilty please	Strong influence on decisions. Odds of a conviction being higher with DNA or fingerprints.	Guilty verdicts produce custodial sentences for homicide. No significance on length of sentence in manslaughter cases.
Serious Assault	Positive predictor, although not significant	No significant effect on inducing guilty please	Strong influence on decisions	Blanket sentencing for all serious assaults, positive but not significant correlation with length of sentence.
Property offences	Sole predictor that cases would be prosecuted	Highly significant relationship	Cannot be tested, cases not heard in front of a jury.	Cases not heard in front of a jury, less likely to receive custodial sentence.

Table 7 demonstrates that the availability of DNA evidence (and fingerprint evidence in some cases) has the potential to affect whether cases reach court and whether a jury find the offender guilty [98]. This is one of the few studies carried out which tests the value of forensic evidence and detailed assessment into this issue could demonstrate the benefits of specific evidence types for the investigation of volume crimes. Briody [98, 260] also aimed to assess the capabilities of DNA evidence to reach the prosecution stage of various crime types by utilising forensic intelligence databases. He found that databases had limited impact on the prosecutions and were responsible "*for achieving convictions in one percent of reported burglaries*" [261].

The only study to assess the cost-effectiveness of forensic investigations has been carried out by Roman *et al*. [99] in the United States. The aim of this study was to assess how the number of suspects identified, arrested and convicted could be increased. Focusing on only on volume crimes in five US counties, Roman and his colleagues [99] collected data to assess the additional cost to a case when DNA evidence is processed at each stage of the investigation. They found that it costs approximately $4,500 dollars to solve a case using DNA analysis in cases that would otherwise go unsolved [99]. Insight into cost benefit analysis (in terms of type of evidence which produces beneficial case outcome) could be provided by detailed assessment of the utility of forensic evidence by identifying the most effective and efficient means of utilisation [99, 262].

Roman *et al.* [99] also assessed the costs of labs which outsourced their DNA analysis compared with counties that used local laboratories. On average, outsourcing cost twice as much as local analysis of DNA evidence. However, evidence processing costs are shared by all three investigative organisations in the USA – the local crime laboratory, the state crime laboratory and the police departments involved [99]. They found that, for cases which progressed across all five sites, over two thirds of costs (66%) are paid by local crime laboratories, state labs pay approximately one tenth (9%) of the costs, and the remaining 25% are paid by police departments[99]. Again, better understanding of budget and cost-benefit analysis could provide evidence to establishing whether forensic evidence and

forensic service provisions are aiding the effectiveness of the investigation of specific crimes.

Similar to findings by Bond [82], Roman and his colleagues [99] found that DNA evidence needed to be collected quickly in order to provide a better chance of a profile compared with other evidence types. They found that often DNA materials are contaminated or have deteriorated as CSEs did not attend quickly enough or realise the possibility of the availability of DNA evidence [99]. Overall, they found that volume crime cases involving property offences where DNA evidence was available identified and arrested twice as many suspects compared to other evidence types and more traditional means of investigation [99]. They also determined that when DNA evidence was collected from scenes and analysed, more than twice as many cases were accepted for prosecution. Therefore, in the investigation of property offences, DNA evidence "*increases the rate at which suspects are identified, arrested and prosecuted*" [99]. Roman *et al*. [99] concluded that in order to improve the effectiveness of the investigation, more emphasis should be placed on DNA-led investigations for identifying suspects and solving criminal cases. Although these results are very powerful for providing evidence of the value of DNA, they must be corroborated by more research in different jurisdictions and for different crime types.

Like the work carried out by Briody [98], Roman *et al.* [99] assessed the overall effects of DNA evidence in relation to the likelihood of cases reaching court, suspects pleading guilty, offenders being convicted, and length of custodial sentences for cases where DNA was present than cases where there was other evidence types. Positive bivariate correlations[14] identified that the first two relationships were found to be significant (i.e. DNA did have an effect on cases proceeding to court and offenders pleas), however (like the work by Briody [98]) they found that DNA evidence had no influence the type of conviction or the length of the custodial sentence [99].

[14] The measure of the strength of the relationship between two variables, where no distinction is made between them (dependent and independent).

The introduction of national DNA databases in various jurisdictions around the world since the late 1990s, not only provided a means of electronically storing DNA profiles from the criminal population (mainly) but was also intended to be utilised to reduce volume crimes through faster sharing of intelligence and potential effects on recidivism rates (deterrence) and crime prevention [261, 263, 264]. However, this impact is difficult to judge or measure and requires long term analysis in order to obtain any systematic data [92]. Roman and his colleagues [99] identified that in comparison with fingerprint evidence, DNA was five times more likely to identify a suspect, and individuals identified by DNA had twice as many previous criminal convictions than individuals identified and arrested by traditional investigations (i.e. non-forensic).

Roman *et al*. [99] also reiterated that the effectiveness of the investigation of crimes hinged on the collaboration between each of the organisations (which they termed actors) involved. The lack of feedback and communication between various members was highlighted [99]. There was disconnected communication between police officers and the forensic laboratory, where "*officers and investigators had to wait long periods of time to hear any results*" [99]. That officers gave up on contacting laboratories to enquire about DNA results was also found [99]. Police require feedback from the laboratories regarding how effectively they are collecting evidence from scenes, and laboratories clarify the suitability of that specific evidence for achieving the requested outcomes [8]. That police and forensic service providers must have mutual understanding of what can effectively be achieved was reiterated [16, 23, 40].

In order to improve relationships between individuals involved in the investigation, improvements to training of the capabilities (and limitations) of forensic science and investigative practices has been recommended [99, 169, 177]. That training needs must be identified so that programs can be targeted specifically was found by Doak [169] and others [177, 265]. This would not only require data relating to the prevalence of evidence types collected from crime scenes but also data which identifies the evidence types which provide the best value (e.g. higher likelihood of

identifying a suspect). A comparison between the two would determine whether they are in agreement and the outcome could be used to direct training programmes [99].

Horvath and Meesig [8] reviewed the literature available, predominantly from the USA which assessed the use of forensic evidence. They found that physical evidence is greatly underutilised and for most cases "*physical evidence is not determinative of case outcomes*" [8]. Therefore, they suggested the introduction of better collaborative training measures which focused on the value, utility and limitations of forensic evidence [8]. In order to enhance the use of forensic evidence, they recommended tailored training programmes which covered the whole investigation and involved all of the different roles. Horvath and Meesig [8] also identified that policy makers and forensic consumers receive "*sporadic, unsystematic and uncoordinated*" training, although their roles require them to be in control of determining how evidence is used in the investigation. The variations in length, content and applicability of training programmes identified in the US, also reflects the situation in England and Wales, where the need for standardisation was suggested in the 1980s [40, 222].

The National Academy of Sciences (NAS) report [6] from the USA stated that the "*quality of forensic practice in most disciplines varies greatly because of the absence of adequate training and continuous education, rigorous mandatory certification and accreditation programs, adherence to robust performance standards, and effective oversight*" [6]. Judged one of the most critical reports of recent years, the NAS report identified the need for more funding; the desire for standardisation (by establishing standard protocols); the need for basic research into accuracy, reliability, and validity of many types of evidence; and the need to improve the quality of the graduate programs in forensic science [6].

Training and education programmes were recommended to be regularly assessed and updated, and should be more comprehensive than the "*apprentice-like transmittal of practices*" where "*scientifically valid principles* [are] *acquire*[d] [from] *rigorous interdisciplinary education and training*" [266]. Accreditation, education and training should not simply be about setting a standard which is then adhered to

without question but should focus on regular improvement of scientific techniques [267]. The NAS committee [6] stated that robust, systematic and suitable training programmes help to provide each member of the investigation with some understanding and knowledge of the how various parts of the investigation of a crime works.

The publication of the NAS report highlighted the need for more research on every aspect of the investigation in the US. The publication of this report has also drawn the forensic science community together to discuss how the problems can be addressed within each individual jurisdiction and more globally [6, 268]. Since its publication, the forensic science community has tried to estimate the effects on their jurisdictions and a number of follow up meetings have been held to discuss implications, strategies for change and to understand the findings [266, 267, 269-272]. Possible legislative and practical changes are still being carefully considered and deliberated by the stakeholders in many countries. Protocols for improving the national and international provision of forensic science can only be implemented once the gravity of the current situation has been thoroughly assessed and the implications of the outcomes understood [6, 267].

Most recently, the work by Peterson *et al.* [45] in the USA investigated the how different types of evidence routinely collected in an investigation is used (collected, submitted and examined). They were particularly interested to determine the "*role and impact of such evidence on criminal justice outcomes*" [45]. They found that forensic evidence can have an effect on case processing decisions but vary depending on type of forensic evidence, crime type, offence type and other case variables. The collection of evidence was much more extensive in serious crimes (mainly homicide) and the rates decreased for other crimes (e.g. rapes, assault, burglary and robbery). The samples most frequently collected, submitted and examined were fingerprints, firearms and body fluids (blood and semen). Forensic evidence was a "*consistent predictor of arrests*", situational variables such as victim reports, relationships between suspect and victim and arrest methods were also important [45]. Current

findings from Peterson *et al*. [45] support many of the findings from previous (older) research which indicate limited changes over the years [253, 254, 273].

2.4. Work carried out in Scotland

In Scotland, very few studies have been carried out into the effectiveness of the use of forensic services [44, 93], and none have investigated the utility of forensic evidence. Table 6 demonstrates the limited number of studies which have been carried out. The earliest work into investigative practices was carried out as part of a thematic inspection by the Scottish Government and HMICS in 2003 [44]. The inspection investigated the management of volume crime, assessing call handling, crime recording, police actions and the use of technology. It was also interested in whether the victim's needs were being met effectively. It found a "*need to ensure effective joined up working within an across forces and criminal justice organisations*" in order to address volume crimes [44].

That better collaborative working practices between investigative organisations are required in order to "*make significant strides in both solving reported crime and reassuring the wider public"* has been clearly stated [44]. The crime management process is complex, where the involvement of different investigative agencies, policies and procedures (of scene attendance, evidence evaluation, etc.) and jurisdictional boundaries affect the course and efficiency of the investigative process as well as the effectiveness of the outcomes [44]. The Scottish Government report "*emphasises the need for balanced deployment* [of resources] *to ensure the fundamental needs of crime investigation are met"* [44]. Ensuring resources are tasked appropriately to scenes which are judged to provide the best chance of collecting evidence which can further an investigation mirrors the work and findings of SWIM [37] in England and Wales.

Benefits of forensic databases (specifically the national and Scottish DNA database) on the effectiveness of the investigation were also discussed by Fraser [93] in his review of the acquisition of DNA and fingerprints in Scotland [274]. Fingerprints and DNA have been identified as the most reliable means available to identify individuals and the use of such evidence in databases provides valuable potential benefits to the police and other organisations in the criminal justice process [250, 275, 276].

Fraser [93] concluded that databases provided the means to: accurately identify individuals (to a high degree of confidence), efficiently eliminate innocent individuals from enquiries (e.g. victims, witnesses, medical personnel), increase identification and detection rates of offenders locally and across jurisdictions, and as a result of these factors it also has the potential for "*speedier more effective prosecutions*" [93]. However, databases need effective management in order to achieve their primary aims [274]. If the "*potential contribution* [of databases] *to the investigation of crime and criminal justice*" is to be maximized, policies and practices must be well known and shared effectively [93]. Databases rely on sampling policies relating to relevant individuals, crime scenes as well as policies for providing elimination profiles of investigative staff [277-279]. The use and value of databases (and the evidence contained within them) require protocols to be established which effectively measures and monitors the potential benefits which are gained from them [93]. The use and value of forensic evidence and the databases associated with them to investigations is currently not known in Scotland.

2.4. Utility of forensic science

> "*There has been little research to demonstrate whether and how* [forensic evidence] *impacts on the investigative process and outcomes*" [53].

There is a limited amount of work in the UK and elsewhere investigating the utility of the forensic science to investigations. Studies have failed to systematically evaluate which types of evidence add the most value towards the outcomes (e.g. secure a conviction or increase the chances of obtaining a confession/guilty plea) [17, 53, 262]. The need for this type of research has been partially recognised previously. For example:

- Horvath and Meesig [8] in the review in the US showed that researchers failed to address the value of forensic evidence, instead predominantly focusing on the type and number of samples collected during the investigation. Very little attention was given to issues "*related to scientific analyses of such items*" [8].

- Bond [55] identified that "*focusing on individual aspects of the investigative chain*" produces limited success, as the effects on the process as a whole are not considered.

- Both Fraser [93] and Williams [15] recognsied the lack of data relating to the "*analysis and utility of DNA and fingerprint identifications*" and the effects on "*detection rates for cases involving DNA or fingerprints*".

That the "*growth and acquisition of knowledge in the investigative use of forensic science takes place in an incremental and fragmented manner*" has been stated by Fraser [200]. The increasing importance of forensic science to criminal justice means that more research is required which increases understanding, competence and integrity as well as expanding the knowledge of current techniques and practices [280].

Rigorous studies exploring the value of specific evidence types is not only lacking in England and Wales, but has been identified to be an issue in Scotland, the USA, Australia and (it can be assumed) in many other forensic communities across the world. More detailed research addressing this knowledge gap could be used to

determine how materials collected affect the investigation [14]. Previous evaluations of the forensic process have concentrated on the examination of scenes, the selection of evidence for submission to the laboratory and the evaluation of materials in terms of the number of items produced or analysed [8, 14, 18, 94]. SWIM [37] states that performance measures assessing the value of evidence towards achieving efficient and effective investigative outcomes would be beneficial towards determining areas for improvement [37].

The ACPO [23, 43] together with HMIC developed a set of performance indicators (PIs) in an attempt to measure the value and use of forensic science. They determined that measuring factors such as: the number of scenes attended, the percentage of fingermarks recovered from scenes, the percentage of DNA matches from evidence and the levels of crime detection were a means of evaluating forensic performance [281]. However, such indicators focus on the quantity of samples (i.e. number of outputs), and not necessarily on its quality to contribute to the outcome of an investigation [23, 282, 283]. The effectiveness of an investigation does not solely rely on the quantity of samples collected but is also related to the quality of the work.

However, as SWIM [37] and McCulloch [12] identified, many police forces did not routinely collect the data required to assess effectiveness. "*Without reliable outcome based data it is difficult to* [...] *establish a benchmark by which to judge the relative performance of forces*" where forensic services are also unable to "*measure their contribution*" [40]. By concentrating on internal variables which assess their degree of success (i.e. clear up rates), the effects of their contribution to the entire investigation cannot easily be evaluated. HMIC [40] in 2000 recommended that all scientific support staff should be subjected to regular reviews regarding performance so that efficient processes can be maintained and competence improved. The follow-up inspection in 2002 [108] reiterated the need for the improving the collection, submission and analysis of performance data on an annual basis. The inspection stated that in order to better assess the effectiveness of the system, factors such as the conversion of forensic identifications into detections and detections into convictions

must be recorded and analysed [40]. It was found that they were not available in a standardised format hindering comparison and examination [108].

That forensic science is part of a complex system was identified in the introduction. However, the contribution forensic science makes to the criminal justice system is little understood [284]. The need for more research has been discussed in this section in order to begin to address this issue. The awareness of the value and potential for maximising what forensic science can do is needed. Recognising how forensic science should best be deployed to ensure it delivers the greatest benefits and has the most impact is also important [285, 286]. Only if the contribution that forensic evidence can make to the investigation is recognised by those involved (police officers, forensic service providers, legal representatives, lawyers, judges, etc.) can it be of greatest benefit to achieving effective outcomes [13-15, 55, 200].

No previous empirical research is available which addresses the value of forensic evidence in the investigation in Scotland in terms of identifying their contribution towards case outcomes. This section has demonstrated that the work most closely related to attempting to assess the value and use of forensic evidence has been undertaken by researchers in Australia [98] and the USA [99].

2.5. Recommendations made by previous studies

> "*It is one thing to recognise that there is room for improvement in the use of forensic science in support of investigations but more difficult to identify the underlying reasons and find ways to bring about changes*" [225].

As well as exploring a number of different themes which affect the investigation of crimes over the years, the previous work carried out in England and Wales also made recommendations towards improving specific issues identified [5, 14, 16, 18, 23, 37,

40, 42, 87]. The disconnected and often vague range of 'solutions' previously identified will be shown to have had a limited effect on the complex involvement of individuals in the investigation of crimes and the application of forensic science. Table 8 illustrates a number of recommendations put forward from some of the studies utilised in this report that have been classified into generic categories which include: procedures, resources, training, technology, management, and areas for more research. Recommendations for solving each issue individually fail to address the interconnectivity and complexity of many of these issues.

Recommendations relating to advances in technology were made in the 1980s. Byford [96] identified a need to introduce compatible computer systems which had the potential to be interfaced with other forces to provide a comprehensive means of accessing case data as well as a mechanism of sharing intelligence between forces. Information management systems have the potential to help oversee the collection and utility of forensic evidence [16]. Integrated systems allow the effects of case outcomes to be shared across "*police, prosecutor and court organisations to facilitate and enhance the understanding, interpretation and use of forensic evidence*" [8].

Touche Ross [18] and the Audit Commission [287] have previously recommended that statistics relating to the use of scientific support should be collected nationally. However, McCulloch [12] found that the data collection for her research project was laborious and time consuming, even though there was a "*high level of interest in the data*" and "*strong support for the collection of national statistics*". Therefore, in order for forces to compare performance measures, the data must be easily accessible, comprehensive and up-to-date [12].

Table 8: Recommendations previously made by studies carried out in England & Wales

Study	Recommendations					
	Procedural	**Resources**	**Training**	**Technology**	**Management**	**More research**
Byford Report [96]		Sufficient administrative staffing to effectively handle incoming information.	Specific training for 'specialised' staff (e.g. Chief Officers, SIOs).	Computerisation of records effective and management of system.	Regular audit of system.	
Ramsay [16]	HOLAB3[15] forms need redesigned.	Rate of admission of evidence improved by better communication.	Police officers must be suitably competent to deal with scene investigation		Better control of information for CID, and joint monitoring of cases	Use of forensic evidence by investing officers needs to be considered.
Touche Ross Management Comp. [18]			Introduction of manager to oversee training of CSEs and police officers.	National indices (blood groups, shoemarks, etc) of convicted persons to be developed.	Guidelines on the selectivity & prioritisation of evidence need to be considered.	
Amey *et al.* [94]		Single visit strategy for crime scene examination.	Specialist knowledge of the law for arresting officers		Move from reactive to proactive investigations	

[15] Home Office Laboratory Submission Form

Study	Procedural	Resources	Training	Technology	Management	More research
Coupe & Griffiths [87]		Formal crime scene screening to improve selection of viable scenes	Training for screening officers.		More rigorous analysis of crime patterns, promote intelligence driven policing.	
FSS & ACPO [23]	Standardisation of QC/QA measures across all laboratories and scene work.	Increased proactive use of forensic science.	Decision making staff to have adequate awareness of scientific support.	.	Better performance indicators needed to encourage flexible working.	
Gill *et al.* [76]	Development of 'good practice' for investigation of high volume crimes.	Better use of crime desk officers as investigative resources.		Police systems not making effective use of intelligence from all evidence types.		
McCulloch [12]	Standardisation of crime definitions and evidence evaluation scores			Improvements to SOCIMS to use offence codes, removes input errors/variations	Better collation of data for national analysis of cost effectiveness.	To determine the rationale begin the difference in the utility of forensic science

Study	Procedural	Resources	Training	Technology	Management	More research
Tilley & Ford [14]	All forensic service providers should be quality assured and quality controlled		Continued lack of awareness of forensic science and its utility.	Influence and impact of the development of the NDNAD on other evidence.	Increased proactive use of forensic science.	Cost effectiveness, value for money, use of forensic science, etc.
HMIC [40]	Development of nationally agreed minimum standards of training.	Review of CSE attendance policies for volume crimes and submission criteria for DNA.	Regular performance review of staff, assess professional competence.	Systems to comply with NDNAD & audit methods in place.	Strategies and supporting policies are current and understood.	
Jacobson *et al.* [38]	Interview techniques of suspects in custody.	Minimum requirement of scene examinations clearly defined.		Transparent crime screening. Regular updated of database.	Constant flow of information between officers involved in investigations.	
Burrows & Tarling [42]	Data collection for national evaluation to be determined.			Improve means of data collection – NAFIS & NDNAS.	Routine collection of data relating to the use of forensic science	Analysis of volume crimes from data available from other forces.
Williams [15]	Nationally agreed performance measures.	CSEs performance variations in the overall investigation of crimes.		Introduction of a robust case tracking system.	Requirement of improved systems to monitor the contribution of forensic science.	Sharing of findings from pilot studies between forces.

Study	Procedural	Resources	Training	Technology	Management	More research
Bradbury & Feist [5]	CSE working practices to be defined and commonly implemented.		Improved training results in a more coherent approach to detection and performance	More use of cold-searching using technological advances (e.g. NAFIS)		Effects of call handlers on the investigation.
Burrows *et al.* [9]	Screening procedures to be developed (blanket or discretionary attendance)	Reduce case work load per CSE to allow adequate time to effectively investigate cases.			Provision of an idealised managed model (procedural, discretionary and mixed).	More systematic research using control samples to assess the effects of resources, etc. on investigations.
SWIM [37]	Review and standardise submissions policies and procedures. Streamline Bureau Policies.	Change shift patters to mirror crime patterns. Balance CSE resources	Raise submission levels by sharing best practice	Need for better IT management systems. Address poor data quality in existing systems to maximise their use.	Implement policies to maximise attendance rate. Ensure effective tasking and process management	Conduct detailed process analysis

Information should follow formal channels (e.g. briefings, memos) but should also be encouraged to occur informally whereby information is conveyed quickly and directly between members of the who may require the intelligence to proceed [38]. A more integrated approach to investigations of crimes was recommended using a combination of written, oral and electronically available communication systems [23, 38]. In order to utilise their resources most effectively, Jacobson *et al*. [38] recommended that clear understanding how to "*routinely make best use of available information sources*" is required and they suggested that this could be achieved by better communication and closer relationships.

Ramsay [16] stated that closer collaboration was required between forensic service providers (in this case the FSS) and police forces via the introduction of information and reception units. Staffed by a representative mix of roles (scientists, police, etc.) this would provide a point of contact not only for obtaining information or intelligence regarding a case but would also provide a source of knowledge in relation to more specific actions or detailed process (e.g. scene investigation) in the investigation [16, 96]. Used as a knowledge base, clarification relating to actions at specific stages of the investigation or benefits of particular evidential items can be obtained easily and efficiently from a reliable, well trained advice source [96].

The need for improved collaborative efforts were first identified by Byford [96] and Ramsay [16] who recommended that police officers and forensic scientists should undergo "*occasional short-term attachment*[*s*]" in their partner organisations in order to develop and improve the understanding of the tasks, responsibilities, problems and work pressures they face [18]. Selective arrangements which were in place at the time, involved no systematic deployment and often was underutilised as it was optional [18]. Although encouraged, scientists were inevitably too busy with urgent case work to spend any time at the crime scene and experience the "*practical police operations which their work is intended to support*" [96].

Sufficient training should be provided to everyone, which covers the value and use of, as well as the limitations of forensic evidence and scientific techniques [8]. HMIC [23] recommended that ACPO developed nationally agreed minimum standards for the training of all investigative staff (scientific, technical, police, etc.) which could be quality controlled/assured. "*Forensic Science On Trial*" [19] also noted concerns regarding the lack of mandatory training of legal personnel (lawyers) in forensic science aspects. They found that the reliance on the "*interest and self-motivation*" of lawyers to receive some training is "*wholly inadequate*" [19]. Therefore they recommended that members of the Bar implement compulsory training for all legal representatives, to develop a minimum level of knowledge for all lawyers and provides the opportunity for continued professional development in forensic science [19].

Byford [96] also recommended the need to standardise methods of documentation (e.g. reports, briefs) and Ramsay [16] suggested that the forensic submission form utilised by police forces at that time (the HOLAB3 form) needed to be redesigned to ensure it was more accurately and thoroughly completed by investigative staff. Improvements have been noted in this area; however, the degree of completion of a form is difficult to control as was previously identified by Ramsay [16]. Investigating officers are often under time pressure, and notes taken on notepads or simply kept in mind to be filled into the relevant fields of the report are patchy, illegible or get forgotten due to new pressures [16]. Incomplete information was identified to be a problem in many of the studies reviewed [12, 38, 40].

Touche Ross [18] suggested that alleviating the strain on investigative staff can be achieved by better management, tasking and utilisation of resources. The production of guidelines which determined the prioritisation of scenes for attendance by crime scene staff was first suggested by Touche Ross in 1987 [18]. Routinely requesting CSEs to scenes was highlighted as the norm by Coupe and Griffiths [244] in 1996, however they recommended that a set of "*predictors*" (procedural rules) should be identified which enable police officers to make a more accurate assessment about scenes which would benefit from a CSE visit. A review of how CSEs are tasked to

crime scenes, especially volume crime scenes, was recommended by the HMIC inspection in 2000 [40]. They stated that tasking policies should be clearly understood and actioned by investigating officers [40]. SWIM [38] stated that tasking policies ought to be transparent and consistent to improve accountability; and appropriately managed to ensure tasking officers are adequately trained so that the initial actions taken do not negatively affect the investigation [41].

It was also suggested that in order to be tasked effectively, shift patterns of CSEs should mirror crime patterns so that the most scenes can be attended quickly and efficiently [14, 37]. The implementation of dedicated officers to attend specific crime scenes only (e.g. burglaries, car crimes) was suggested by Jacobson in 2003 [38]. However, the confused perceptions of the roles of CSEs as identified in section 2.2.7. means that "*a common approach to the role*" of CSEs should first be considered [18]. Williams [15] stated that CSEs should be seen as "*co-investigators*" where they are able to provide scientific advice to investigative officers and use their professional judgement when examining crime scenes [18, 23]. All investigative staff should "*think in terms of cases not items or tests*" [23].

The ACPO and FSS report [23] stated that clear criteria should be implemented for laboratory submission procedures to ensure a timely process and limit backlogs and delays. They also state that the current patterns of usage of forensic science could not reveal its investigative cost-benefit potential and that the usefulness of scientific support, rather than the effectiveness of their tasks should be measured (outcomes not outputs) [23].

Forensic science is not used often in a proactive manner, and investigators react to incidents reported [41, 288]. However, changing investigation to be more proactive has been said to require more manpower, time, effort and money compared to current reactive methods [14, 23, 41, 87, 94]. Benefits of a more proactive process have previously been discussed by Stockdale and Gresham [289]. Establishing connections between linked scenes could potentially identify crime hot spots or provide intelligence for the further focused deployment of resources. However,

effects on resources requires careful consideration before further recommendations are made [8, 102].

Recommendations have also touched upon accreditation. Standards for laboratory work, crime scene work, training programmes, education institutions and courses were considered. [19]. Recommendations for mandatory accreditation of forensic science practitioners (e.g. laboratory staff) were originally made in 2005 [19], when it was suggested that practitioners needed to be registered by the CRFP (Council for the Registration of Forensic Practitioners) in order to be actively involved in case work. Although the CRFP has now collapsed and the register no longer exists, similar ideas have been recommended by the NAS report [6], however on a much bigger scale, involving a larger number of groups of individuals. Current deliberations have discussed the implementation of a new register of chartered forensic practitioners as a means of assessing professional development and competent practice [290, 291].

This section has demonstrated that the number of recommendations previously published to address specific issues have often had limited impact. The main problem with previous suggestions has been that all the issues identified cannot realistically be addressed simultaneously, nor resolved immediately [5]. The factors affecting the investigation and the underlying sources contributing to the situation are not easily rectified. Many of the studies make recommendations towards a single issue, or fail to address the complex interactions of individuals or organisations or the interconnectivity of many of these factors. Facilitating change requires the active involvement and contribution from all the organisations involved and relies on the mutual desire by those involved to implement changes [292].

2.6. Summary

This chapter has reviewed the literature available which has previously addressed the use of forensic science in the investigation of crimes. In order to gain a better understanding of the themes affecting the effectiveness of the investigation, a range of studies, reviews, audits, inspections and reports were consulted. These studies have demonstrated that the themes predominantly identified in work carried out in England and Wales are also present in the (limited) literature available on this topic from other jurisdictions.

This chapter has highlighted that:

- There is continued interest in the routine use of forensic science in the investigation of crimes.
- Twenty-four studies from England and Wales have identified eight interconnected, recurring issues which affect the use of forensic science.
- There is a necessity to improve the effectiveness of forensic science to provide better support to policing throughout the UK.
- There is some evidence that similar issues affect the investigation of crimes in other jurisdictions.
- Previous attempts to alleviate some of the problems identified have been made but have failed to have a significant impact.
- The complex interconnected nature of investigations and the varying number of processes which are utilised throughout makes it difficult to carry out research.
- There is a need for to improve the collection and publication of performance data from each party involved in the system which identifies the use, performance and competence of their staff as well as their understanding of forensic science in criminal investigations.

- There is a distinct need for more research in many areas, particularly the utility of forensic evidence on the CJS in terms of decisions making throughout the process.

Chapter 3: Materials & Methods

> "*A* [survey] *is a technique of data collection in which each person is asked to respond to the same set of questions in a predetermined order*" [293].

A survey was devised and distributed to the four major Scottish Police Services Authority Forensic Service (SPSA FS) units – Aberdeen, Dundee, Glasgow and Edinburgh – as well as the two largest police forces in Scotland - Lothian and Borders Police and Strathclyde Police. A copy of the cover letter and survey can be found in Appendix 5 and Appendix 6.

It was considered that a survey was an appropriate means of gathering data to investigate the issues identified from the literature. Gaining an understanding of the attitudes, perceptions, opinions or behaviours of individuals within a target population by questionnaire requires careful consideration of how questions are phrased [107, 294-297]. Attitudes are a complex mental state which identifies how a person feels about something as well as how strongly they feel. Attitudes influence an individuals' behaviour, the physical (re)action to specific circumstances [294]. Attitudes and behaviours are difficult to measure, however collected together they can indicate how an individual feels and how this may influence their action or conduct [294]. Surveys allow subjects from a population of interest to relay information, facts or opinions on a particular topic in a standardised format which can be analysed in a manner which will allow statistical interpretation of results [107, 294, 295].

3.1. Data collection – Survey

Surveys are a fast and inexpensive method of collecting data to help identify an association or explain the relationship between variables (e.g. cause-and-effect; 'analytical research'). They can also be used to count and describe the variability between them (e.g. opinion polls or attitudinal surveys; 'descriptive research') [107, 297, 298]. Surveys can be classified into two groups: self-administered/self-completed surveys (e.g. postal survey) or researcher-administered (e.g. structured interview) [103]. The absence or presence of the researcher is the main difference between these two types and the choice of survey type can affect the validity, reliability and honesty (in terms of responses) of the results [295-297]. As this project was interested in gaining attitudinal data, a self–administered survey was determined to be the most suitable and practical methods for obtaining the most complete picture of people's opinions [107, 294].

Further reasons for choosing a self-administered survey method include:

- 1) it was the most cost effective means of obtaining data as it did not require travelling all over to the country to visit individual sites of interest;

- 2) opinions were sought from a range of roles at police forces and forensic service providers and questionnaires saved respondents time and encouraged engagement [106, 299];

- 3) it has been shown that more individuals were likely to respond if they were not directly observed by the researcher and were able to complete the survey in their own time and confidentially [300, 301]; and

- 4) so that interviewer bias or question manipulation between different groups can be avoided. Self-administered surveys are more objective by ensuring everyone was asked questions in a standardised manner (i.e. no alteration in wording or tone of voice as may be experienced by researcher-administered interviews) [105].

Furthermore, by creating a distance between researcher and respondent it was believed answers provided in relation to opinions and attitudes would be more truthful as "*respondents are less likely to under-report activities that induce anxiety or about which they feel sensitive in self-completion questionnaires*" [302]. The advantages of using a survey method for the collation of data for the purposes of this study included the ability to generate a broad range of answers from a large, dispersed sample group involved in the investigation of volume crime incidents [106, 299].

One major issue with self-administered surveys is ensuring that respondents remember to complete and return them [300]. This particular issue was overcome by establishing good contact with heads of departments at each site of interest and nominating a designated point of contact (a specific individual) responsible for returning all surveys to the researcher. It was believed that having a member of staff at each site responsible for the distribution, collection and return of surveys would provide a greater return rate. The local point of contact within each investigative agency was hoped would encourage the completion and return of as many of the surveys as possible due to the communication and interaction with someone within the organisation (i.e. a colleague) [300, 301]. It was understood that reminders would have to be sent closer to the return date, to ensure one last drive of gathering surveys together within the organisation.

Other methods of data collection were not considered as suitable for the data collection as a survey. Structured interviews and focus groups would have been useful for collecting more detailed views to the research questions, however these are difficult to implement and analyse as answers do not follow a set format [103, 104]. Also, restrictions would have had to be imposed on the sample size due to limitations of distance, costs and time. Participation in the research may also have been affected, as the anonymity of a postal survey was thought to have persuaded respondents to assist in the research, whereas if respondents had been identified many may not have been prepared to take part in interviews or focus groups [300].

3.1.1. Pre-test and Pilot Study

In order to assess the content, wording, and layout of questions, the survey was pre-tested throughout the Centre of Forensic Science and feedback was obtained from academic staff and PhD students. Respondents were asked to consider the set of questions presented in table 9 whilst completing the survey. Very few comments were received and limited alterations were made at this stage to the survey. Prior to the survey being distributed to the forensic service providers and police forces, the survey was also piloted at a one-day seminar hosted at the University of Strathclyde which included approximately fifty individuals from a range of professions and organisations related to forensic science (e.g. lawyers, forensic practitioners, academic police officers) [267]. Again, informal feedback was requested in terms of length, time taken to complete, general layout and clarity of wording. No further alterations were suggested, and the data was found to be recoverable in a format that allowed the researchers to obtain and exploit the most from the given answers.

Table 9: Questions to be considered by respondents of the pre-test and the pilot study of the survey

Approximately how long did it take you to complete the survey (minutes)?
Did the length of the survey affect your decision whether to complete the questions?
Was the survey relatively straightforward to complete?
Was the design of the survey (e.g. layout) suitable and easy to follow?
Were any of the questions ambiguous or difficult to understand?
Do you have any other comments/suggestions/improvements?

By keeping the survey as short as possible, in format that was easy to follow and complete, and simple to return, it was hoped that a more active participation could be obtained.

3.1.2. Survey design

Often a number of different types of questions are asked in surveys, to gather a rich and diverse set of data [103]. As most commonly encountered in surveys, the survey utilised in this project began by asking questions regarding general demographic information (e.g. age, sex, place of work) [103]. These questions are, in part, designed to put the respondent at ease by asking for a number of simple, easy to answer responses [295, 298]. The survey also covered the areas of training and forensic knowledge; sources of advice; as well as questions relating to policy and management (e.g. scene attendance). The wording of the questions addressing attitudes and measuring levels of knowledge on certain subjects was carefully considered so that they were as unbiased and non-intimidating as possible so that respondents did not feel uncomfortable and necessary to guess the 'right answer' or lie [295-298].

The survey was predominantly interested in volume crimes, with specific focus on crimes of theft by housebreaking, theft by opening–a–lockfast–place, as well as theft of and from a motor-vehicle. That the focus was on these crimes alone was clearly stated in the introductory letter provided to each participant (see Appendix 5). The majority of the questions were designed to be closed questions or asked for the rating on a scale (Likert scale) [303, 304]. Closed questions were chosen as they limited the number of responses which could be given by the respondents in order to make the coding and analysis of the data easier for the researcher, without losing any of the reliability and accuracy of the information provided [295, 303].

There are also a number of disadvantages of using closed-ended questions, including: there is the potential frustration from respondents if not being able to express themselves fully, the limited options provided by the researchers may result in some areas not being addressed, or questions may simply not be answered as respondents did not 'agree' with any of the options [295, 303]. The last of these possibilities was avoided by including an option for 'other' whereby respondents had a free choice of answers [103]. The questions which were interested in the opinions of respondents utilised a range of possible answers using a five-point Likert Scales [303, 304]. This has been utilised in this study also, as it was found that any more than seven points provides too much choice for respondents and results in them often picking a more neutral answer than when there are lesser choices [304, 305]. The questions also included a mixture of numbers and labels, to ensure the gaps between answers (e.g. between poor and very poor) were of equidistance apart.

Approximately 400 survey packs were distributed to the six locations throughout Scotland. The location and response rate of the participants can be seen in table 10. Each pack distributed included a covering letter (Appendix 5) as well as self-addressed return envelopes and the required number of surveys which reflected a rough estimation of the number of staff working at each particular site. Due to the direct contact with each site individually, more blank surveys could easily be emailed if necessary (e.g. if the number of staff were grossly underestimated by the researcher, or the survey pack got lost).

The rate of return was 68%, and given that this was a voluntary survey, this return rate is excellent and far exceeds the average response rate achieved by attitudinal research of under 35% [298, 300]. It has previously been shown that response rate in the region of 70% can be considered statistically valid and the data obtained an accurate reflection of the population, without needing to consider the possibility of bias [107, 294, 296-298]. This is a survey which assesses levels of knowledge and for the purposes of this project; it is our discretion to assume the answers given are the actual knowledge of the respondents. The fact the surveys allow individuals to respond to "*accounts of behaviour, attitudes or intentions*" provide a means of

reflection on the foundations of these actions in the form of their underlying knowledge and perceptions [301].

Table 10: Breakdown of the location and response rate of survey participants

Project Partner	Approximate no. of surveys distributed	No. of surveys returned	Return rate
SPSA FS Aberdeen	40	13	33%
SPSA FS Dundee	40	20	50%
SPSA FS Glasgow	100	88	88%
SPSA FS Edinburgh	60	27	45%
Strathclyde Police	100	81	81%
Lothian &Borders Police	60	44	73%
Total	**400**	**273**	**68%**

Analysis was carried out using non-parametric statistical tests as participants were asked to rank their observations or perceptions on a Likert scale in terms of the level of agreement or disagreement with specific statements (1 strongly agree → 5 strongly disagree). Correlations were tested using Kendall's Tau (τ) and significance was tested to the conventional levels of 0.05 and 0.01, followed by further statistical analysis for statistical significance.

3.2. Statistical analysis using SPSS

In order to record and assess the significance of the results the researchers developed code book of answers was developed for SPSS statistical software version 18.0. Within this codebook, a numerical value which was recognised by the software was attributed to each potential answer available from the questions contained in the survey (e.g. sex of respondent: 1=Male, 2=Female). Questions which had multiple answers were also considered and a numerical value for all the combinations of results were provided (e.g. Type of training received: 1=formal training, 2=coaching/shadowing … 16=formal training, on-the-job and reading material, etc.). The code book used which was used to perform statistical analysis within the software package can be seen in Appendix 7.

3.2.1. Kolmogorov-Smirnov Test

Questions within the survey asked participants to rank their observations or perceptions; therefore requiring the data to be analysed using non-parametric tests. The data involves assessing preferences on an ordinal scale. The Kolmogorov-Smirnov (KS) test demonstrated that the data was not-normally distributed, confirming the need for a non-parametric test. The KS test assesses if the largest difference between the observed and theoretical cumulative distribution is significantly different and is defined as:

$$F_n(x) = \frac{1}{n} \sum_{i=1}^{n} I\,\mathrm{x}_i \leq x$$

Where:

F_n = the empirical distribution function for a number of independent and identically-distributed (*i.i.d.*) observations X_i

$I_{X_i \leq x}$ = the indicator function (equal to 1 if $X_i \leq x$, equal to 0 otherwise) [306].

Compared to the χ^2, the KS test measures whether the data follows a normal distribution, as opposed to testing the significant difference in the expected distribution as calculated by the χ^2 and consequently is considered to be a more discriminating test [306-308]. Generally, non-parametric analyses are simpler, more robust and make fewer data assumptions than corresponding parametric tests. Therefore, they are more widely applicable. However they offer less opportunity for misinterpretation of the results or incorrect use [309]. Non-parametric statistics are less discriminating than standard statistics however; this is offset by the large population size from which conclusions can be drawn at a reliable degree of confidence.

Data can be classified as nominal, ordinal, or interval/ratio. Nominal data refers names of data (e.g. place of work), ordinal data refers to numbers that are in a natural order of preferences (e.g. the level of agreement), interval data is numerical data where there are equal difference (intervals) between values (e.g. temperature), and ratio data has a natural zero point. The data collected in the survey predominantly used categorical variables and therefore was classified to contain ordinal data. Using the Likert scale respondents were asked to state their level of agreement or disagreement with a specific statement (strongly agree → strongly disagree). Ordinal association analysis studies the relationship between different responses.

Statistical tests were used in this research to calculate the probability (p-value) of the results obtained occurring due chance or error. All statistical significances were tested to the $p < 0.05$ level (less than one in twenty) and the $p < 0.01$ (less than one in

one hundred) [310]. Values higher than the given p-values can be attributed to a sample size that is too small, or indicate that no calculated differences existed between the two given variables (or groups). Values outside of this calculated range can either be attributed to too few values or non between different groups [310]. P-value of 95% confidence interval is also the size of rejection region which is the default in SPSS.

3.2.2. Kendall's Tau (τ) correlation coefficient

Kendall's Tau (τ) correlation coefficient analysis tests ordinal association and measures the relationship (correlation) between two variables without any assumptions about the nature of their relationship [307, 311]. It is defined as:

$$T = \frac{n_c - n_d}{\frac{1}{2} n(n-1)}$$

Where:

n_c = the number of concordant pairs;

n_d = the number of discordant pairs in the data set [312].

Kendall's Tau (τ) makes the following assumptions:

- A coefficient value of 1 = perfect agreement between two rankings;
- A coefficient value of -1 = total disagreement between two rankings (e.g. the rankings are the reverse of each other);
- A coefficient value of 0 = complete independence between rankings [306].

Kendall's Tau (τ) was chosen over similar non-parametric tests such as Spearman's Rho (ρ) as it specifically looks at Likert scale data as utilised in the survey in this study [307, 308].

3.2.3. Kruskal Wallis Test

Further non-parametric analysis was carried out using the Kruskal-Wallis test. This test compares three or more groups of data under the assumption that it is distribution free (i.e. populations have identical distribution). Kruskal-Wallis is used when assumptions of the ANOVA test cannot be met (that data is normally distributed). Data is replaced by their ranks. It is defined as:

$$H = \frac{12}{n(n+1)} \sum_{i=1}^{k} R_i^2 - 3(n+1)$$

Where:

H = Kruskal-Wallis Test

n = total number of observations in all samples

R_i = Rank of the sample [312]

It is the extension of the Wilcoxon-Mann-Whitney Test for three or more groups [307, 308].

3.2.4. Wilcoxon-Mann-Whitney Test

The Wilcoxon-Mann-Whitney test is used as an alternative to the unpaired or independent (two-sample) t-test, when non-parametric conditions apply. It tests whether two samples come from the same population (i.e. medians are equal). It also calculates the observed difference between the two samples (whether one is larger than the other) and is defined as:

$$H_0 : P(x_i > y_i) = ½$$

$$H_1 : P(x_i > y_i) \neq ½$$

It compares every observation of one sample (x_i) against observations in another sample (y_i). If the medians are the same then there is an equal chance (½) of x_i being greater or smaller than y_i. It uses ranks of data and assumes the two distributions are similar in shape [307, 308].

3.3. Longitudinal Study – Theft by housebreaking

Limited previous by research Bradbury and Feist [5] has indicated that forensic science plays relatively small role in criminal investigations, and that the majority of cases are solved using traditional police work. To test this, a linear study was devised using performance figures to track the use of forensic science in a specific number of cases throughout the investigation. Cases were tracked which were recorded as theft by housebreaking (dwelling premises) by Lothian & Borders or Strathclyde Police This part of the project involved the close collaboration with all organisations involved in the criminal justice system: the police (Lothian & Borders, Strathclyde

Police), the forensic service providers (Edinburgh SPSA FS, Glasgow SPSA FS) and the Crown Office Procurator Fiscal Service (COPFS).

The baseline and background statistics utilised in this study have predominantly been obtained from annual reports and inspections relating to the organisations in question, e.g. Scottish Office Statistical Bulletin, Scottish Government, SPSA Annual Report [313-317]. Those relating to specific police forces were obtained from annual reports or via direct communication [24, 318, 319]. Data relating to specific cases were analysed for the calendar year of 2008. Obtaining a sample of cases for analysis proved difficult as "*offences involving forensic science*" is not a recognisable classification system [21]. Therefore, using the crime management system utilised by SPSA FS, specific search filters were used to identify cases which contained forensic evidence. Theft by housebreaking cases (dwelling) were extracted using their Crime Classification Code (code 1904) from the databases at SPSA FS.

The cases sampled included information about turnaround times for various stages of the investigation, evidence analysis procedures, how national databases were utilised, forensic gateway interaction as well as investigating the level of communication of findings to respective parties (e.g. police forces, SPSA, procurator fiscal service). Finally, case proceedings, pleas and case outcomes were to be measured utilising reference numbers obtained from the COPFS to determine case attrition rates, conviction rates and use of forensic evidence.

Due to the number of theft by housebreaking (theft HB) offences which occurred within the Strathclyde area adjustments were made to control the amount of data which could be analysed in the time available. In order to focus on the most novel aspect of the research, more specific inclusion criteria were introduced which would allow a representative sample size for data analysis. The following criteria were chosen as essential for shaping the revised data collection.

Firstly, it was determined that the two forces providing data should be treated as similarly as possible for the purposes of this project. Crime pattern analysis over the past 5 years helped to establish that the two areas were similar in their spread of crime over any given year [73, 318, 319]. Therefore, the fact that one force experienced a much higher volume of crimes would be less significant and the sites were essentially comparable.

Secondly, in order to limit the amount of data available for analysis the project utilised evidence types which could be databased. Analysis of evidence strength can still be conducted, in relation to value and case outcome, but will have slightly less impact as these are well known evidence types which essentially have already proven their value as good evidence. However, analysis of evidence impact on case outcome (e.g. number of convictions) has never been done in Scotland. This can provide a baseline for future work.

Thirdly, only theft by housebreaking offences of dwellings were considered as these are always investigated by the police [24, 319]. These case types offer the potential to examine a larger number of cases which contain fingerprint and DNA evidence, that will be analysed in the forensic laboratory and fingerprint bureau whenever it is available. A single calendar year was chosen (2008). Sufficient time was allowed for cases to work their way through the system in order to obtain the PF data also. Unfortunately, not all aspects of this research were achievable within the limits of the project, and data from the COPFS was not received in time to be analysed. However, some analysis of the data obtained can contribute to achieving the aims of this project.

Chapter 4: The Survey: Assessing the current situation in Scotland

From the 400 surveys distributed throughout SPSA FS and Strathclyde and Lothian and Borders Police forces, approximately 270 were returned (response rate of 68%). The relative distributions of returns from the different roles are illustrated in table 11.

Table 11: Demographics of survey participants (n=273)

Variable		Frequency/ Summary statistics (n)
Gender:	Male	59% (*160*)
	Female	41% (*110*)
Age:		19 to 62 years (*M=37.8, SD=7.96*)
Years of experience in the field:		6 months to 39 years (*M=12.37, SD=7.94*)
Role/Rank:	Crime Scene Examiner	12% (*31*)
	Forensic Scientist	32% (*85*)
	Fingerprint Examiner	12% (*31*)
	Constable	22% (*58*)
	Sergeant	18% (*48*)
	Senior Police	5% (*14*)
Organisation:	Police Force	46% (*125*)
	SPSA FS	54% (*148*)

As the data was shown to be not normally distributed using the Kolmogorov-Smirnov test (KS-test), non-parametric statistical analyses were carried out [306]. Kendal's Tau correlation coefficients were calculated to determine whether correlations existed between variables, which could be further analysed using statistical tests. The results of these correlations and their significance are shown in Appendix 8. The significant correlations have been identified and will be considered throughout this chapter. Figure 7 illustrates the comparatively even split of participation from police forces and forensic service providers (46% and 54% respectively). Strathclyde Police, as the biggest force, provided the most returns (62%). Of the 46% SPSA FS participants, 32% were laboratory scientists, 12% were Crime Scene Examiners (CSEs) and 12% were fingerprint examiners. Police constables and police sergeants showed a similar response rate (22% and 18% respectively).

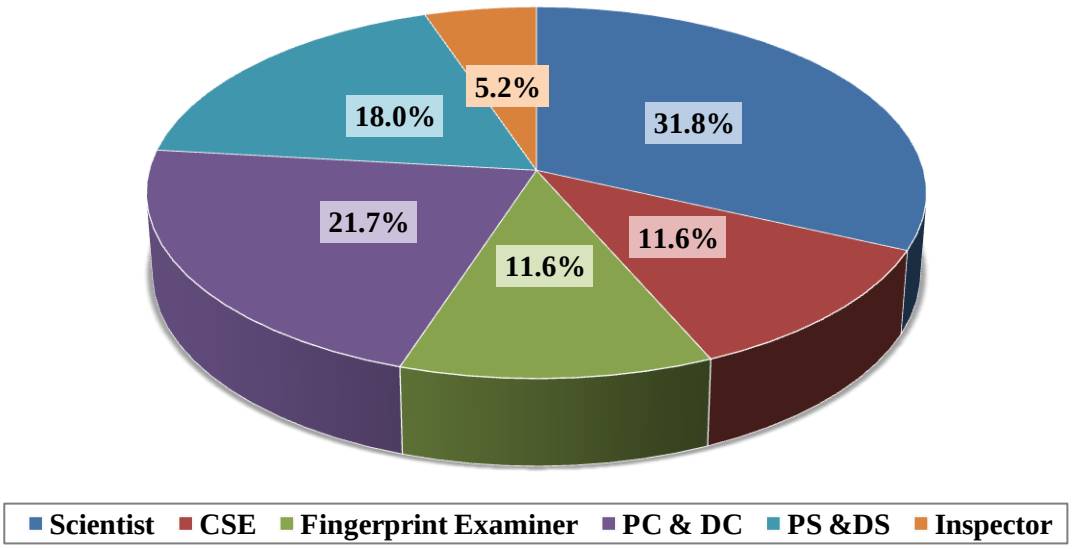


Figure 7: Breakdown of roles from survey participants.

4.1. Education

Participants were asked to declare the highest academic qualification they had attained. The results are shown in table 12 and demonstrate that the levels of education varied greatly according to participant's roles. Most police forces do not require formal qualifications as an entrance criterion [320], therefore many junior police officers (sergeant and constable) have not needed to continue in education. This is reflected in the data where 65% of police sergeants completed education to secondary school level only. The data did however show that many officers elected to attend university or college as 30% of police constables and 23% of police sergeants indicated they had an undergraduate degree. Table 12 also illustrates that higher education (undergraduate and postgraduate degree) was most commonly obtained by those in scientific roles at SPSA FS. Ten percent of scientists furthered their education to complete studies to PhD level. The data has shown that more specialised roles have more advanced qualifications.

Approximately 80% of CSEs stated that they have an undergraduate degree and/or the supplementary scene examination diploma. The professional Diploma in Crime Scene Investigation offered by the Forensic Science Society (FSSoc) as well as the Diploma in Crime Scene Examination offered by NPIA are recognised qualifications in the UK [226, 321]. However, it was not possible to determine, from the limitations of the survey, which of these diplomas had been obtained by CSE respondents. The Scottish Police Training college states that it offers some evidence collection, handling and preservation training in the initial training course for new recruits, as well as optional modules for detective training, and some forensic input in the initial investigator training to raise the awareness of "*forensic and technical resources*" [322].

Table 12: Breakdown of the highest education levels for each role

Role	Highest level of education			
	Secondary School	*Undergraduate Degree*	*Postgraduate Degree*	*Other qualifications*
Scientist	4% (3)	48% (41)	41% (35)	7% (6)
Fingerprint Examiners	41% (12)	28% (8)	7% (2)	24% (7)
Crime Scene Examiners	10% (3)	47% (14)	7% (2)	37 % (11)
Police/ Detective Constable	46% (26)	30% (17)	2% (1)	21% (12)
Police /Detective Sergeant	66% (31)	23% (11)	0	11% (5)
More Senior police	35% (5)	43% (6)	7% (1)	14% (2)

4.2. Training

The survey also addressed the issue of training, which for the purposes of this research is defined as *"a process which is planned to facilitate learning so that people can become more effective in carrying out aspects of their work*" [323]. This definition allows all aspects of training to be considered, including on-the-job learning, formal courses and self-directed training. Three interlinked questions on training were asked, including:

Q1) Have you received any specific forensic training?

YES ☐ *NO* ☐ *(if no then please got to Q2)*

Q1 (a) Please indicate the type of training you received:

Formal training (e.g. Police College)	☐	*Coaching/Shadowing*	☐
On the job training	☐	*Reading material*	☐
Other (please specify)	☐	_____	

Q1 (b) Please estimate the total amount of training you received:

_____*HOURS/DAYS/WEEKS/MONTHS (Delete as appropriate)*

The data showed a large variation in the amount and type of training received between the different roles surveyed. The majority (80%) of all roles had received some form of forensic training. Due to the compulsory three-year training programme for fingerprint examiners, the data reflected that all fingerprint examiners (100%) had received specialised forensic training. Also 96% of all other forensic SPSA roles (scientist and crime scene examiners) stated they had received forensic training. The data for police roles was more varied. Of the participants who expressed they had not received any specific forensic training, 85% were uniformed police officers. This was a significantly higher proportion than any other role surveyed. Approximately 5% of police roles stated they had received some forensic training, some indicated they had attended specific courses – e.g. the recovery of fingerprints from motor vehicles or short presentations on digital evidence recovery. More scientists and crime scene staff received forensic training compared to police officers (of all ranks). Although statistically significant (Mann-Whitney, $p < 0.05$) this was not particularly surprising.

4.2.1. Amount of training

Designing a survey to capture data relating to the amount of training which was received by respondents was difficult. It was anticipated that an open question style (i.e. not providing specific time blocks as answers – e.g. < 1 month, 6 months, 1 year, > 1 year), which gave respondents control of the range of answers, would make it easier to provide a more accurate representation of training amounts [296]. However, participants still found it very difficult to quantify the amount of forensic training they felt they had received throughout their (sometimes relatively long) careers (mean of 12 years experience). The correlation between the amount of training and role of an individual can be seen in Appendix 8.

Much of the training was described as constant; 20% of SPSA FS staff and 10% of police officers reported receiving continuous training. Thirteen percent of everyone surveyed expressed the view that they had received continuous training. The notion of having to add up hours of training potentially meant that participants could potentially have been discouraged to answer numerically as it was too difficult to quantify. Participants may have chosen to note continuous training where they had received forensic training over some period of time or throughout their working career and were unsure of a numerical value. Therefore, the analysis of amounts of training must be considered with caution as constant training may not necessarily reflect a continuous process and more detailed analysis using a quantitative collection method would be required [299]. Over one quarter (28%) of the sample population expressed the opinion that they have received less than one month of forensic training over the course of their career, where 10% reported they had received less than one day (< 24 hours) of training. Figure 8 illustrates the variation in the amount of training reported by police officers and SPSA.

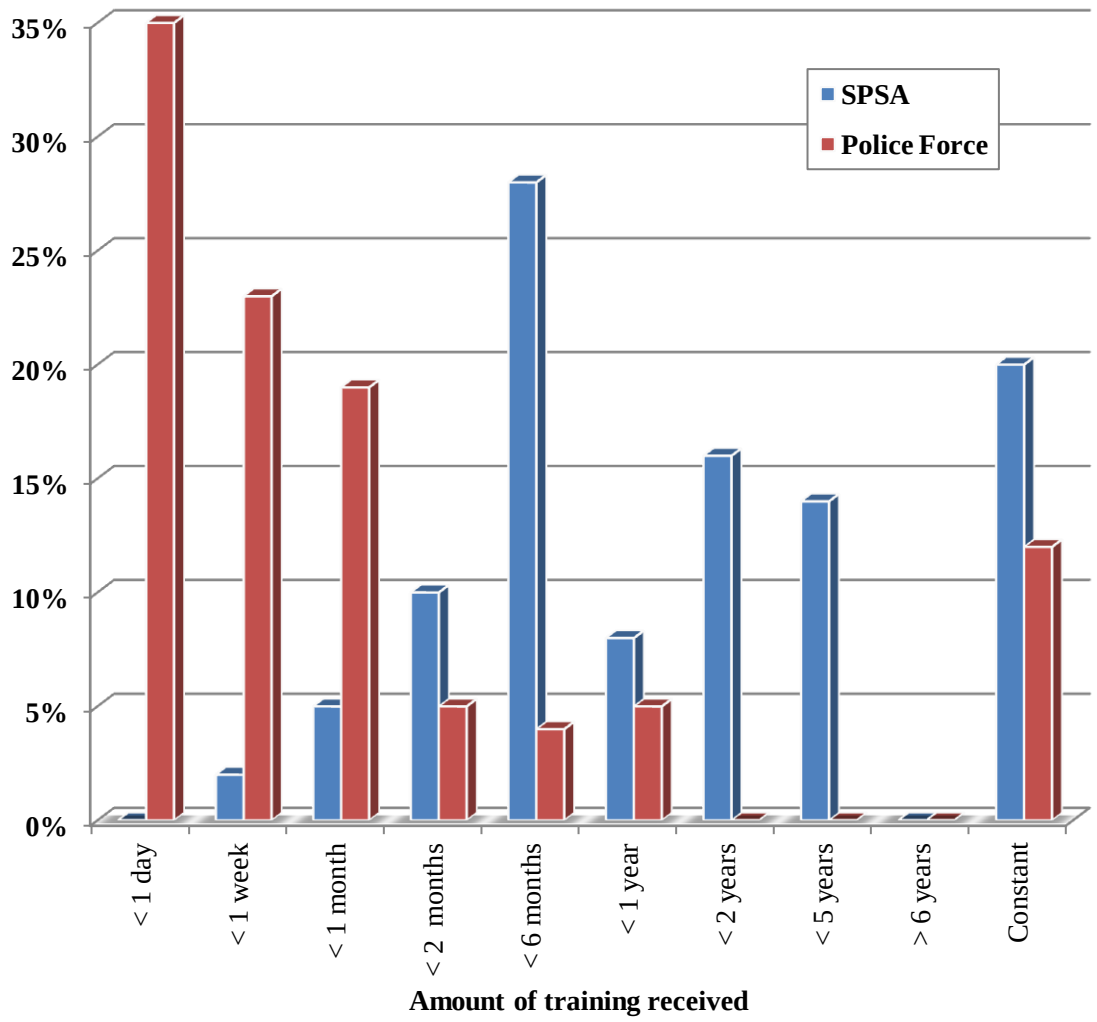


Figure 8: Amount of training received SPSA and police forces.

The data has shown that training varied greatly within and between roles. Furthermore, there appeared to be no correlation between the years of service within the current role and the amount of training that had been received. The accuracy, relevance and applicability of the original training received to current developments could not be confirmed due to the limitations of the survey.

Table 13 indicates that amount of training actually decreased as the number of years in the job increased. This suggests there is a limited focus on longer-term training even though 13% of survey respondents expressed the view they had received continuous training. Although some training did appear to be available, detailed investigation of syllabuses and quality of training programmes currently available would be needed in order to determine the relevance and accuracy of the content. Studies in England and Wales have repeatedly recommended improvements in training for investigators [16, 23, 40]. As well as recommendations for improvements, they have also highlighted the need for good practice guides which are based on working procedures which have been found to be effective [222]. The limited number of similar reviews in Scotland [222] means that much less data on these issues is available compared to England and Wales. Recommendations made in these studies in England and Wales have not necessarily been implemented in Scotland.

SPSA respondents indicated that they had attended courses relating to specific areas of their work (e.g. low-copy number DNA training, advanced fingerprint training). Detailed information regarding specific training was not given by police participants therefore; it could not be identified whether such opportunities had been available to them.

Table 13: A comparison of the average number of years of experience and the amount of specialised forensic training received by respondents. Negative correlation, as years of service increase, amount of training decreases.

	Average Years of Service (YoS)		
	SPSA FS (*M* YoS = 11.5 yrs)	Police Force (*M* YoS = 13 yrs)	All roles (*M* YoS = 12 yrs)
<1 day	9.5	15.3	13.0
< 1 week	3.0	14.9	12.0
< 1 month	16.3	16.8	16.6
< 6 months	9.9	19.0	13.5
< 1 year	8.6	26.0	17.3
< 2 years	13.9	0.0	13.9
< 5 years	13.0	0.0	13.0
> 5 years	7.0	0.0	7.0
continuous	9.2	10.5	10.1

NB: M YOS – mean years of service

4.2.2. Type of training

It is apparent from figure 9 that a wide range of methods was applied for training investigative staff in forensic science. Although participants found it difficult to quantify how much training they had received, they were able to indicate the type of training they had received. Participants were asked to indicate from the following, all the types of training (learning) they had been exposed to: formal training (FT),

coaching or shadowing (CS), on-the-job (OJ), reading (RM), any of these in combination or all of these types.

The data indicates that most participants had received on-the job training, where they were introduced to some of their daily routines. Participants were able to tick any combination of training options; and often several different training methods were identified. Forty-two percent of respondents stated that they had received training in combination. This suggested that a single method was not sufficient to learn their roles. Some participants received all of the training methods available (29%). Due to the limitations of this survey, it was not possible to ascertain the order in which training occurred or whether one format was more heavily relied on or used than another.

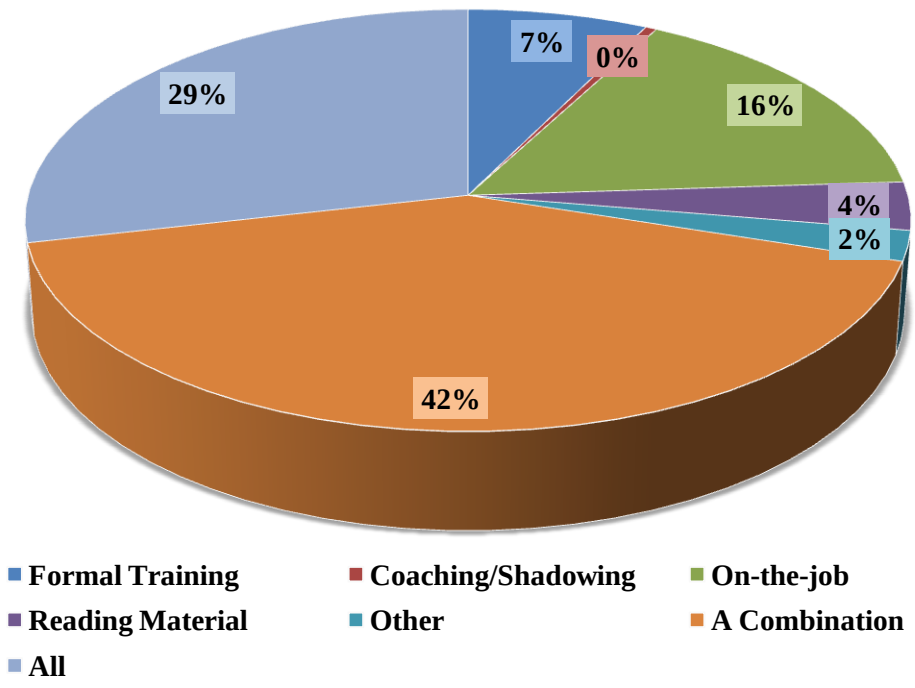


Figure 9: Types of forensic science training received.

There was no significant difference between the types of training received between different investigative staff, so although the training was varied this was not deemed statistically important (Kruskal-Wallis, $p > 0.05$). It could be argued that an appropriate degree (e.g. forensic or scientific) qualified as formal training. Not including education, the number of participants who had received formal training only was relatively low, at less than 20%. Again, the restraints of the survey allowed the conclusion to be drawn that participants have been exposed relatively equally to various types of training, shown by figure 10.

Figure 10: Forensic training received by role (n=273).

The combination of training and education has been considered as mutually beneficial [22, 177, 224, 324]. "*The ability of an individual to acquire knowledge, skills and attitudes in a training context may depend directly or indirectly on* […] *previous educational experiences"* [224]. Education provides underlying or foundation knowledge on which further skills and knowledge can be built. Training brings about more immediate changes to the behaviours of the individual [224]. Therefore, closer relationship between training and education has the potential to improve the levels of knowledge in general and forensic knowledge specifically of individuals working in the investigation [169, 224].

The data also demonstrated very little difference between roles and the types of training they had received. Figure 10 illustrates the main training methods offered in the survey for a number of different roles. Scientists received slightly more formal training (23%) than all other groups and all police roles received slightly more on-the-job training (20%) than SPSA roles. However, the differences between roles are too small to be significant. Although difficult to assess, it appears that the majority of persons who realistically should have received some forensic training had indeed received some.

Training provides one method for acquiring new knowledge, skills or expertise, learned via formal teaching, practical experience and vocational application [325-327]. Unfortunately, it was not possible to obtain training materials used for the training of police and CSEs from the institutions currently providing such programmes. Many authors have shown that different people learn in different ways therefore the training programmes made available to individuals ought to employ a range of techniques [328-334]. This appears to be reflected by the data, where the majority of respondents were exposed to a combination of two or more different types of training. Kolb [334] identified that learning should be a continuous task. Professional development builds on the foundation knowledge gained from initial courses or qualifications, and maintains and updates the skills and expertise of the individual throughout their working life [224, 323].

The data from the survey shows that training is varied in format and length, and depends on the investigative roles. Inevitably, more specialised roles receive more training, however the lack of a standardised training for many of the other investigative roles results in sporadic training as the content is not regulated in the UK [5, 16, 40, 335]. The issue of training appears to be partially addressed for more skilled roles; however there does not appear to be much progression since the early reports for other roles [16, 18].

Chan *et al*. [160] stated that training may not be pursued due to lack of motivation, time constraints, and lack of coordination. It was unclear from the survey whether police personnel had insufficient access to formal training opportunities or whether they preferred not to utilise it. Potentially, police are required to focus on learning aspects more closely linked to crime control, supervision of society, maintenance of law and order, etc. Forensic training may therefore be perceived as secondary to all other aspect of training new recruits are exposed to [145, 168].

Forensic training for all police officers has previously been recommended to be incorporated into all police training syllabuses; from initial training, refresher courses, specialist role training, etc. to ensure a basic level of forensic understanding [8, 40, 336]. As was mentioned previously, NPIA was the main provider of training programmes in England and Wales. NPIA was also one of the few organisations in the UK which had acknowledged the issue of non-standardised training but had also proposed to implement changes to address this. How and where training will be provided after the closure of NPIA, as well as who will be responsible for providing programmes will need to be assessed in the future [234].

4.3. Knowledge

In order to assess the knowledge levels of forensic science and its potential contribution to an investigation, respondents were asked to rank the value of specific evidence types on a Likert scale (1 = low, and 5 = high) for two particular scenarios – the value of forensic materials for furthering investigations and the strength of evidence for providing a link to scenes or offenders. The purpose of these questions was to determine whether participants were aware of the potential intelligence value of specific types of evidence other than DNA and fingerprints (particularly footwear marks and toolmarks). "*Forensic intelligence is the accurate, timely and useful product of logically processing forensic case data*" [337]. Ribaux *et al*. [337] stated that it is important to recognise that the collective "*outcomes of forensic analysis become the source of intelligence*" [338]. Forensic intelligence has traditionally been focused on link crime scenes, identifying repeat offenders via similar *modus operandi*, etc. Forensic intelligence can also be used to provide knowledge for future criminal cases and to inform investigative activities [13]. The results from both questions demonstrated strong links to more recognised forms of evidence (e.g. DNA, fingerprints) which consequently scored high. Greater variation in understanding of other evidence types (e.g. footwear marks, toolmarks, and glass fragments) was also shown.

4.3.1. Intelligence value of forensic material for furthering investigations

In the first of the evidence knowledge questions, participants were asked to rate several types of forensic material (DNA, fingerprints, footwear marks, glass fragments and toolmarks) in terms of their value to volume crime investigations in providing intelligence to further an investigation. The perceptions of the intelligence value of forensic materials are illustrated in figure 11. This figure shows the trends which were expected based on the evidence from the previous literature; DNA and

fingerprints were considered as more valuable than all the other evidence types [339, 340].

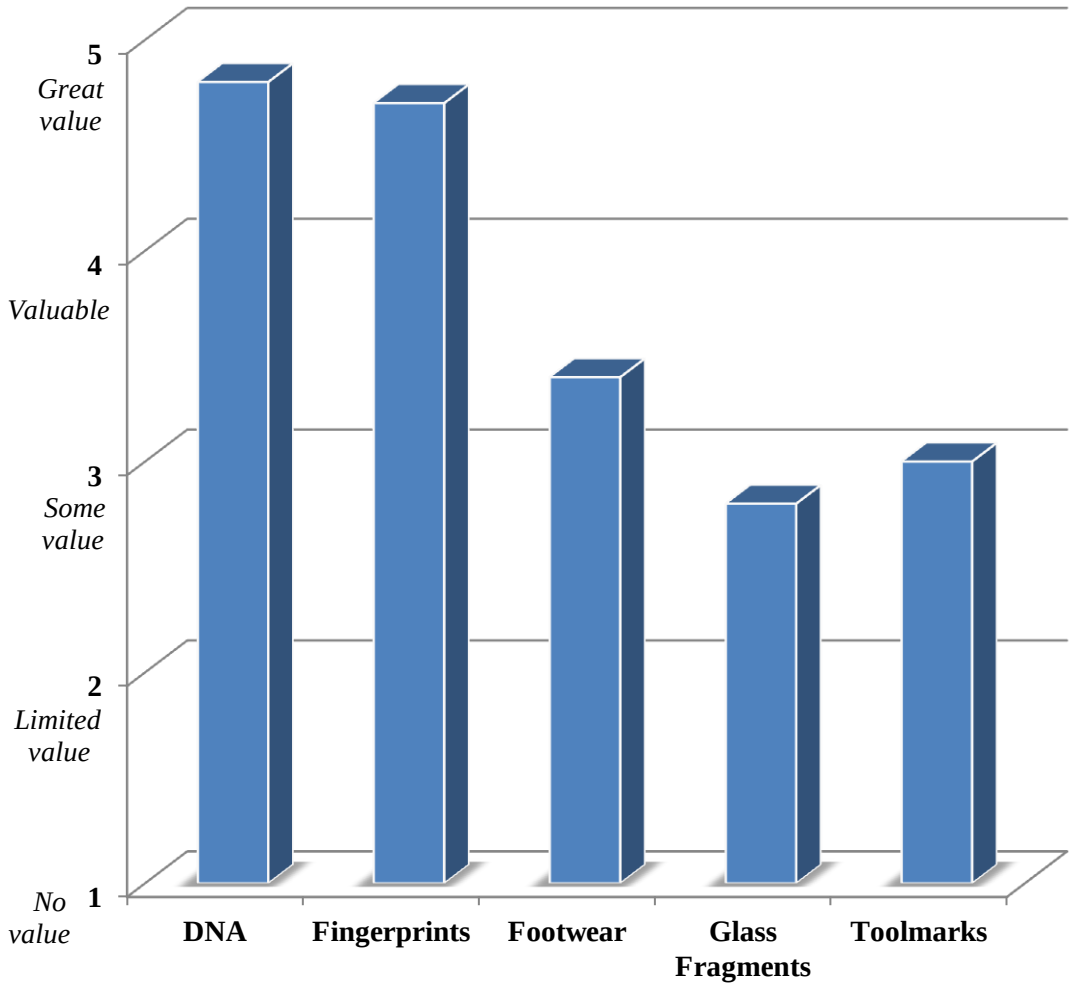


Figure 11: The assessment of forensic material in terms of their value to volume crime investigations in providing intelligence to further an investigation (n=273).

DNA and fingerprint evidence have the power to provide intelligence which can aid in the direct identification of a particular individual [250, 341]. However, a lack of systematic data which assesses DNA in investigations means the true value of evidence cannot be assessed and the perceptions of the value evidence held by individuals cannot be confirmed as accurate. The data indicated that the other forms of forensic material such as footwear marks, glass fragments and toolmarks were less valued as evidence. Although unable to directly identify individuals, footwear marks and toolmarks can be particularly useful for establishing a link to an individual or in providing intelligence on which investigators and officers should focus in their investigation (e.g. details of a particular type/brand of shoe) [57, 342]. The data shows that these lesser known evidence types were recognised by participants to contain some value in furthering investigations (mean score of 3), although to a lesser extent than DNA and fingerprints (mean score of 5).

The perceptions by different roles (e.g. scientists, CSEs, police officers) of forensic evidence types did not greatly vary. Figure 12 illustrates the mode value of evidence type by each investigative role. Glass fragments were valued lowest and footwear marks were valued highest by scientists (after DNA and fingerprints). Closer evaluation of the mean value indicated that CSEs, senior police ranks and fingerprint examiners also valued fingerprint evidence as fractionally stronger than DNA. All other groups valued DNA slightly stronger for providing intelligence to furthering investigations (Kruskal Wallis test, significant to $p < 0.05$).

The perceived value of specific physical material in terms of it utility to the investigation appears to be varied amongst survey respondents. The priority awarded to certain evidence to be put forward for submission for laboratory analysis hinges on the interpretation of its (intelligence) value by the investigating personnel in relation to the circumstances of that particular crime [19].

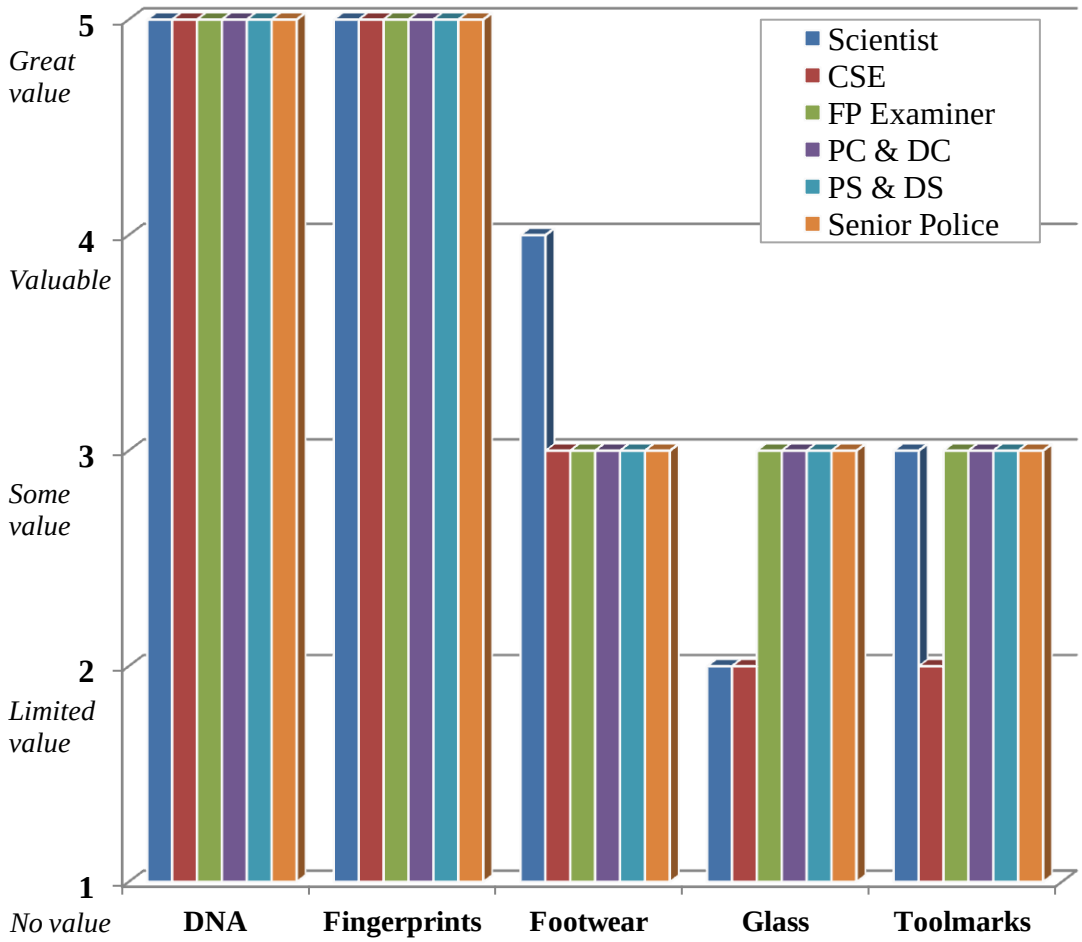


Figure 12: The assessment of the value of forensic materials as perceived by each role (mode value).

4.3.2. Strength of forensic evidence to link scene(s) and offender(s)

Following on from the question relating to the value of evidence, a second question regarding the strength of evidence was included in order to assess whether any difference in scenarios resulted in differing perceptions of evidence types. Participants were also asked to rate each type of forensic material in terms of their maximum strength of evidence in establishing a link between suspect(s) and crime scene(s). Figure 13 illustrates that DNA and fingerprints were valued equally in

terms of strength, both scored very highly on the scale (where 1 = 'limited support' and 5 = 'conclusive support'). Reflecting the results of the previous question, DNA and fingerprints again were considered better evidence compared to the other three evidence types (toolmarks, footwear marks and glass fragments).

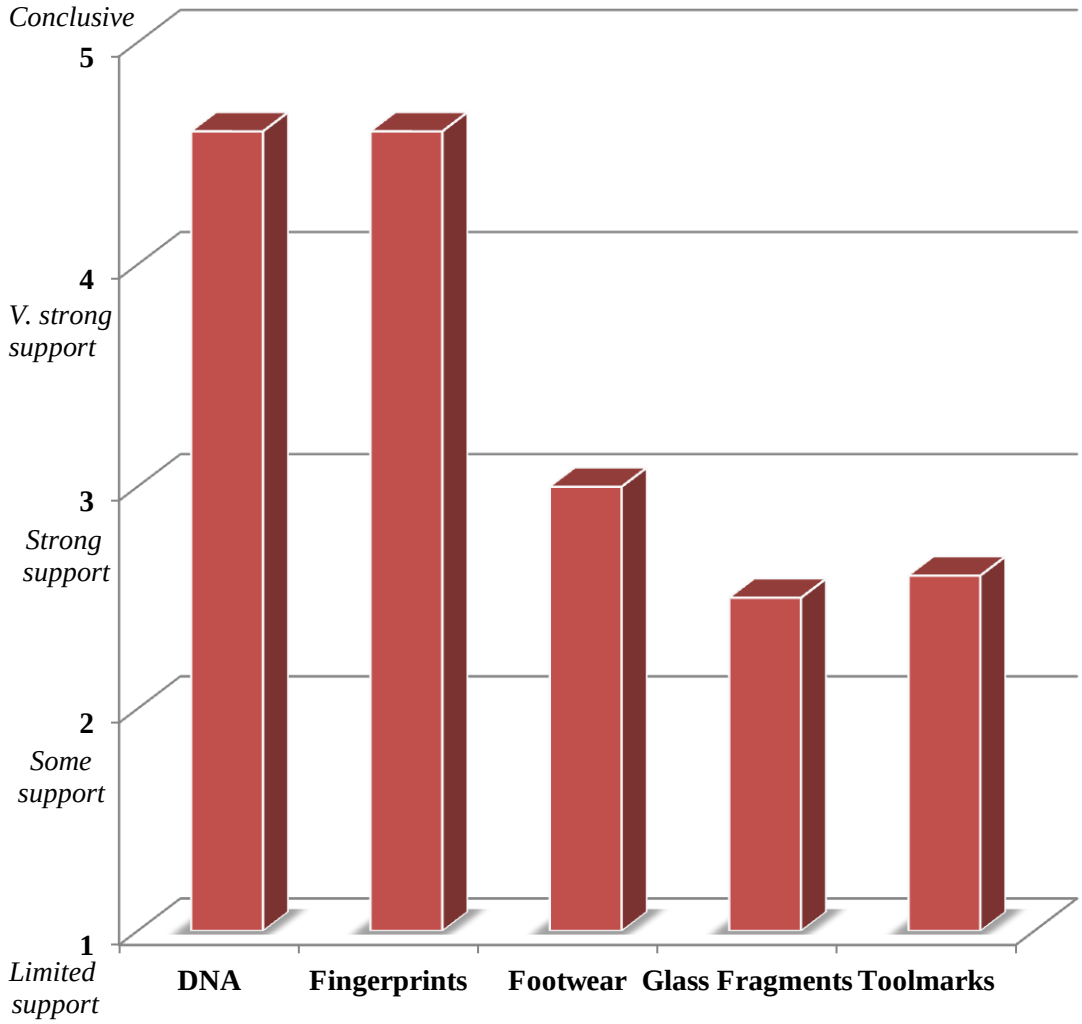


Figure 13: The assessment of forensic material in terms of their maximum strength of evidence in establishing a link between a suspect and a crime scene (n=273).

Figure 14 illustrates that all evidence types were assessed as providing some form of potential link between suspect and crime scene, however the strength of that support was deemed less for footwear marks, glass fragments and toolmarks. The data indicated that scientists perceived the strength of DNA as very strong support (scale point 4) and not conclusive support like most of the other roles (scale point 5). This can potentially be attributed to their more extensive training with an increased understanding of the limitations of the evidence [343, 344]. Scientists recognise that DNA evidence is probabilistic, and therefore does not provide conclusive results [21, 272, 345].

For the purposes of assessing the knowledge of evidence types, these five different forms of forensic material were specifically selected as: they offered a mixed selection of well established evidence as lesser known evidence types, they were perceived to be most commonly associated with volume crimes and they provided a range of evidence in terms of their evidential nature (e.g. transient, permanent, trace) [23, 40]. This evidence was also stated as highly prevalent by the Volume Crime Manual published by ACPO in 2002 [43] as guide for crime scene examiners. Previous studies [23, 40, 41, 196, 338, 346, 347] had shown great variation regarding the perceptions of their value and these questions were used to test some of these assumptions.

Many criminal investigations (both volume and major crimes) have become reliant on forensic evidence (especially DNA) [196, 341]. Forensic intelligence sources such as DNA and fingerprint evidence have become part of a standard range of investigative techniques utilised in the investigation of most crimes (major and volume). However, rigorous data which indicates its value to achieving prosecutions and convictions in court is currently unavailable [55, 343]. Forensic science contributes to the CJS by "*generation of intelligence to assist investigations*" [348]. Providing *"evidence to convict the guilty or exculpate the innocent represents a* [...] *significant part of its role*" [348].

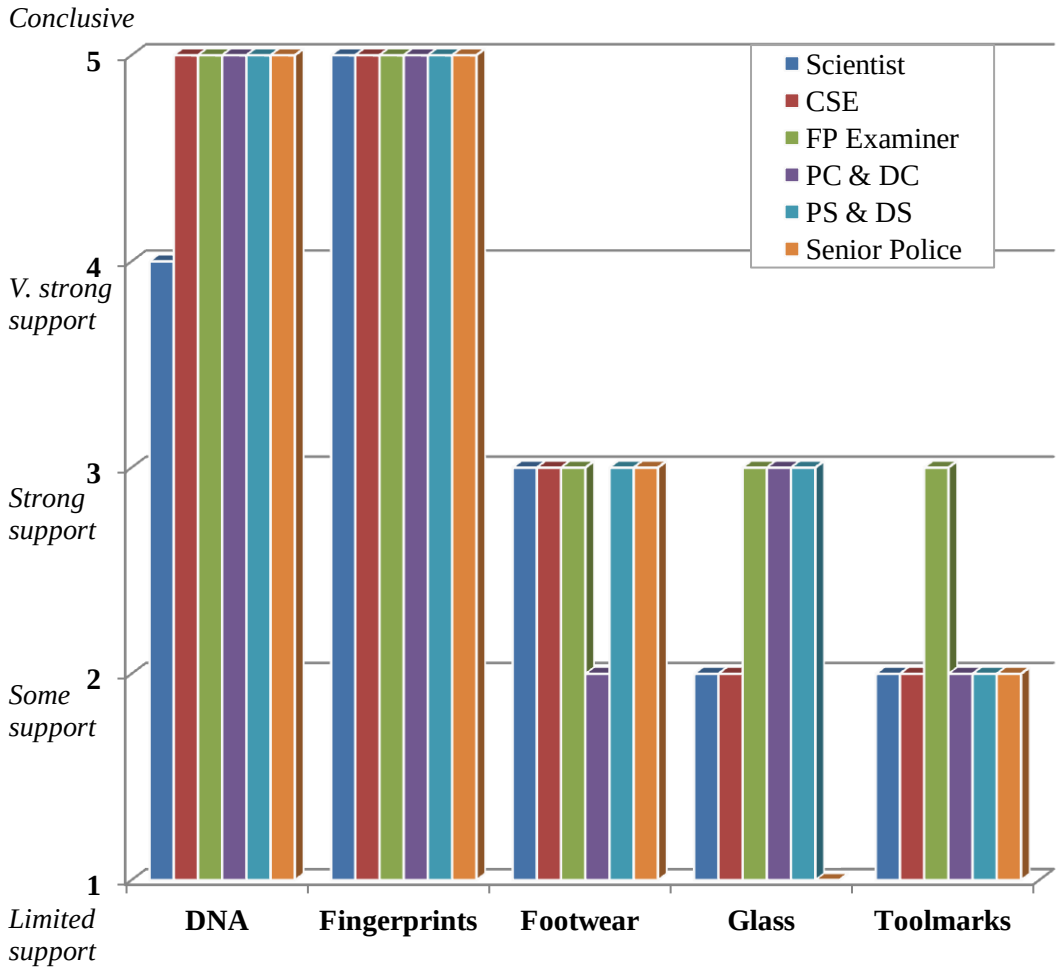


Figure 14: The assessment of the weight of forensic evidence types as perceived by each set of investigative roles (mode value).

This research also indicated that there was some understanding of the value of footwear marks as these scored higher than the remaining two forms of evidence (glass and toolmarks) by most investigative staff. The data showed that CSEs, scientists and fingerprint experts appeared to have some knowledge of the utility of footwear mark evidence. The limited use of footwear evidence in Scotland contrasts with England and Wales where studies have shown that toolmarks and footwear marks are useful in the investigation of crimes, volume and major crimes [9, 283, 342, 349]. As a consequence, special attention has been placed on the recovery of

footwear and footwear evidence in England and Wales, including changes to the Police and Criminal Evidence Act [1984] allowing for speculative searching (such legislations do not exist in Scotland) [350].

In England and Wales, speculative searching[16] has been used to identify unknown suspects, by searching scene evidence (e.g. DNA, fingerprints, footwear marks) against national databases in order to link them to relatives or other scenes [351]. Profiles held on the DNA database, for example, are "*now subject to indefinite genetic surveillance through the continuous speculative searching of their DNA profiles against all new crime scene and subject profiles loaded onto the database* [352]". Legislative changes as well as increasing interest in footwear evidence have resulted in police forces increasing their use of this source of intelligence more effectively [353].

Furthermore, parts of England and Wales have implemented the National Footwear Reference Collection (NFRC), a database which allows footwear marks recovered or photographed at crime scenes to be searched against a known collection to identify a specific make or type of shoe [353]. That footwear marks are considered valuable to the investigation in Scotland is show by the data, consequently, CSEs and other investigative staff should be encouraged to collect this evidence more. Toolmarks can provide a similar link between suspect and crime scene, however the data demonstrated that CSEs did not rate them highly. More detailed analysis into the benefits of these evidence types could be used to encourage their use and increase their rates of collection.

The limitations of the survey did not allow for interpretations of the reasons behind these perceptions to be clarified directly, however the transient nature of tool surfaces (e.g. screwdriver heads) as well as the fact that items themselves can be easily moved, passed on or discarded, may be a possible reason of the low opinions by CSEs of this evidence types [24]. That potential for forensic evidence to generate

[16] A search against other samples or against information derived from other samples.

investigative leads has previously been discussed [39, 337, 354, 355]. Crimes suspected of being linked can be analysed using "*selective comparison of traces collected*" which have "*the potential to support or refute this hypothesis*" [39]. Further analysis using focus groups or interviews could establish whether training currently received does focus on the value of these evidence types, or whether policies regarding the collection of this evidence are limited or whether any other possible reasons currently not considered explain these perceptions.

Interestingly, opinions relating to the perceptions of evidence were broadly similar between different investigative roles (e.g. CSE, scientist, police officer). Forensic service providers and police officers were shown to have similar opinions about the strength and value of evidence – DNA and fingerprints were valued higher than footwear marks, toolmarks and glass evidence. This was some indication that knowledge received via education and formalised training did not have a significant effect on the perceptions of the utility of evidence by individuals. Therefore previous beliefs that training would resolve these issues were not supported by these data [5, 18, 40, 108]. The data from the survey indicated no correlation between training and evidence perceptions. However, the lack of correlation must be considered with care as the amount and type of training that had been received by respondents was not clear from the survey. The fundamental question relating to the amount and type of training received by respondents requires further analysis before any conclusions the effects of training one evidence can be made. Future analysis of these two variables requires a more detailed study.

The strong perceptions of DNA and fingerprint evidence are often associated with their ability to identify offenders and provide a substantial link between evidence, crime scene and offender. An increasing number of investigations are becoming reliant on such evidence, however their actual (or true) potential and value is not known [19]. Bond [55] identified that the combination of fingerprints and DNA evidence from a crime scene had no effect on determining the outcome of a case (prosecution). It would be expected that the combination of these two 'strong' evidence types, useful for the identification of suspects, would build a stronger case

for prosecution and consequently provide a better chance of obtaining guilty pleas of securing a conviction than other evidence types [55]. Research is currently lacking regarding the effects of a combination of other evidence types (e.g. DNA and footwear, fingerprints and toolmarks).

Previously, CSEs have been shown to have some input in relation to decision making regarding the collection of forensic evidence from crime scenes [81]. However, the utility of the material in terms of what could be achieved were not known. It has previously been suggested that a system of "*discipline and discretion*" is introduced to improve performance [42, 356, 357]. In order to ensure the potential of evidence is not overlooked, a similar system could be applied to forensic material [356]. This would identify certain evidence types which should always be collected by CSEs when located at a crimes scene (as stated by rules) and other material should only be collected which is judged important by the CSE for that particular case (CSE discretion) [356].

Current perceptions of CSEs have identified a "*technical assistant*" role, with the main responsibility for collecting and packaging forensic materials from a scene. Defining evidence collection patterns using the rules and discretion model means CSEs could focus on the collection of evidence as per specified rules [42, 238]. However, employing the discretionary approach which "*leaves scope for judgement*" a CSE could become involved in an investigation by providing information or possible intelligence regarding specific evidence available at a given scene [42, 76]. This has the potential to provide a system which reduced the chances of valuable evidence being overlooked (i.e. due to lack of knowledge or training), without restricting scene collection procedures which disregard any other evidence types. However, detailed analysis of the benefits is required before such systems could be implemented.

As well as implementing rules and discretion, establishing and developing good relationships between police forces and forensic service providers means that uncertainties or queries relating to evidence can be dealt with quickly [358]. Better

use of CSEs, who are well trained and knowledgeable as information sources, has previously been recommended, and they could provide the link between police forces and other investigative staff [15]. It has been suggested that part of their role requirement is to "*participate in the provisions of* [...] *advice* [...] *in order to raise awareness regarding the availability and value of forensic evidence at crime scenes*" [359]. Good communication reduces the pressure on the different members of the investigation to know everything relating to any aspect of the enquiry [43, 185]. There is only a certain amount of information that can efficiently be retained at any one time and better collaboration and communication provides a mechanism for obtaining information from the best source [167]. However, cohesive relationships must overcome a number of themes (e.g. cultural or system differences) in order to effectively share and utilise knowledge bases elsewhere [14, 18, 238].

4.4. Communication

In order to evaluate the flow of information and levels of communication in an investigation, participants were asked to identify advice sources when considering the potential value of: attending a crime scene, the evidence at a scene, collecting evidence and submitting the evidence to the laboratory. Participants were asked to identify all of the sources they would seek advice from in each stage of the investigative process mentioned above. Figure 15 illustrates the breakdown of the range of advice sources in order of preference for seeking advice by the all police forces and forensic service providers surveyed. The data shows that when seeking advice on the value of scene attendance, 43% of participants identified they would ask a colleague of the same experience, a more experienced colleague or their immediate supervisor for advice. A higher percentage of police would ask a supervisor or colleague (55% of the time) for advice compared to 35% of the time for scientists.

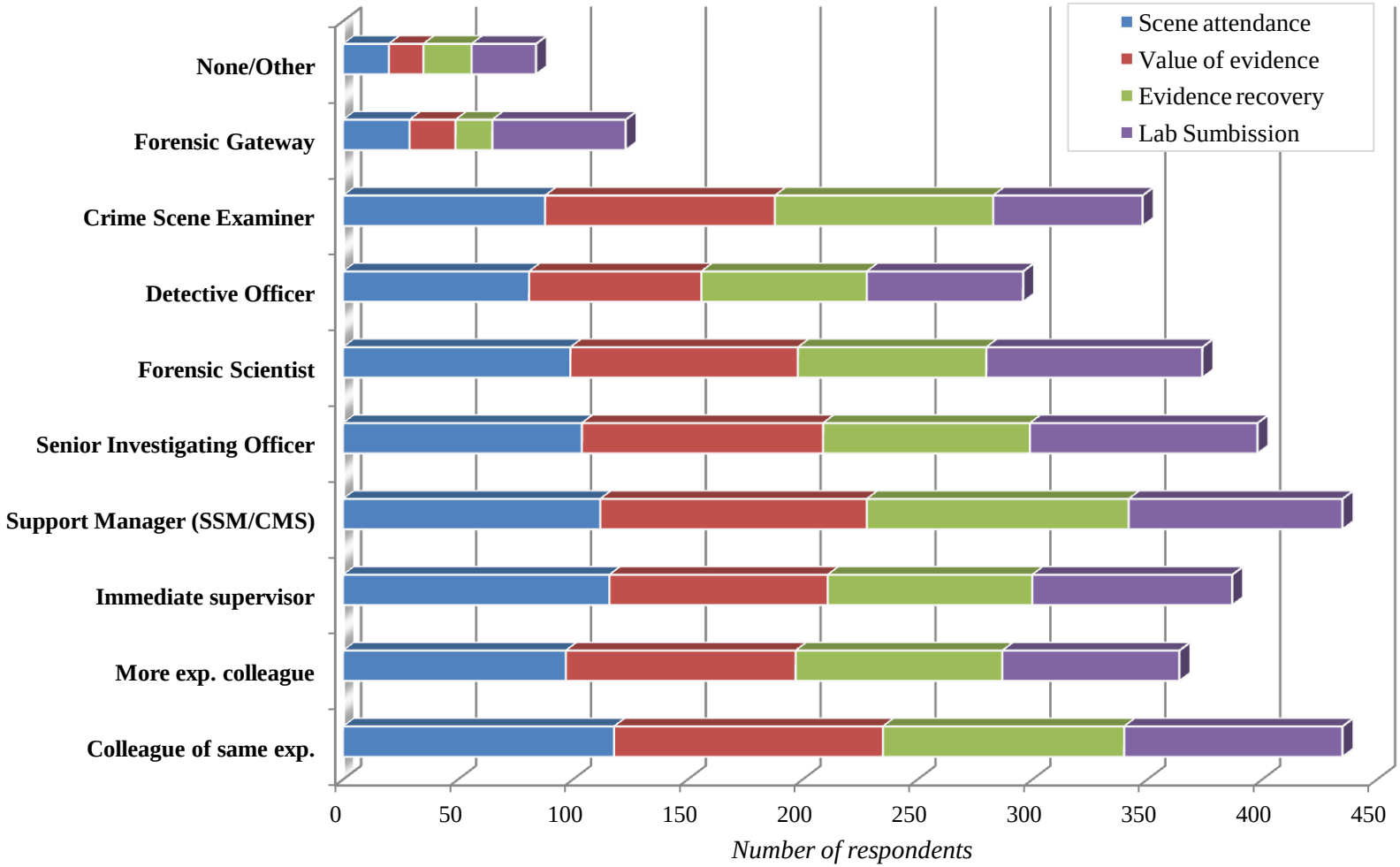


Figure 15: Advice sources for specific forensic issues utilised by SPSA and police forces (n=273).

Similar to the question about scene attendance, advice on assessing the value of evidence at a scene was mainly sought from colleagues, supervisors or the Senior Investigating Officers (SIO) (40%). Police officers tend to ask their Crime Scene Manager (CSM), Scientific Support Manager (SSM), or a Crime Scene Examiner (CSE) for advice in these circumstances; the data determined that these should be the most appropriate source for reliable and accurate information (60% of the time). The most popular advice sources for assessing what forensic material to recover from a crime scene were colleagues or the CSM (40%). Again, police officers were inclined to turn to their CSM (58% of the time) and the CSE (53%) when unsure of what should be collected.

The predominant advice sources for the submission of samples to the laboratory were identified as CSMs, SIOs or forensic scientists directly (35% of the time). What was noteworthy was the relatively low numbers of participants (circa 20%) who would contact their local Forensic Science Gateway for advice on such issues. The gateway is supposed to manage laboratory caseloads, determine the potential value of the evidence and recommend the cases which warrant continuation for forensic examination [70]. However it is worth mentioning here that there appears to be some confusion regarding what the Gateway is, how it works and when it should be contacted [24]. The Gateway has been shown to be poorly understood and utilised in practice.

It was not possible to determine the reasons behind the varied (and limited) use of the forensic gateway due to the restrictions of the survey however; there are a number of possible explanations which can be considered. These include (but are not limited to): aspects such as poor communication and transfer of information between individuals and organisations; some cultural resistance to (or limited acceptance of) this management body and poor implementation; inadequate management of relationship; inappropriate organisational structures; limited policies directing how and when the gateway should be used; and that the provision of a single body is not fit for purpose to meet the needs to the different units and forces across the country (false assumptions that standardisation will suit everyone) [360]. This is by no means

an extensive list, and any number of factors may be contributing to the variation, however, without further analysis (e.g. using focus groups or interviews) the source of the issues cannot reasonably be identified.

If the Gateway was not contacted, police officers would ask the CSE (52%) for advice in these circumstances; whereas SPSA employees continued to mainly ask their colleagues (54%). There was very limited use of the Forensic Science Gateway by SPSA forensic services staff (used only 10% of the time), and its contribution towards a more effective process and working relationship was consequently limited. Care must be taken in interpreting these results as it was not possible to ascertain the sequence in which advice may have been sought as participants were asked to identify all advice sources they might access. Therefore, participants may firstly ask a colleague before their supervisor or a number of combinations. The results must be considered within the limitations of the survey, where clarification of such issues must be obtained from further research (via focus groups or interviews) which may help to identify some of the reasoning behind participant's particular choices.

This question was posed in order to assess the transfer of information and gain understanding of the actual practices (as opposed to espoused practices) that occur in the day to day procedures as well as to establish the degree of tacit knowledge exchange [205]. This confirmed what has previously been identified by many management theorists that individuals were more likely to turn to their colleagues for help and that "*advice is not mediated by the organisation's structural bureaucratic order*" [167, 361]. Advice is much more often requested from individuals located in close proximity or perceived as easily approachable [167, 208].

The nature of informal relationships between members in the workplace has been discussed previously [127, 362, 363]. The results from the survey regarding advice sources reflect the theory that people seek knowledge from trusted colleagues [204]. Handy [361] identified that within organisations, people were up to five times more likely to ask a colleague or friend for advice or answers, compared to any other form of information (including Standard Operating Procedures - SOPs and dedicated

experts). This was shown to provide a direct relationship between friendship groups and knowledge, as trusted and capable colleagues were most often consulted [133, 204].

Generally, communication appeared to continue to vary greatly. There seemed to be an awareness of the relevant sources of advice for specific situations and their importance was also recognised. However, it appears they are underutilised. Figure 16 illustrates that although 95% of participants agreed that having expert advice available and having a well trained SIO are vital, only a small number of investigative staff (CSEs and police officers) actually utilised these sources regularly. As stated by Manning [364], the "*mere availability and accessibility of information [intelligence or advice sources] does not necessarily mean that it is used effectively*".

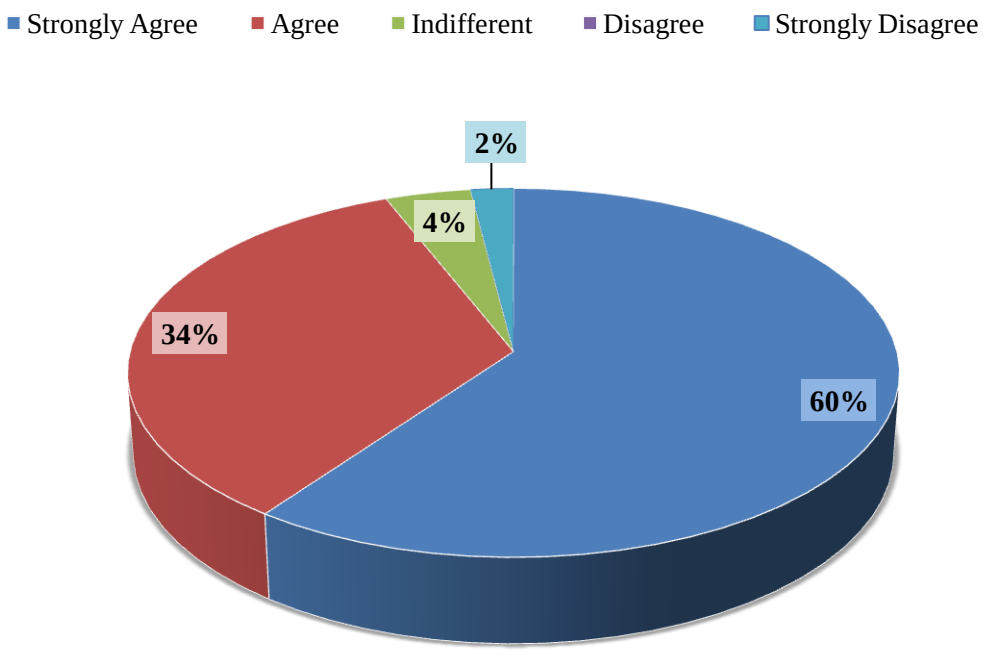


Figure 16: The importance of the availability of expert advice (n=273).

Encouraging individuals to seek information from the most appropriate sources must acknowledge that individuals have been shown to be reluctant to consult those outside their 'community' let alone other organisations [125]. Cultural differences have already been demonstrated to affect the relationships and collaboration between different investigative organisations [115, 122]. "*Participants form close relationships and develop idiosyncratic ways of engaging with one another,* [...] *causing a barrier of entry to outsiders*" [167]. Knowledge sharing is a fundamental aspect of the investigation, where success often depends on the efficiency and effectiveness of the knowledge being shared [365]. Knowledge sharing may also have an impact on the degree of collaboration and level of interaction between various organisations [365] and consequently affect the effectiveness of the process as a whole. The development of good communication networks within and between investigative roles in order to share information has previously been suggested [38, 117].

Communication has been identified as particularly important in networks or systems in which forensic science is a part [27, 366]. It is the "*connecting and integrating link*" that maintains the relationships within various parts and between different "*levels of the system as a whole*" [27]. Consequently, due to the complexity of many investigations and the interconnected nature of the relationships, communication and information transmission is required to optimise the collaboration between different individuals and agencies [30, 366].

4.5. Frequency of involvement in decision making

Participants were asked to determine the frequency of involvement in three aspects of the forensic process: crime scene attendance, evidence recovery, and lab submission. Table 14 illustrates that police forces were more regularly involved in all of the three investigative stages, whereas SPSA FS have limited involvement in scene attendance but were often involved in evidence collection in volume crime

investigations (Kruskal Wallis significant to $p < 0.05$). This is reflective of what was expected from the role requirements of SPSA experts, as high volume crimes such as housebreakings rarely require the scientists to attend scene.

Table 14: Frequency of involvement in decision making within the forensic process by police personnel (n=120) and SPSA FS (n=147)

		Always	Regularly	Sometimes	Rarely	Never
Police roles	*Scene attendance*	10%	*60%*	*24%*	5%	2%
	Evidence collection	10%	*54%*	30%	5%	1%
	Lab submission	7%	*50%*	31%	10%	2%
SPSA roles	*Scene attendance*	14%	16%	14%	11%	*45%*
	Evidence collection	*24%*	14%	*24%*	16%	23%
	Lab submission	14%	21%	*24%*	23%	18%

4.5.1. Crime scene

Fourteen percent of forensic staff (scientists, fingerprint examiners and scene examiners) stated that they were always involved during the decision making of scene attendances. This stage of the investigation was primarily associated with the role requirements and responsibilities of scene examiners (83% always or frequently attend scenes). In comparison, scientists and fingerprint examiners were rarely requested to attend the scene of a volume crime such as theft HB, therefore their figures of 53% and 58% respectively of never attending crime scenes were not unexpected.

The low police figures (17%) for always being involved in scene attendance decisions were somewhat unexpected, however some explanation may be available from the fact that they are often indirectly involved with the situation once the incident turns into a scene but much more involved in other aspect of the investigation, such as the taking of statements [23, 76]. These are not tasks directly related to scene attendance, and police officers are despatched to incidents every time (blanket attendance). Senior police officers stated they were regularly to always involved in decision making (almost 50% of the time) relating to scene attendance.

4.5.2. Evidence collection

Decisions on whether to collect forensic evidence from a crime scene illustrated similarities to decisions regarding scene attendance. CSEs stated they were frequently to always involved (84%) and most fingerprint examiners stated they were rarely or never involved (70%). Slight variations exist between scientists, as one third (33%) indicate they were regularly involved. Police constable and detectives were involved in evidence recovery 90% of the time, and police sergeants 85% of the time.

4.5.3. Submission of evidence to laboratory

The final question related to the frequency of involvement in decisions about evidence submission. Similar trends were identified; crime scene examiners were regularly to always involved 77% of the time, and scientist and fingerprint examiners only 63% and 71% never to sometimes involved respectively. Again, this was reflective of responsibilities of specific roles. Only in very serious incidents would a forensic scientist be called out to the scene; fingerprint examiners are solely situated in the fingerprint bureau.

Police officers (constable and sergeants) stated they were involved regularly (57% and 48% respectively) and senior police roles were frequently involved (70% sometimes, regularly or always). Uniformed officers are not necessarily required to be involved in the submission of forensic evidence therefore; the rather high involvement as shown by the data by police constables and sergeants would require further analysis to determine some of the reasoning for these responses and may identify areas of police work that had not been clearly recognised. Saulsbury *et al.* [17] identified a number of different factors which they found to influence the decision making of police officers when considering whether to submit evidence for forensic examination including: forensic budgets, evidence perceptions, waiting times, training, relationship and communication with laboratories and so on. Further analysis into this issue could identify whether similar considerations occur in Scotland.

Figure 17 illustrates the frequency of decision making between SPSA FS respondents and police roles in the form a of a whisker plot, indicating where the majority the results lie. These types of graphs measure the distribution of data ranges which convey central tendencies as well as rates of dispersion. The box indicates the inter-quartile range which spans from the 25^{th} to the 75^{th} percentile, includes the majority of the results. The solid line depicts the median and can often indicate a skew in the dataset (e.g. forensic service provider data for crime scene attendance). The whisker lines extending from the boxes indicate the maximum and minimum values measured by the data. Values outside the whiskers are outliers for any of a number of reasons and are displayed as circles [367]. The significance of the results was tested using the Mann Whitney test and found to be significant ($p < 0.05$). It could be concluded that the place of work was significantly important in making decisions about scene attendance, evidence recovery and laboratory submission.

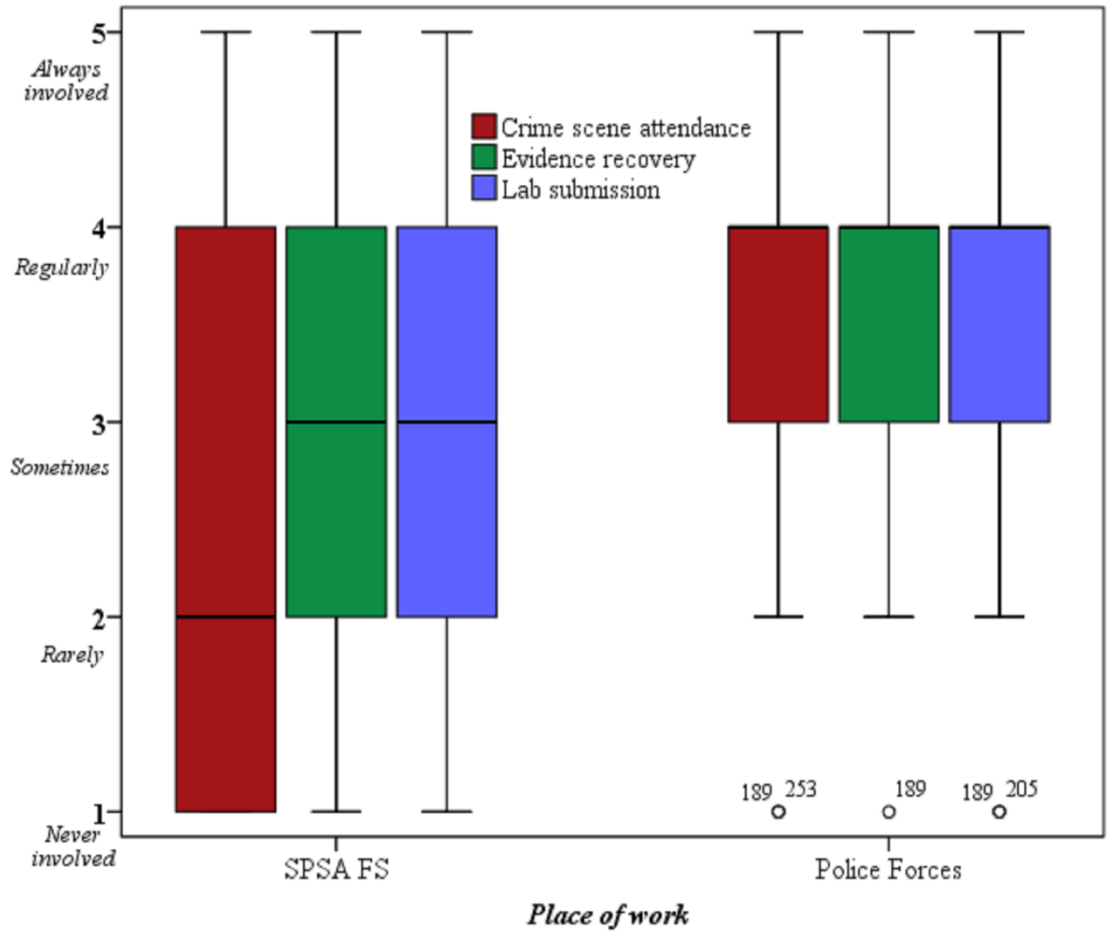


Figure 17: Frequency of decision making between SPSA FS and police officers.

Figure 17 also illustrates that generally police forces were evenly involved (mean = regularly involved) in all three situations of decision making. The outliers on the graph have been identified as containing a several missing variables (predominantly incomplete answering of the any one of the three frequency questions) and can therefore be ignored for the purposes of this comparison. They have been shown to have no effect on the overall spread of answers if removed from the sample. Although SPSA FS respondent have been shown to range all the possible answers (from never to always), the mean answers for the situations most important to their

role (evidence collection and laboratory submission) is located at the sometimes involved mark.

This data indicated that most individuals were involved at the stages they should be and to the degree that would be expected in accordance with the understanding of their roles and responsibilities. Throughout the investigation, decisions must be made at various stages. Ranging from whether to record a call, attend the scene, collect the evidence, submit and analyse productions in the lab, and so on; a number of different individuals are involved within the decision making processes that must be aware of the potential value (and risks) of the decisions they are making [39, 76, 246]. Very little research has previously identified how decisions are made, or what factors affect this [368].

During the decision process, there are often a number of "*rational*" sets of actions which will help individuals to achieve their desired outcome [168, 193, 369]. This assumes that individuals will choose the most appropriate course of action from a range of stable set of options, constantly assessing the benefits of achieving organisational aims [364]. "*Rational decision making incorporates evaluations of facts and values with organizational principles and procedures*" [368]. However, information is often incomplete and time is valuable and limited in which decisions must be made [360, 370]. Consequently decisions may be based on the interpretation of the current situation (often with limited information) [183].

The dynamic and complex nature of investigations means decision making is often affected by time and resource pressures [360, 370]. The different factors which are thought to compete with each other when it comes to decision making relating to scene attendance and evidence collection must be understood [371]. Therefore, in order to optimally utilise forensic science, coherence is required between different organisations involved which demonstrate a mutual understanding of the investigation [372]. Effective decision making also needs accurate information or intelligence on which to base evaluations [183].

4.6. Role perceptions of crime scene examiners

In order to assess any differences between the roles and responsibilities of CSEs and the perceptions of their roles, respondents were asked to select role descriptions from the following: evidence collectors (EC), forensic investigators (FI), specialist advisers (SA) or any combination of these. The level of knowledge, responsibility and involvement in the investigation between each description varies. Based on the work by Williams [15], where the distinction between an "*expert collaborator*" and a "*technical assistant*" reflected difference in levels of knowledge, the degree of integration and responsibilities; the question relating to CSEs in this survey aimed to identify whether similar perceptions were present in Scotland.

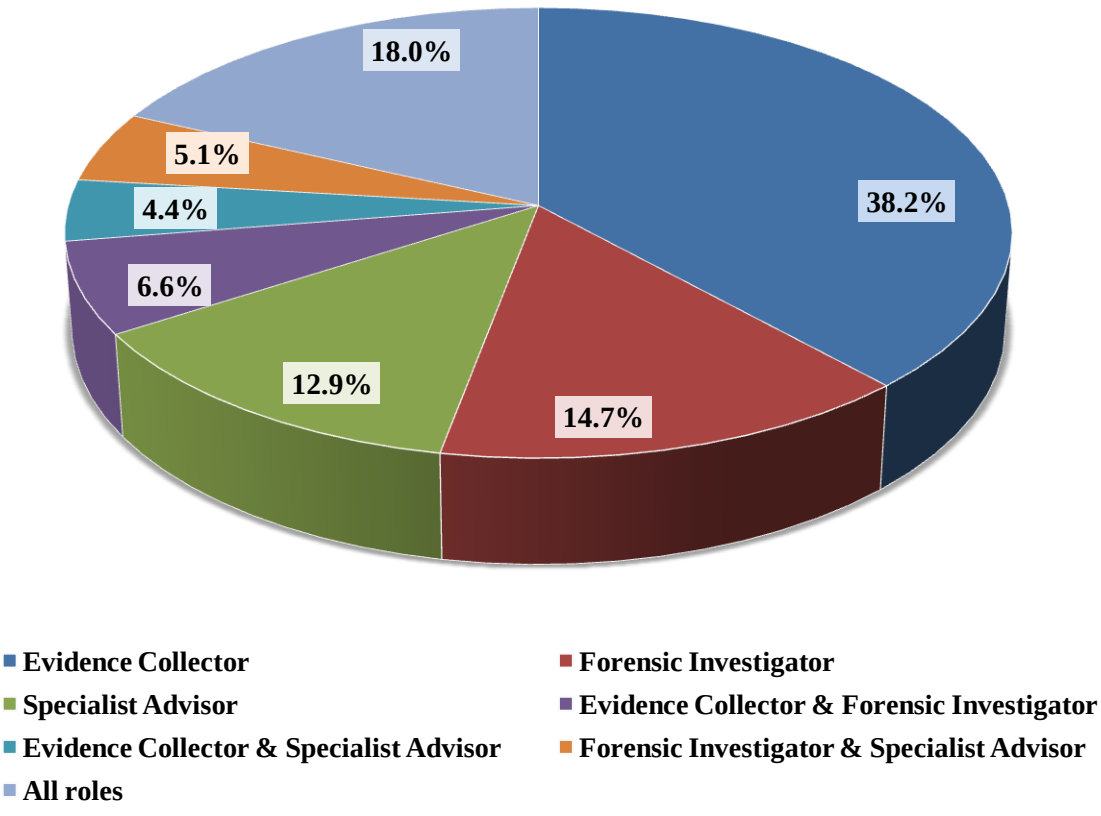


Figure 18: The perceptions of the main role of crime scene examiners

Figure 18 contains a breakdown of the role perceptions of CSEs for the sample population and illustrates that most CSEs were perceived by other roles as 'evidence collectors' (38%). The variation in perception between the different roles was found to be significant to $p < 0.01$ (Kruskal Wallis). Thirteen percent of the sample population identified the main role of CSEs as specialist advisors, apparently indicating a role with greater scope in terms of identifying intelligence and supporting the progression of the investigation. Less than one-fifth (18%) of the population, identified CSEs as a combination of all three roles. The combinations of roles could allow CSEs to provide authoritative judgments and specialist services to the investigation.

Table 15 illustrates that role perception of CSEs varied between roles. It is worth highlighting that a significant proportion (36%) of CSEs also perceived themselves as evidence collectors only. "*The notion that scientific support provides technical assistance to investigators is a longstanding one*" [15] and the data suggests that this remains the case in Scotland also. Considerable insight could be gained into this issue with further analysis of CSE perceptions in different crime types to determine whether any variation exists. SPSA documentation states that at major crime scenes, CSEs were expected to "*interpret circumstances and situations and contribute to the investigative process through provision of advice*" [359]. The differences in role expectations for different crime types requires further exploring to determine what subsequent effects this has on the role perceptions of CSEs.

The data shows that police officers perceived the role of CSEs as more complex compared to other roles. This higher perception of the responsibilities by police is important, as the investigation usually begins with the collaboration between officers first arriving (FOA) at the scene and CSEs [15, 23]. If the significance of the role of CSEs and the value of their work were to be better accepted at the initial stages of the investigation then this has the potential to be carried through the investigation [5]. The predominant perception (38%) that the main role of CSEs involved the collection and packaging of evidential items recovered from a crime scene only. This implied a relatively low level of expertise, with no input from the individual towards

the development of the investigation. This fails to recognise other significant elements of the role and limits potential contributions to other aspects of the investigation [15, 248]. It also presupposes that evidence is always evident and easily identifiable for the CSE to simply 'collect and package'.

Table 15: Perceived role(s) of crime scene examiners (CSEs)

Role		**EC only**	**FI only**	**SA only**	**EC & FI**	**EC & SA**	**FI & SA**	**All roles**
SPSA FS	Scientist	46.4%	15.5%	4.8%	14.3%	1.2%	2.4%	15.5%
	CSE	35.5%	9.7%	3.2%	6.5%	12.9%	0%	32.3%
	Fingerprint Examiner	32.3%	12.9%	3.2%	9.7%	6.5%	12.9%	22.6%
Police	PC & DC	34.5%	19%	27.6%	0%	1.7%	6.9%	10.3%
	PS & DS	33.3%	18.8%	16.7%	2.1%	4.2%	8.3%	16.7%
	Senior Police	42.9%	0%	28.6%	0%	14.3%	0%	14.3%
All participants		**38.2%**	**14.7%**	**12.9%**	**6.6%**	**4.4%**	**5.1%**	**18.0%**

* *Note: EC = Evidence Collector, FI = Forensic Investigator, SA = Specialist Adviser*

However, this ignores the fact that the process of evidence collection cannot be separated from other processes such as observation, judgement, tacit knowledge, etc. According to their job description obtained from SPSA, CSEs were expected to "*assess, prioritise and carry out scenes of crime examinations*" (emphasis added by

author) [359]. This indicates the recognition that often CSEs are required to determine the best of a number of prints from which to collect, so as to provide the highest chance of obtaining a clear lift for analysis [82, 196]. Therefore, this role requires some investigation ability and technical skill on behalf of the CSE. If CSEs are more widely accepted as members of the investigative team and the variations in role perception of the role of CSEs (by CSEs themselves as well as others) are addressed, significant improvements in the relationships between investigative organisations can be possible [5, 15, 248].

Although the dominant perception of CSEs relates to the collection of evidence from the crime scene, the data also illustrated that one-fifth (18%) of the population sampled recognise that CSEs fulfil a more complex role and should have a more comprehensive input to investigations. The high percentage of CSEs that recognised their roles encompassed all three elements (32%) demonstrates some understanding of the complexity of their role requirement and responsibilities. This contrasts with the perceptions of others in the survey. CSE role requirements need to be more clearly defined, levels of training standardised and the contribution to the investigation identified [18, 23]. The main issues lies in the lack of clearly defined role description in Scotland which state the general responsibilities, purpose and duties of the job as well as the levels of knowledge and skills required for crime scene examiners to effectively carry out their job [224, 359]. Standardising the role requirements may not change the perceptions of the roles of CSEs. However, nationally agreed role profiles will provide clearly defined tasks and accountability which may reduce the confusion surrounding this roles [15, 23, 373].

Variations previously identified relating to training, demand, levels of performance and management, recruitment, pay and perceptions of CSEs still require some addressing [14, 16, 18, 23, 37, 40, 108]. The complexity of their role in terms of the expectations of their tasks and responsibilities in the investigation of crimes requires further analysis to determine how they are currently being used by forces. Some role descriptions indicate that they are expected to "*interact and work as a team with specialist personnel from police, other organisations and specialist suppliers*" to

ensure optimal use of forensic science and to "*provide forensic intelligence to assist the information gathering and investigative decision making process*" [359]. If role expectations are not clearly defined or mirror the perceived requirements by the individuals undertaking the work, misperceived opinions of the quality, value and type of work carried out by CSEs can inherently affect the investigation [15].

The effective recognition and utilisation of CSEs as "*activity drivers*" in an investigation has the potential to benefit resource allocation, knowledge management as well as cost-analysis [55, 99]. CSEs could be used to determine the what materials and the amount of evidence to be collected from a crime scene and submitted to the laboratory [6, 15]. As previously mentioned, the rules and discretion model could also influence the collection process. CSEs that are knowledgeable, well-informed, and respected are better utilised in the investigation [15, 23, 40]. Improved perceptions could provide a greater input in determining evidence which displays the greatest value towards the investigative needs [15, 23, 40]. Further analysis would be required which could help determine whether improved perceptions of CSEs could be the key to improving the integration between forensic service providers and police forces.

4.7. Effective use of resources – Tasking policies

A range of questions were asked relating to tasking procedures for specific crime types. Firstly, it was established whether participants were aware of tasking procedures of CSEs for volume crime incidents (answer options = yes, no, don't know). Specific tasking procedures have been shown to be a means of managing resources available to investigate the scenes which hold the most potential for providing useful evidence [239, 243]. In order to assess the awareness of the tasking procedures, participants were asked to state whether blanket or selective attendance policies were used for the following crimes: theft, theft by housebreaking (HB),

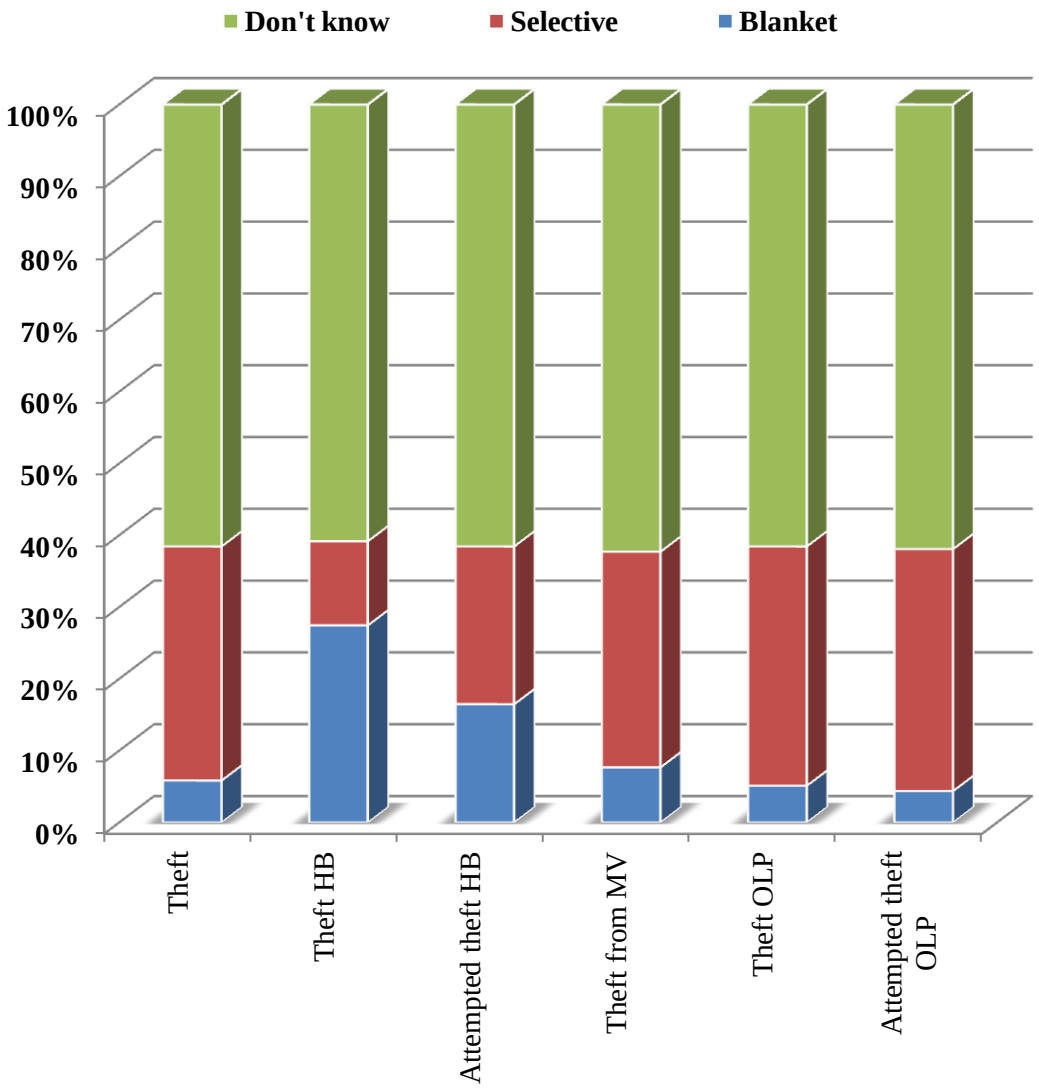
attempted theft HB, theft from a motor vehicle, theft by opening a lockfast place (OLP) and attempted theft OLP.

Blanket attendance was used to describe the response of individuals who attend every incident reported; there were no screening mechanisms in place. Selective attendance describes policies where screening mechanism may be in place (i.e. call centre staff deploy individuals to incidents which meet specific criteria) and not every incident is necessarily attended (immediately or at all). The data illustrated in figure 19 indicates a mixed response from participants surveyed in relation to knowledge of the tasking process. Over half of the sample population (55%) were unaware of or did not know what the tasking policies for specific volume crime types were, 14% expressed the view that their workplace (police force or SPSA FS) did have policies, and 31% stated that no such policies existed.

Generally, theft by HB produced the highest response for policies of blanket attendance. This number is still fairly low and only 25% of respondents held this view. The remainder of respondents either didn't know (65%) or held a different view (10% selective attendance). The data demonstrated that there was some confusion surrounding tasking of investigators to volume crime scenes. Whether this was a reflection of the poor knowledge of the existence of such policies, it because such policies don't exist or respondents don't agree with them (or have alternative views) cannot be established from the survey. Information obtained from SPSA FS suggests that policies do not appear to exist or were not easily obtainable for consideration in this project [24].

Previous recommendations have repeatedly stated the need to ensure effective tasking management in order to effectively investigate (volume) crime scenes [5, 18, 40, 55, 276]. SWIM [37] identified a large amount of variability was identified in relation to attendance and productivity of CSEs in different forces. It was noted that some forces had indicated that they would have a CSEs attend all housebreaking scenes, whereas were more selective [5, 40]. As shown by Bond [55], blanket

attendance of all crimes within a specific volume crime category was not possible due purely to resourcing implications.



** NB: Theft HB = theft by housebreaking, MV = motor vehicle, Theft OLP = theft by opening lockfast place.*

Figure 19: Participant's knowledge of tasking policies for certain volume crime types.

In 2003, HMICS [44] recommended that police forces publish concise attendance policies for specific crimes types which clearly explained the level of service that can be received by members of the public. This appears to remain unchanged as many Scottish police forces still appear to lack tasking policies. Tasking mechanisms trialled by SPSA Glasgow in 2009, using a dedicated unit for attending volume crime scenes in the Govan, area have generally been deemed successful [24, 374]. A crime specific call handling sheet was designed and was followed to determine the requirement of scene attendance. Also part of this process was a schedule-type system of attendance, where the call handler determined a convenient time (for both CSEs and the caller) for a member of the Scenes of Crimes Unit to attend to the scene. Thereby less urgent call outs were scheduled for future days and victims do not feel they were sidelined or ignored [374]. The example call grading flowchart used can be seen in Appendix 9, and was implemented force wide for consistency [374].

Tasking CSEs to crime scenes in accordance with the call handling sheet, part of the 24/7 shift implementation, has meant that CSES in the Govan Unit were able to attend an extra 100 volume crime scenes each, collect more fingerprint, DNA and footwear mark evidence per crime scene per examiner and had a higher evidence recovery to identifications percentage [24]. A reallocation of resources would need to be considered in order to change the methods of scene attendance. This could allow for more efficient and timely attendance of crime scenes which considers geographical and resource demands [23, 240-242]. This would allow CSEs to optimize their time effectively for attending crime scenes and spend less time on non value-added activities [41].

Variations in tasking policies continue to occur. Differences have been identified between forces, areas and crime types and are often linked to the crimes which are currently deemed as problematic (prioritised) and requiring targeted attention (focused tasking) [43]. Standardisation of tasking procedures for appropriately trained, specialised scene personnel to attend scenes which are determined forensically viable has previously been recommended [239]. SWIM [37] identified

that tasking policies can be used to assign CSEs to the "*optimum number of high forensic value crime scenes*", in order to "*maximise productivity and consistency*". Effective and efficient utilisation of resources would result in staff being tasked to the appropriate scenes quickly [23, 40].

4.8. Timeliness of forensic investigations

As part of the longitudinal study evaluating the role of forensic science in an investigation, case file information from over 2,000 was received from the calendar year 2008 from two SPSA FS units (Edinburgh and Glasgow). A number of different factors affecting timeliness (or turn-around-times) were calculated. Dates already recorded in the case files was utilised and included: date incident occurred, date incident attended, date productions (evidential material) received at the laboratory, date productions analysed, date analysis completed and date report completed. These provided measureable points from which various aspects of timeliness could be calculated.

4.8.1. Cases containing DNA evidence

The analysis of DNA evidence in cases of theft by housebreaking (theft HB, n=669) demonstrated great variation in timeliness which is shown by figure 20. The greatest variation was noted in the time required for DNA evidence to be submitted to the laboratory. Analysis of the case files demonstrated that on average 35 days were required for DNA evidence to be submitted for laboratory analysis after the incident had occurred and had been reported. However, this time ranged from as little as one day to almost one year (n=362). The data showed that the time evidential productions spent in the laboratory also varied greatly. Figure 20 illustrates that on average this took between 50 and 140 days, however was extended to over 400 days in some

cases. On average DNA evidence spent 105 days in the laboratory. Unfortunately, it was not possible to calculate the actual time required to carry out the analysis as this was not recorded in the database and would require further detailed case file analysis.

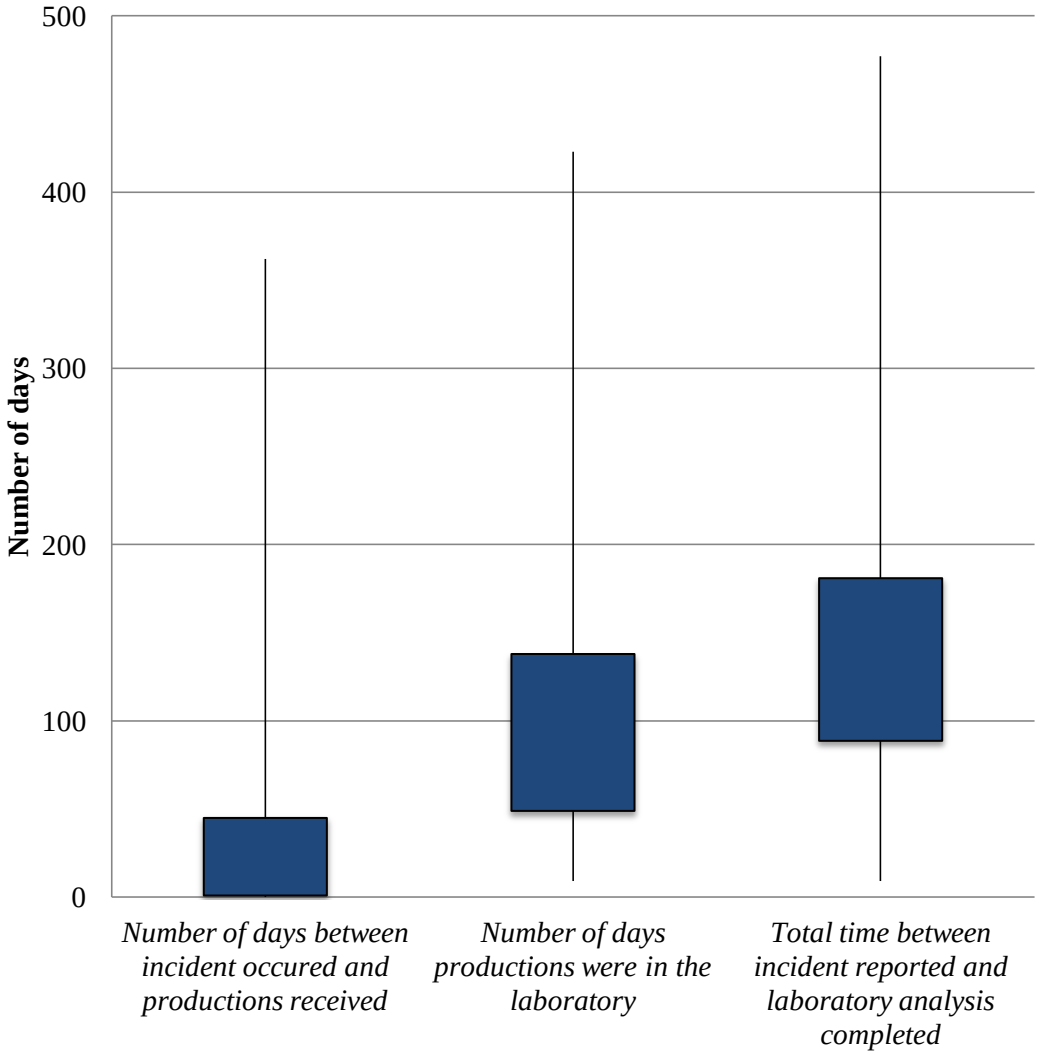


Figure 20: Time taken for theft HB cases to reach the laboratory and the time taken for the case to be analysed where DNA evidence was collected (n = 669). The number of days were calculated from the date evidence was first collected from the crime scene to the date when the report with results was produced by the laboratory.

The data also showed that there were approximately 50 days between DNA evidence arriving at the laboratory and the sample being uploaded onto the national DNA database for searching. It also took less than 24 hours to identify an individual on the database once it had been uploaded. This indicates that databases are working the way they should be in quickly indentifying individuals [375]. However, it was also found that after the initial time delay in evidence being received by the laboratory (35 days); the next greatest delay occurred when completing cases once a DNA hit had been established on the database (it took 20 days for case files to be completed once the sample was loaded and a hit occurred on the database). The data demonstrated that (for the majority of cases) between 90 and 180 days were required for DNA evidence to be collected from a scene of theft by housebreaking, to be analysed in the laboratory and the results becoming available for the case report. On average, it was shown that it took approximately 3.5 months (139 days) to carry out this stage of the investigation.

The workload between the two SPSA units used for this study also showed great variation. The SPSA Glasgow unit received 542 DNA cases and SPSA Edinburgh unit received approximately 127 DNA cases in the year 2008. However, the detailed breakdown of the analysis of timeliness for these two units illustrated that DNA evidence spent a similar amount of time in the laboratory waiting to be analysed (average 96 days). The reasons for these delays are unclear and further research addressing this issue would be required.

Figure 21 illustrates that two-thirds of the samples analysed produced mixed, partial or unsuccessful DNA profiles. It has previously been identified that "*blood and saliva samples are significantly more likely to yield usable profiles when compared with samples consisting of cells from items that were touched or handled*" [99].

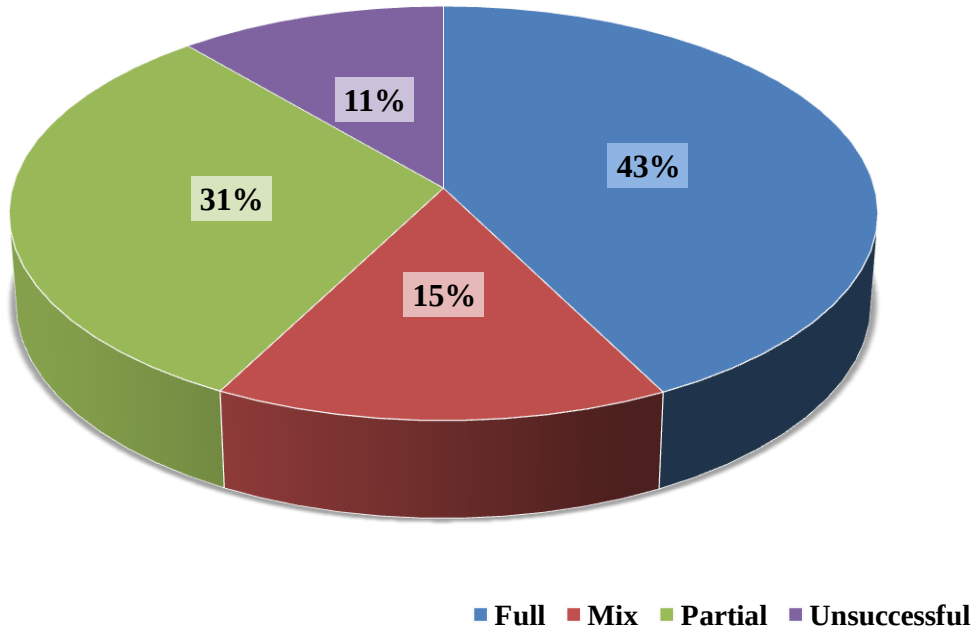


Figure 21: Results of the analysis of biological samples for DNA profiles in the laboratory

This was confirmed by the data from the sample and is illustrated in figure 22. Almost 90% of blood lifts and 80% of saliva samples (recovered from cigarette butts) produced a full DNA profile compared with less than 50% of DNA samples classified as touch samples. This suggests that implementing a system of rules and discretion, specific biological evidence types which have been shown to yield better results should always be collected by scene personnel. Other sources of DNA which are less likely to provide a full DNA profile (e.g. touch samples) or which require a more comprehensive analysis should be collected at the discretion of the CSE.

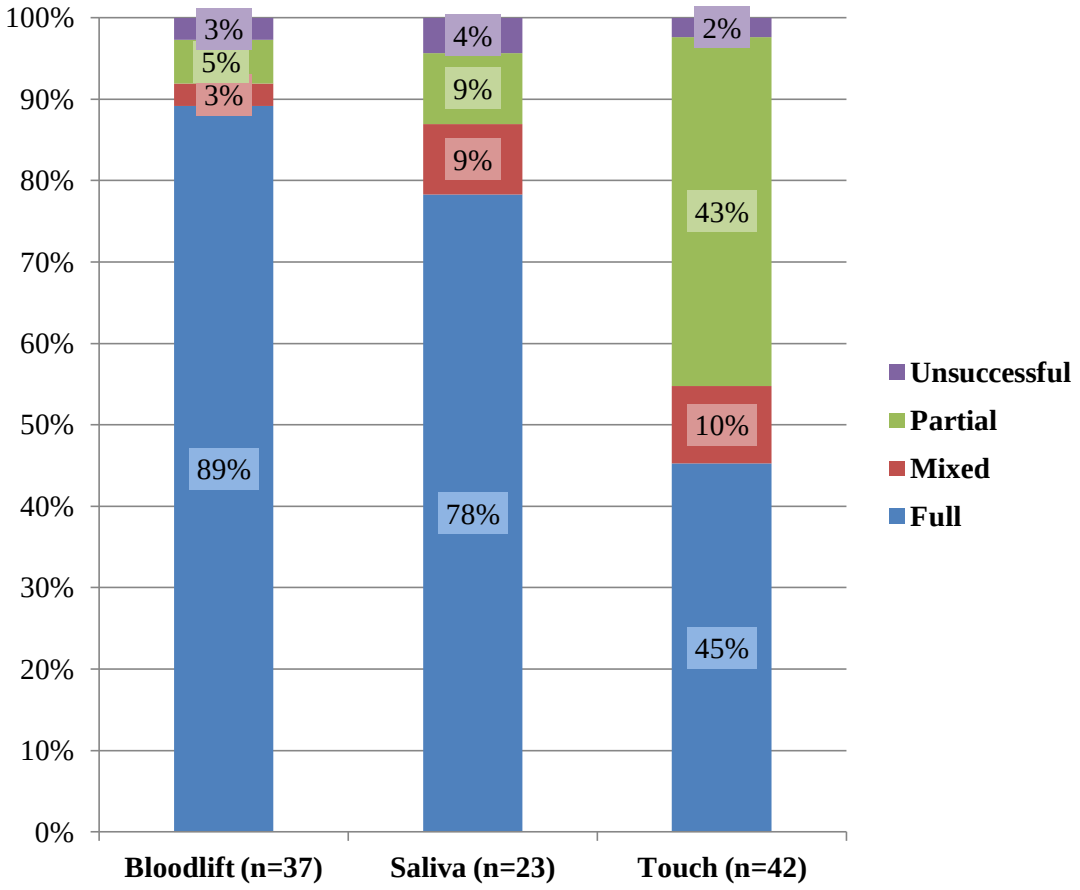


Figure 22: Outcome of DNA analysis from different sample types.

Research by Roman *et al.* [99] has also shown that "*locating and analysing blood samples is considerably more cost-effective than the alternative*" as they are approximately five times more likely to produce profiles which can obtain a database hit. This allowed them to make some evaluation of forensic processing in economic terms [99]. Further work into this issue could produce considerable insight into the value of forensic evidence in terms of value for money. Discretionary collection of biological samples other than blood and saliva samples could be considered in volume crime offences in line with these findings.

4.8.2. Cases containing fingerprint evidence

Turnaround times for fingerprint cases were analysed for the same year as the DNA cases (2008). The time required to submit fingerprint evidence to the bureau once the incident had been reported and attended is shown by figure 23. On average, this varied less than the DNA cases which can be seen due the closeness of bars in the boxplot. Most incidents took between 6 and 17 days to be attended and examined, and the average time taken to receive fingerprint cases was 11 days. Again, the range of this period extends to over one year (381 days).

The amount of time which elapsed before the results were available was also assessed. The data indicated that range of time fingerprint cases spent in the bureau was between 7 and 43 days, where productions spent on average 35 days in the bureau before the results were obtained. The turnaround times between the two bureaux involved in this part of the project must be considered with care as data was not always complete. This is particularly true for the time between the commission of the crime and the receipt of evidence at the bureau. However, for the purposes of demonstrating variations in timeliness, the available data was able to provide useful information. The amount of time required to load impression onto the IDENT1 database took slightly longer in the SPSA Edinburgh unit (29 days) compared with SPSA Glasgow unit (20 days). The total time between cases being received and analyse being completed ranged between 16 and 63 days and on average took 58 days.

The data sets obtained from the two fingerprint bureaux were analysed to ensure an accurate representation from each was obtained. Case files which had many missing variables were excluded to avoid bias in the results [105, 299]. Therefore, all turnaround times calculated were expected to be higher (i.e. longer) due to the presence of some incomplete cases. Discussions regarding the effective use of fingerprint evidence in terms of maximising their potential to identify offenders have been focused heavily on timeliness of fingerprint processing [55, 246, 250].

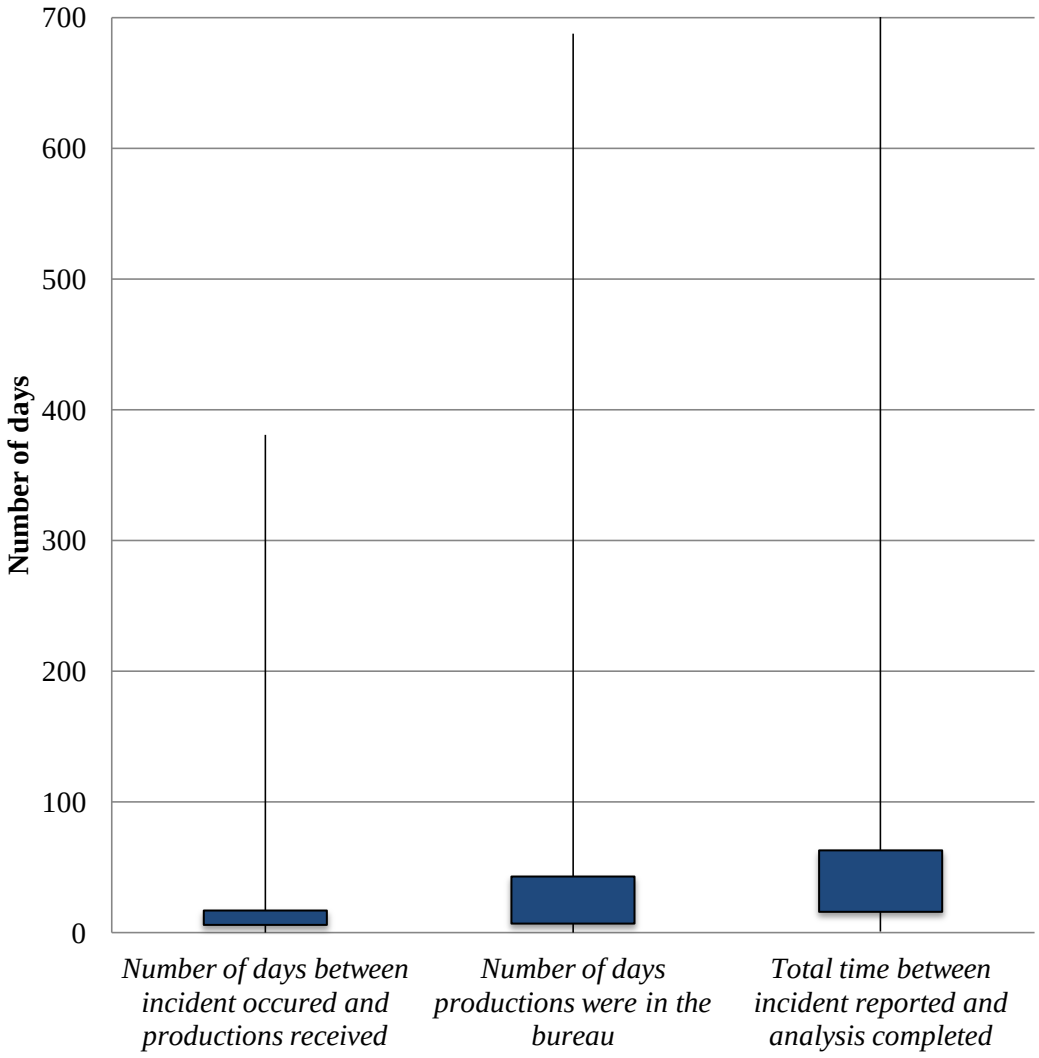


Figure 23: Time taken for theft HB cases to reach the fingerprint bureau and the time taken for the case to be examined where fingerprint evidence was collected (n = 1,652). The number of days were calculated from the date evidence was first collected from the crime scene to the date when the report with results was produced by the bureau.

4.8.3. Turn-around-times: DNA versus fingerprints

The differences in turn-around-times for cases involving fingerprints and DNA were very high. Figure 24 illustrates that DNA cases took three times as long as fingerprint cases to be completed. A fingerprint case took an average of 50 days to complete, where DNA cases on average take approximately 140 days.

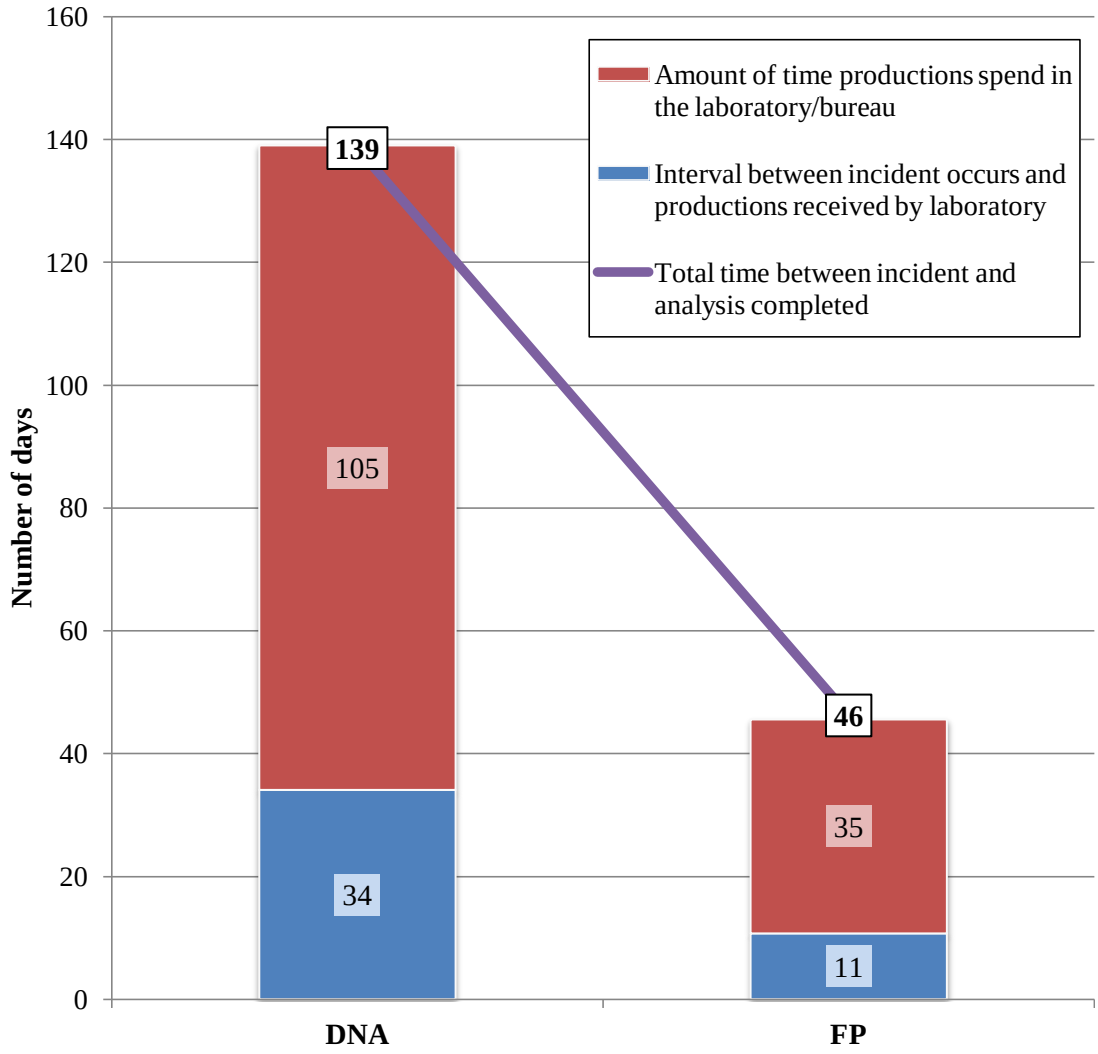


Figure 24: Comparison of the average time taken for cases involving DNA and fingerprint evidence to reach the laboratory or bureau and the time taken for the analysis to be carried out.

Proportionately, DNA and fingerprint evidence required approximately the same amount of time (of their total time – number of days) to produce the case report (25% of total time to be received by the SPSA FS unit and 75% of the total time was spent in the laboratory/bureau during which it was analysed). Overall, the analysis of DNA evidence took much longer. Interestingly, the Edinburgh SPSA FS unit dealt with a much larger number of fingerprint cases in the bureau (665) than they did DNA cases in the laboratory (140). Further analysis could determine whether issues of DNA case backlogs need to be taken into consideration.

Data briefly explored in this part of the project assessed the speed of fingerprint and DNA analysis from figures provided by SPSA FS. Approximate calculations indicated that on average, cases involving fingerprint evidence proceeded three times faster than cases involving DNA evidence. At this stage it must be noted that the cases utilised for this part of the project were from the calendar year 2008 (January to December), and are therefore historical in nature. As was stated in section 3.3, this time frame was chosen to ensure that the laboratory analysis was completed, and potentially case outcome data (e.g. legal proceedings) could also be analysed. However, project time restrictions meant that fully pursuing this part of the project was not possible.

It was not possible from the data gained for this project to determine whether cases which did not contain DNA or fingerprint evidence took substantially more or less time than those cases which did. Previous work has identified, that often cases involving DNA and fingerprint evidence took much longer when a suspect was not immediately available (due to a lack of a database match) [196]. The impact of severe time delays may also allow a prolific offender to continue offending during the time delay [41].

Nor was it possible to assess the effect long turnaround times had on the investigation in terms of achieving effective outcomes. However, as previously identified by a number of different studies [23, 240-242], the timely analysis of evidence is essential to promote good working relationships and effective building of

cases for prosecution. Timeliness has been identified as a matter of concern, as many previous studies have identified significant delays in several stages of the investigation where identification evidence such as DNA and fingerprints can be vital [23, 55, 196, 252]. The work in this project also found that processing of fingerprint and DNA evidence from crime scene to case report required a substantial amount of time.

4.9. Summary

This research explored the use, value, knowledge and perceptions of forensic science in Scotland in the investigation of volume crimes, considering organizational, professional and cultural factors that may impact on its effective use. A summary of the key findings are highlighted below.

The data showed that a number of different training courses were available, and a number of different methods were in place for various members of the investigative team. There appeared to be very little difference between different roles and the types of training they have received. However, the constraints of questionnaire made this difficult to assess. More detailed analysis would be required to determine whether any one type of training was perceived to be better or more effective than others and how practitioner responses compared with management perceptions and current training policies.

The amount of training was found to be role dependent. There was evidence that the mix and combination of training types for all investigative roles is fairly similar, including formal programmes and practical experience. Training did not appear to have any significant effects on any of the other factors assessed in the questionnaire including the perceptions of the value and weight for different types of forensic evidence. Difficult to quantify (and to assess), and varied in type, there appeared to be a fundamental issue regarding the amount of training received by individuals.

Individuals indicated they had received forensic training, but were unable to clarify the amount of forensic training they felt they had received throughout their (sometimes relatively long) careers (mean of 12 years experience). A clearer understanding of this issue could be provided by more detailed assessment of training practices currently utilised by investigative organisations.

Responses of the perceived value and strength of specific forensic materials from the questionnaire matched the expectations of the researchers based on previous literature [12, 17, 18, 40]. Perceptions of the value of fingerprints and DNA evidence was greater compared to other forensic materials. There was evidence of some knowledge of the potential of footwear marks and toolmarks to provide good intelligence information when searching for suspects [9, 43, 283]. There was no correlation between training and evidence perceptions as SPSA FS respondents and police officers were shown to have similar opinions about the strength and value of evidence. Further analysis could provide suggestions how the awareness of the value of these evidence types could be increased amongst different investigative roles (e.g. through changed training programmes, more publications, specific knowledge transfer events).

The sharing of information, in terms of seeking advice in specific situations, has been shown to follow predictable patterns [120, 167]. The data from the research indicated a similar pattern where advice was most often sought from colleagues or immediate supervisor, rather than the most knowledgeable (and appropriate) information source [120, 167, 204, 361]. Effective communication requires collaboration and mutual understanding (of processes, systems, roles and responsibilities) in order to share specialized meanings of knowledge [376]. Other issues of communication were difficult to assess using a survey method; further analysis could ascertain how information exchange and communication most frequently occurred.

This data indicates that most individuals were involved at the stages they should be and to the degree that would be expected in accordance with the understanding of their roles and responsibilities. Police forces are more regularly involved in all of the

three investigative stages, whereas SPSA FS have limited involvement in scene attendance but were often involved in evidence collection in volume crime investigations.

The perception of the role of CSEs indicated that most CSEs were perceived as evidence collectors only (38%). Thirty-six percent of CSEs viewed themselves as evidence collectors only also. However, some variation of CSE perception was evidenced between different roles. SPSA documents indicate that some CSEs are required to "*assist enquiry officers in the detection of crime through the interpretation of scenes and provision of forensic intelligence*" [359], and suggests their job descriptions requires more than just an evidence technicians role. This clearly indicates that role profiles currently in use to define the purpose of the roles of CSEs did not match the expectations of the jobs CSEs are perceived to carry out.

The job profiles received have stated that CSEs are expected to assist in the "*investigative decision making process*", contribute to an investigation through the "*provision of advice*" and intelligence, and to effectively "*interact and work as a team*" [359]. However, the current perception of the (limited) role of CSEs does not effectively meet any of these criteria, suggesting CSEs are currently not used effectively. CSEs are well trained in the use of forensic science and its potential impact on the investigation, however were expected to simply collect evidence from crimes scenes without providing investigative input on the value of that evidence [15]. However, poor perception of the roles of CSES has been shown to hinder their effective utility [15].

Timeliness has previously been shown to affect all aspect of an investigation – the police investigation, the scientific analysis of evidence, the production of the case reports for court [40, 87]. The analysis of evidence from crime scene to completion of the case report was shown to take a substantial amount of time (sometimes up to a year). The data indicates that cases containing DNA evidence took an average of 3.5 months (139 days) and cases containing fingerprint evidence took an average of 50 days to be collected, sent to the laboratory, analysed and a case file to be produced.

Therefore, cases involving fingerprint evidence proceeded (on average) 2.5 times faster than cases involving DNA evidence for the time period studied. Further analysis into this issue would be required to establish the effects of increased timeliness in the investigation as a whole. The impact of slow turn-around times on the rest of the investigation has been discussed previously; improved timeliness could potentially result in faster identification of offenders and a more rapid arrest and prosecution [15, 55, 377].

Effective use of resources in the investigation of crimes has been discussed previously [5, 12, 15, 18, 37, 40, 108]. Much of the focus of resources has been on the ratio of scene personnel to crime rates, however, the effective availability and deployment of resources has also been found to be necessary by everyone involved in the investigation (the police forces, forensic service providers, etc.) [40, 87]. Confusion regarding tasking policies appears to be evident from the respondents questioned. Over half of the sample population were unaware of or did not know what the tasking policies for specific volume crime types were, 14% expressed the view that their workplace (police force or SPSA FS) did have policies, and a third stated that no such policies existed.

Chapter 5: Summary and Conclusion

When considering the themes that have been addressed in this research it is clear that a number of complex issues affect the use of forensic science and the investigation of a crime. Jacobson *et al*. [38] suggested that even the 'simplest' linear model of an investigation was "*part of a much wider network of events*". The high degree of variation of the use of forensic science crimes has been partly caused by the "*plethora of knowledge, practices,* [...] *and interactions*" between individuals involved who must work together effectively in order to arrive at the desired outcome [111]. However, that forensic science involves a "*wide disciplinary range and an extensive variety of ways of working*" has been evidenced [13]. Variations in policies and practices have been established due to a variety of factors and have resulted in a mixed application of forensic science [7, 284].

Predominantly forensic science and the investigation of crimes was found to be "*hindered by* [...] *extreme disaggregation – marked by multiple types of practitioners with different levels of education and training and different professional cultures and standards for performance*" [6]. Taken from the NAS report published in 2009, this quote illustrated that similar issues found in England and Wales were apparent elsewhere (the USA) also. This was the latest in a long line of studies which had assessed the use of forensic science in the investigation of crimes (amongst other themes). Bringing these issues to the attention of the forensic science community has encouraged discussions in many jurisdictions, and many forensic communities have debated how to implement changes [269-271].

Although this research was initiated prior to the publication of the NAS report, it was important to establish the current position for Scotland. Data collected from the survey provided some evidence that Scotland has not been unaffected by these issues. The review of the literature identified a number of recurring themes which were shown to the hinder the effective use of forensic science. Part of an inherently

complex system that is the investigation of crimes, these themes were found to add further complexity to an already dynamic issue.

The limited knowledge of and the untested contribution that forensic science makes also restricts the role it plays in an investigation [13, 111]. Improved education and training as to what "*forensic science can and cannot do in support of police investigation*" was recommended four decades ago [18], as "*the lack of accurate knowledge about forensic science* [...] *inhibits its proper uptake and use*" [225]. However, this research has indicated that training and education did not appear to affect the knowledge of the utility of different forensic evidence types. A stronger awareness for DNA and fingerprint evidence was demonstrated however; the true benefit (in terms of case progression, case outcomes, sentencing, cost, and so on) has not yet been established. More research into the value of forensic evidence on the investigation of crimes was suggested as investigations continue to become increasingly reliant on the use of science and technology [14].

By generating intelligence to assist criminal investigations, as well as providing physical evidence, forensic science was found to be "*critical to the efficiency and effectiveness of the criminal justice system*" [19]. The importance of forensic intelligence (fingerprint identifications and DNA hits) as a standard forensic technique for the investigation and detection of a wide spectrum of crime types has been well established and studies have focused on specific crime types as a means of assessing the value of evidence (in general) towards achieving investigative outcomes [15, 55, 98, 250]. However, due to the "*multiplicity of ways in which forensic science*" can be used in investigations makes it difficult to assess how maximum potential can be best achieved [284].

Over recent years, technological advances and scientific developments have occurred which have greatly influenced the reach and application of forensic science [279, 378]. Investments in (intelligence) databases and technology have been based on the "*assumption that* [they] *will contribute to improvements in the effectiveness of criminal justice*" [13]. However, the direct benefits of these to the criminal justice

system have not been evaluated in terms of value (economic and resource) [282]. Therefore, assessments of the potential impact and value of forensic evidence and related technological advances on the system as a whole require further systematic analysis [5, 13].

Bradbury and Feist [5] stated that "*improving understanding of the costs and outcomes of the application of particular forensic techniques does have a key part to play in improving forensic processes*". Further analysis into this issue could identify the value (in economic terms and evidential terms) of specific forensic evidence and the impact on investigations. Although "*cost-benefit analysis*" could not necessarily improve the "*overall understanding of the use of forensic*" science, better understanding of the impact on resources (e.g. budgets) could determine whether there are any other benefits to improving training or understanding of specific evidence types which have been identified to be valuable evidentially and economically [5, 12, 99, 379].

Measuring the value and benefits of specific scientific outputs towards the outcomes of an investigation has previously been described to require a better shared understanding of the system between all the individuals involved (the police, forensic science providers, prosecution authorities, etc.) [5]. Knowledge of how specific outputs could be utilised at the different stages of an investigation towards achieving objectives, could potentially increase the cohesion of the system as a whole [37].

The role of forensic science has become increasingly important in the investigation of crimes, however, analysis of relationships within investigations have traditionally remained internally focused [16, 18, 23]. This means that the value of forensic evidence, for example, has predominantly been assessed in terms of achieving targeted results, rather than assessing the contribution towards investigative outcomes [37]. Investigative agencies each have their own agendas and targets to meet, and face different pressures to perform within the complexity and diversity of an investigation [37]. "*Variation in levels of provisions and inconsistency in achievement continue*" to have an effect on performance [81].

The inherent complexity of investigations undoubtedly affects the variation in the use of forensic science. The dynamic nature of investigations, and the pressures faced by individuals and organisations to perform effectively and efficiently mean that different working practices have been established [12]. This has previously been discussed in relation to the variations in the collection and utility of performance figures. Performance figures have traditionally focused on process outputs (the results of specific activities – e.g. the number fingerprints collected) rather than system outcomes [23, 37, 40, 81]. "*Without reliable outcome based data it is difficult to* [...] *establish a benchmark by which to judge the relative performance*" where forensic services are also unable to "*measure their contribution*" [40].

Performance figures which count the number of scenes visited and the number of items collected from a scene are useful in determining activity levels of agencies; however they do not provide information of the value of those collections or the attendance of those scenes to achieving the desired outcomes [14, 37]. A focus on more realistic performance figures was previously suggested which address the need to "*implement a more systematic and effective performance management framework covering the end-to-end forensic process*" has previously been recommended [37]. However, performance data continues to focus on process outputs, not system outcomes.

The Govan pilot project run by Strathclyde Police and SPSA can be used an example of this [374]. General performance figures suggested that the pilot project was successful; CSEs attended less scenes but collected more evidence which produced more identifications [24]. However, the success of those identifications in contributing towards a conviction could not be discerned from the case management system in place and were not of priority interest to the unit. Tilley and Townsley [81] stated that performance indicators should "*emphasise outcomes, not processes*". That the focus remains on outputs not outcomes was demonstrated by the Govan Project. The Govan district achieved an extra 54 fingerprint identifications and 40 extra DNA identifications (compared to the year prior to the pilot project). The effects these had on the outcome of the investigation were not analysed [24, 374].

"*A more thorough examination of the contribution of scientific support to crime investigation requires the collection and interpretation of improved numerical data*" [15]. How forensic science was used and how it was perceived can be evaluated to an extent using performance figures [14, 37, 380]. Performance figures relating to collection, submission and identification rates of fingerprint and DNA evidence could be used to evaluate which forensic materials should be collected in order to establish the best chance of an identification, for example. This could then be used to develop the rules and discretion model regarding different evidence types as previously discussed in section 4.7.1. (specific biological material – e.g. blood, saliva, sweat – is always collected, other biological material is collected at the discretion of the CSE). Volume crimes need "*robust systems, rules, habits and standards that can be rolled out and routinely applied across many cases maximising the net benefit at minimum costs*" [81].

Tilley and Ford [81] found that often there was a "*consistent mismatch of what would be done if forensic science were to be used effectively and efficiently and what was actually done*". That espoused practice often varied from actual practice has previously been described and was demonstrated by this research. The importance of expert advice sources and well trained staff were recognised, however they were rarely used in practice. It has been stated that standardisation of practices can reduce the level of variation previously found [5, 12]. However, standardisation of practice and the enforcement of published manuals may also be dismissed in actual practice [201, 381]. Seemingly standardised practices (e.g. fingerprint training) have remained incredibly varied as "*normal practice does not correspond to the explicitly described functions and standard operating procedures within an organization*" [208]. Consequently, understanding actual practice within a process or organisation could be used to establish good practice guides which merges explicit knowledge (espoused practice) with daily routines (actual practices) [162, 212]. 'Normal practice' in terms of the daily procedures carried out by individuals in an organisation, are based on personal experiences and tacit knowledge [167].

That tacit knowledge and experience were considered important in the daily routines of forensic scientists was demonstrated by Doak [208]. Further analysis into the importance of tacit and explicit knowledge and experience throughout other stages of an investigation could provide considerable insight into how education and training is currently used in daily routines by different roles. It has previously been acknowledged that police officers had very limited understanding of how forensic science can be used in investigations [14, 16]; however the data from the survey in Scotland shows that police perceptions of the value of forensic science were similar to other investigative roles including SPSA FS. Therefore, previous assumptions that the optimal use of forensic science is hindered by the limited knowledge of police officers cannot be confirmed [12, 17]. This also raised a number of questions:

- Did training programmes adequately cover the value of different evidence types (if so why wasn't this evident from SPSA FS survey respondents who received more specialised training/education)?
- Did respondents give what they perceived would be the 'expected' answer to these questions (did they answer from knowledge or how they hoped these evidence types could be used)?
- Did respondents understand what was meant by 'intelligence value' towards furthering investigations?
- Are the perceptions of evidence types linked to the frequency with which they occur or are collected form crime scenes, and therefore limited exposure has influenced limited perceptions?

Limitations of the survey did not allow these questions to be analysed as part of this project, however further work could attempt to clarify many of these issues. The lack of awareness of the potential utility of evidence types remains unknown, detailed statistical analysis of the predictive value of forensic outcomes is needed in order to ascertain the most value of different evidence types in specific situations [17].

Crime scene examiners are responsible for "*examining, assessing, interpreting, recording and collecting physical evidence*" [382]. They have often received specialist training and are knowledgeable about evidential material [132]. The role and understanding of forensic science can also be greatly influenced via CSEs. However, a current variation in perceptions and utility limits their input. That the importance of specialist investigative roles (e.g. CSEs) was insufficiently recognised in England and Wales was also found by Williams [15]. The complexity of the role of CSEs and the perception of their responsibilities has been identified as one of the main areas requiring more research [5]. CSEs were found to be an integral part of the investigative process, however they appear underutilised and restrained by their current perceived roles (technical assistants or evidence collectors only) [15]. There are a number of issues. Not only does there continue to be a lack of data which explains how CSEs "*use a repertoire of observational skills, manual competences, logical inferences, technical understandings and other forms of situated practice*" to investigate various crime scenes [111, 242]. Current limitations in their perceived roles in volume crime investigations means the roles of CSEs have become routinised and their training and knowledge not fully exploited.

Secondly, better integration of CSEs into the investigative team would allow them to be used as additional sources of intelligence for furthering investigations [15]. Used as an information, intelligence or advice source, CSEs have the potential to provide valuable insight into how forensic evidence can be utilised in an investigation [8, 14, 43]. Williams [5] questioned whether detection rates would improve if "*CSEs take on more of the investigative role*", and this issue remains unaddressed. Further analysis into this issue could be provided by more detailed assessment of how CSEs are used and perceived, and where they could make valuable contributions to investigations.

The effective use of forensic science in the investigation of crimes "*relies on the knowledge systems and communication processes*" used by different investigative personnel [23]. Improving the mutual understanding, focusing on integration and strengthening forensic science training can prove a challenge as it involves

modifications to varying procedures (management, implementation, communication, etc.) [23, 383]. The recurring nature of the issues affecting the use of forensic science has been demonstrated, and the inherent complexity of the investigations and the use of forensic science highlighted. The investigation of a crime is a series of interdependent procedures, where good communication and closer relationships between all investigative personnel (and agencies) can be considered useful for improving the effectiveness of the investigation [23, 225].

Often the investigation of crimes require the interpretation of evidence [384] and the necessary information source required in order to meet investigative needs must be available [41, 368]. Previous work has been critical of the effectiveness of communication between personnel involved in the investigative process, where the fundamental issue has been suggested to be the lack of approachability between individuals in different agencies (i.e. between police officers and forensic scientists) [14, 23, 40].

Knowledge of how the forensic investigation and the police investigation interlink during the investigation of a crime means that the tripartite of agencies involved in the investigative process who are not natural partners can work together in a more cohesive and effectively manner [14, 76, 244]. Relationships between police forces, forensic service providers and legal representatives could be improved, and previous literature has shown that this extends to government policymakers, as well as academic departments [6, 383, 385]. Better communication across boundaries – organisational, cultural, geographical, jurisdictional, etc. – could allow "*all parties to arrive at a common understanding as the foundation for integrated decision-making and unified action*" and work together more collaboratively [376].

Closer relationships between a number of interconnected stages of an inherently complex system is not easy, however better communication can determine a number of benefits [27, 185]. Better communication can promote the exchange of information (or intelligence); provide accessible and reliable advice and information sources; and improve knowledge of systems, practices and techniques. However, that

articulating knowledge in one part of an organisation often does not translate easily (if at all) to other areas of the same organisation or to another was previously found [167, 204, 386, 387]. Better relationships can encourage communication and knowledge sharing which is not confined to an individual organisation (e.g. police force, SPSA, etc.) [172].

The use of forensic science in the investigation of major crimes (e.g. homicides) was shown to be much better resourced, informed and managed compared to the investigation of volume crimes which received a fraction of the services availability to major crime investigation [14, 242, 388]. The NAS [6] report stated that the investigation of all crimes requires the "*establishment of good working relationships*", effective communication and information transfer, as well as "*sufficient resources and qualified personnel*" to carry out the work. Variations in resources availability may be one explanation for the differences in the rates of crime detection between volume and major crimes; however the maximum impact the contribution forensic science (and evidence) could have on both crimes is potentially very similar [43, 238, 389]. Therefore, the comprehensive application of forensic resources is connected to the accurate understanding of investigative needs and the deployment of staff able to competently achieve required objectives [23].

Factors which are acting as "*barriers to the widespread standardisation of forensic science knowledge and practice*" have been shown to be complex and interlinked [284]. To address many of these issues it is important that the members of the investigative community are aware of many of these themes also, and that it is not just continually reiterated by academics and other individuals not directly involved in the profession. Continuing to suggest recommendations for single issues only or improvements which are not easily implemented and require time to become effective, will not necessarily lead to improvements. Closer collaboration between practitioners and researchers could provide easier access to the necessary data required to carry out systematic, rigorous research. Gaining direct input and opinions from practitioners could also benefit the design of a study in order for it to be

implemented most effectively as specific barriers (e.g. technological, resource, managerial) could be addressed prior to commencement of the research [291].

"*Forensic science researchers, providers and users should all pay particular attention to appropriate communication*[...], *especially in view of the multifaceted nature of research and development in forensic science*" [291]. Current knowledge has been obtained (and shared) via reviews, reports and audits, rather than systematic or empirical research. Although useful in identifying some of the problems in the process, they are limited in their applicability for thorough analysis. Systematic, scientific research is needed to obtain a more detailed analysis of the current situation in order to recommend improvements which will benefit the investigation. The use of forensic science in the investigation of crimes will continue over time [14, 390], therefore improvements to the effectiveness and efficiency must also occur.

5.1. Conclusions

The review of the literature from other jurisdictions has identified a number of interlinked factors which reduce the effective use of forensic science. The data from the survey has shown that these factors were also found in Scotland. The results of this research suggest that forensic science is also being used in a sub-optimal manner in Scotland in the investigation of volume crimes.

The data shows that participants who had received training had been exposed relatively equally to various types of training. There was no significant difference between the types of training received between different investigative staff. Respondents had received a variety of training types, learning via a combination formal training, practical experience, trial and error, or a system of work shadowing and mentoring. The data that were available suggests that police officers received very limited forensic science training, many surveyed received less than one day's worth.

There was no correlation between the years of service within the current role and the amount of training that had been received. Regular refresher training or continued development for experienced staff did not appear to be encouraged. Irrespective of the variation in training, individuals did appear to have some awareness of the utility of specific forensic evidence types in the investigation. Training did not appear to have a great influence on evidence perceptions in terms of their value or strength between different roles. General forensic awareness continues to be problematic.

The perceptions of evidence by different roles (scientists, CSEs, police officers, etc.) of forensic evidence types did not greatly vary. The limited difference in the perception of evidence between the roles surveyed as part of this research suggested that DNA and fingerprint evidence were equally perceived by police officers and by SPSA FS personnel. It appears that roles, training, knowledge and culture do not necessarily affect the perceptions of evidence. Survey respondents did appear to have an understanding of the sources of potential evidence, the utility of forensic material, as well as the potential sources of intelligence to providing links and furthering investigations. Generally, DNA and fingerprint evidence were perceived highly, footwear marks and toolmarks less so, and glass evidence the lowest of these.

This research has confirmed findings previously published in England and Wales, that the communication within and between investigative personnel (police, CSEs and scientists) in Scotland is limited. The data found that respondents were most likely to turn to colleagues for advice rather than the most appropriate or knowledgeable source. Sources of tacit knowledge or expertise were not being used effectively when advice was sought regarding specific scenarios. Although respondents indicated that the availability of expert advice and well trained SIOs was important for the effectiveness of an investigation; actually using these advice sources regularly was shown to be limited. This indicates differences between espoused and actual practice; what people say and what they actually do. The use of the Gateway was shown to be limited, or used differently in some locations. The availability of guidance and expertise is not being utilised effectively.

The place of work was significantly important in making decisions about scene attendance, evidence recovery and laboratory submission. This data indicated that most individuals were involved at the stages they should be and to the degree that would be expected in accordance with the understanding of their roles and responsibilities.

The understanding of the role and the perception of the responsibilities of crime scene examiners was shown to be simplistic and limiting. The role of CSEs is poorly understood and the perception of their duties restricted to the collection of evidence only. Most importantly to come from these findings are that CSEs also perceive their own roles as 'evidence collector' only. This fails to recognise other significant elements of the role and limits potential contributions to other aspects of the investigation.

Knowledge of tasking policies for volume crime scenes was shown to be poor; 55% of respondents were unaware or did not know of what tasking policies existed for volume crimes. Confirmation regarding the existence of such tasking policies could not be obtained from SPSA FS. This suggests that tasking policies did not exist or were not regularly used as a means of managing resources.

The complex interconnected nature of investigations and the varying number of processes which are utilised throughout makes it difficult to carry out systematic research. Forensic evidence is frequently collected and analysed for a wide range of crimes, however the effects this has on the overall outcome of an investigation remains unknown. Failure to recognise the interconnected nature of investigations has meant that previous recommendations have had limited impact in facilitating change. Many of themes first identified 40 years ago remain problematic.

As part of this project, a number of process flowcharts of the investigation and prosecution were produced. The analysis of stages of the criminal justice system using flowcharts as an analytical tool identified measurable indicators to aid in the evaluation of the efficiency and effectiveness of the system. Figures 25-28 illustrate

the investigation of a crime scene where DNA and fingerprint evidence are involved. These process flowcharts are a general illustration of an investigation and are modelled on crimes of theft by housebreaking offences. However, to understand the role of forensic science in an investigation two scenarios of the offence were considered – whether the offender was apprehended at the scene or not. These four process flowcharts present two routes which the investigation could follow, and identify the key stages where effectiveness could be evaluated. This would provide indicators which could be used to judge the utility of forensic evidence.

The process flowcharts were used as an analytical tool, from which a number of stages could be identified that could be potentially measured and might aid in the evaluation of the efficiency and effectiveness of the system [391]. Accurate mapping of the use of forensic science requires the consideration of a number of different case scenarios. Figure 25 illustrates an example where the offender was apprehended at the crime scene, and identifies a series of confirmatory steps which are needed in order to establish identity and to recover evidence that may either eliminate an individual from an enquiry or link a suspect to a scene.

Figures 26 and 27 illustrate a more complex scenario when the offender is not apprehended at the scene, and the offender is unknown. Figure 26 focuses on the stages involved when analysing DNA evidence and Figure 27 illustrates the cases involving fingerprint evidence. They identify the series of sequential steps that must occur in Scotland to analyse and utilise this type of evidence. They cover aspects such as the use of databases (DNA database and IDENT1 fingerprint database), access to the criminal history system[17] (CHS), search for outstanding warrants, and so on.

[17] This is an interactive criminal records database which provides operational police officers with essential information relating to an individual (e.g. names, date of birth, known addresses, etc.).

Figure 25: Process flowchart of a volume crime involving fingerprint or DNA evidence, where the offender is known (i.e. apprehended at the scene)

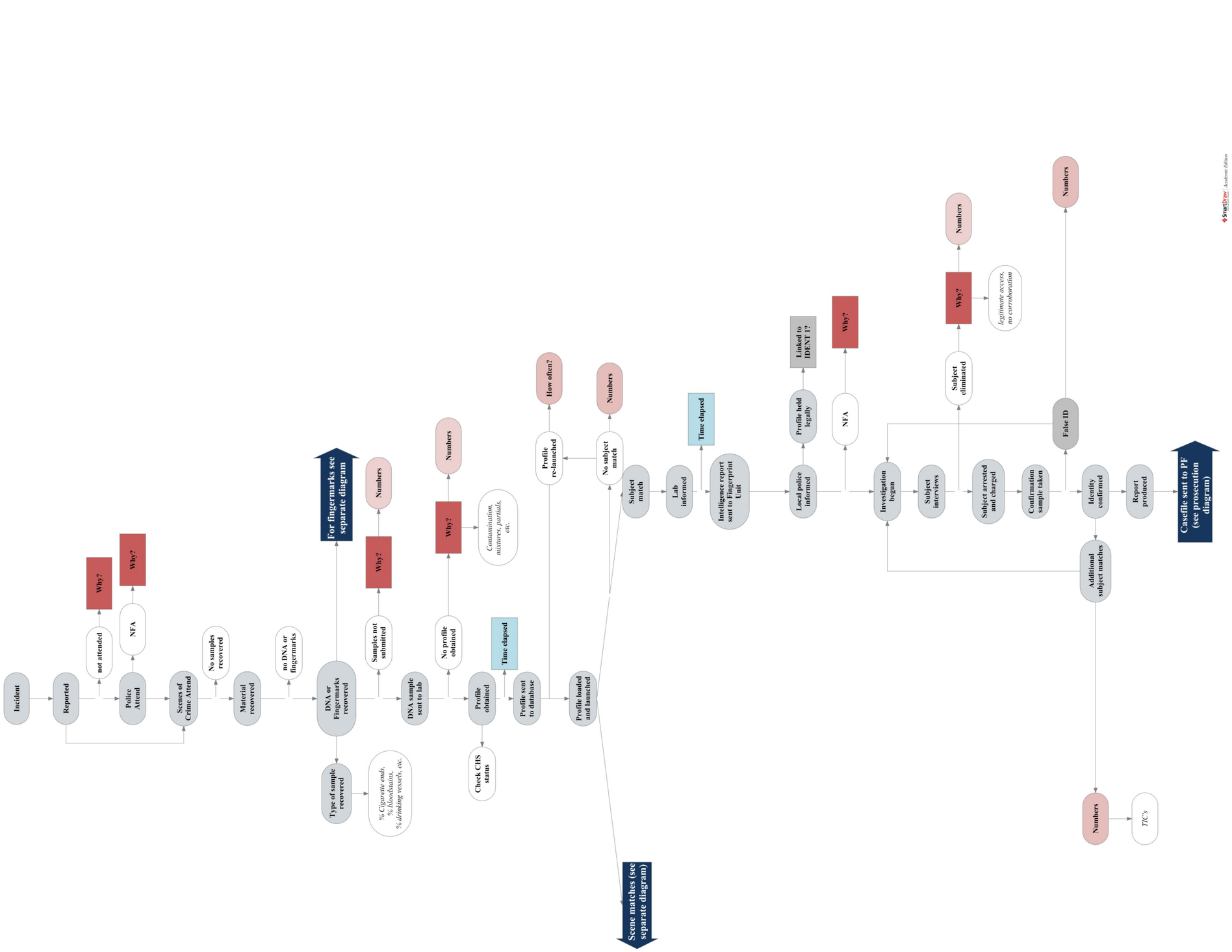


Figure 26: Process flowchart of a volume crime where the offender is not known and where DNA evidence was recovered from the scene.

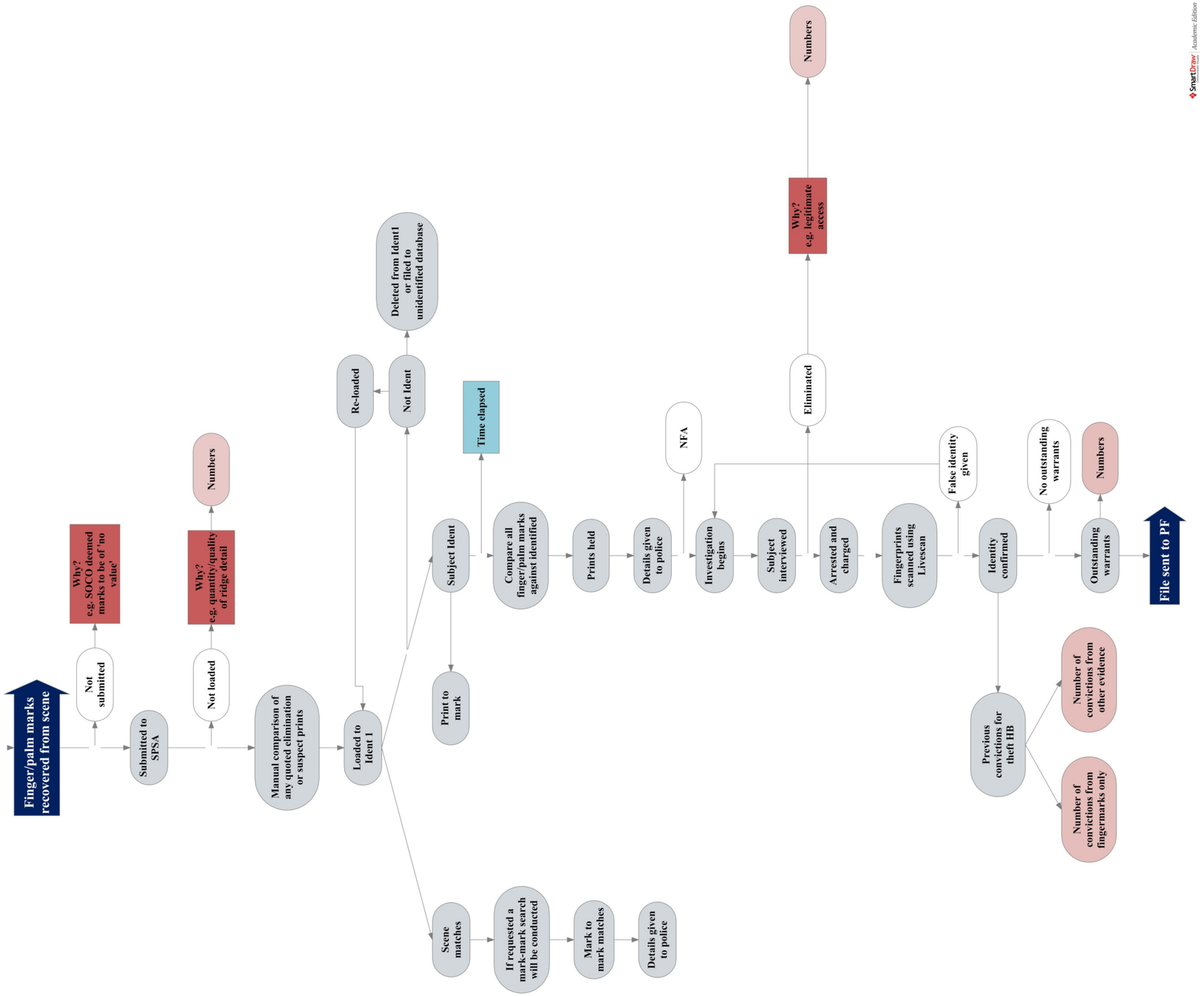


Figure 27: Process flowchart of a volume crime where the offender is not known and where fingerprint evidence was recovered from the scene.

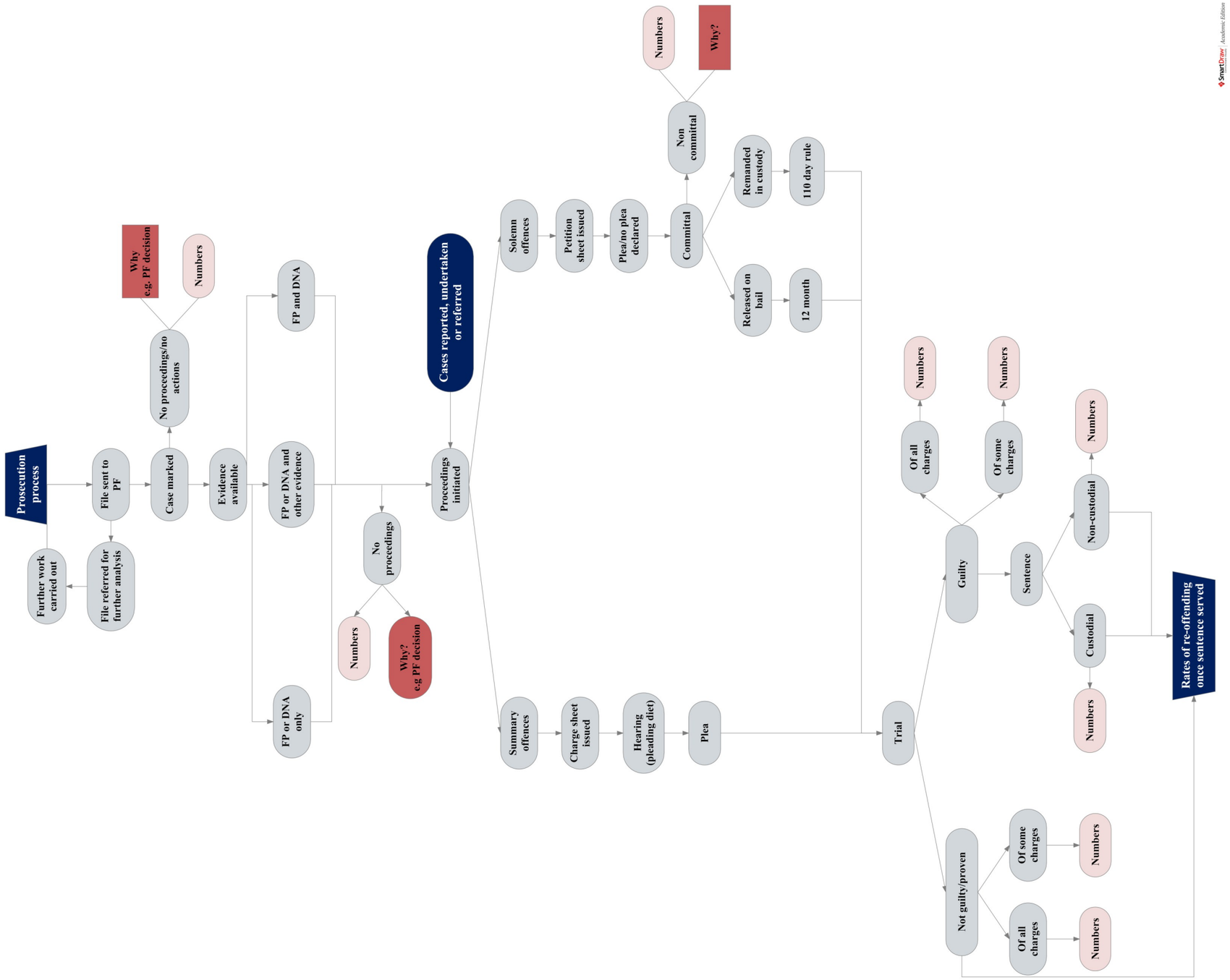


Figure 28: Process flowchart of the prosecution stage of a volume crime incident involving forensic evidence.

Figure 28 is an extension of all three of the previous process flowcharts and highlights stages of the prosecution. It illustrates a number of different activities which occur, including case marking, the pleading diet, charging diet and convictions. It also recognised the importance of previous offences and repeat offenders, issues often discussed as part of crime analysis and crime reduction [74].

Within each of the four process flowcharts a number of stages have been identified (highlighted in pink and pale blue boxes) which would allow further research to evaluate the effectiveness of the investigation as well as to calculate the rates of attrition associated with certain evidence types in the investigation of crimes. The complexity of many of the processes, activities and agencies involved in the investigation meant that a number of difficulties were identified which could affect the input of information and data into the flowcharts.

Firstly, the management systems used to record information electronically in each of the different investigative agencies involved in the inquiry (i.e. the police forces, the Scottish forensic service providers and the prosecuting agencies), were substantially different (and often worked independently). The lack of a standardised information management system has been discussed since early reviews of forensic science [96]. A national system, with the potential to be interfaced with all criminal justice organisations to provide a comprehensive information and intelligence source has been discussed in England and Wales [16, 96, 392]. However, the differences in systems currently in place meant that data collection was difficult and time consuming.

Further complexities arose when several different types of evidence were identified in a case. The outcome of a the prosecution (e.g. conviction, acquittal) cannot be solely attributed to any single type of evidence as a number of other factors (e.g. confession) may have had a greater effect on producing the particular case outcome (which could not necessarily be identified or excluded). However, calculating the number of cases which proceed to court which contain forensic evidence (e.g. DNA and fingerprints) compared to cases which do not may provide some information as

to the value of collecting certain evidence types for the aiding the progression of cases through the system [42, 54].

The flowcharts show that the organisations involved in investigations (and prosecutions) use a series of interdependent procedures (and sequential processes) which must work together collectively in order to achieve the overall goal [26-29]. The investigation of a crime is a "*series of embodied practices*" which requires the interaction of a number of different individuals and organisations and that forensic science is only a small, but important part of the whole system [242]. Forensic science (and its application) is affected by the extensive and complex involvement of the various individuals and organisations involved in the criminal justice system (CJS) [284]. The flowcharts developed can be used in the future to help calculate the rates of attrition associated with certain evidence types in the investigation of crimes. Identifying the evidence types which add the most value towards investigative outcomes has previously been discussed but remains unresolved

The need to improve the collection and publication of performance data from each party involved in the system which identifies the use, performance and competence of their staff as well as their understanding of forensic science in criminal investigations was identified. Often scientific research is focused on technical developments and validity testing which remain important to the advancement of science, however there is a need to research the fundamental issues which have been shown to hinder the investigative process. However, further research requires the investment of resources (time, personnel, money, etc.) in order to tackle these issues. The effects of the current economic climate are already evident, with a number of agency closures, resource restrictions and limited research funding [59, 163, 234, 291].

Nonetheless, the importance of forensic science will undoubtedly continue to increase further in the future, with greater emphasis on improving the effectiveness of the criminal justice system. However, many of the weaknesses first identified by studies in the early 1980s remain important and continue to affect the role of forensic

science. The dynamic and complex nature of investigations makes it difficult to build a shared understanding of the potential value of forensic science. This research has provided a glimpse of the "*small parts of a continuously evolving picture*" which is the use of forensic science and the investigation of crimes [393]. Future research will most likely need to take into consideration individual, agency, national and international needs in order to continue to improve the understandings of the uses of forensic science and to improve the efficiency of investigations. Research will need to continue to take into consideration the dynamic nature of crime investigation and the continued advances in forensic technologies.

This research has demonstrated that there are a range of factors which have been identified as important to the effective use of forensic science. The failure to recognise the prevalence and importance of these issue could potentially continue to result in lost opportunities reducing the effectiveness and efficiency of forensic science and investigations.

5.2. Further work

By carrying out a review of the previous literature and providing some insight into the attitudes in Scotland in relation to previously identified themes, a large amount of potential further work has been identified. However, the limitations of time, resources and funding for the current study means that these must be explored in follow-up research projects in the future which fall under a number of categories.

5.2.1. Further surveys

Although the survey focused solely on attitudes about how forensic science is used by personnel working in the Scottish criminal justice sectors in relation to volume

crime incidents; parallels to major crime investigations should not be ignored [79]. Similar surveys could be carried out for other crime types – crimes against the person, major crimes, etc. – in order to establish whether there are any differences for other crimes. For example, the value of toolmark and footwear mark evidence may be perceived differently for other crime or offence types than it was for volume crimes.

Replication of this work could also be carried out in other jurisdictions (e.g. England & Wales, Ireland, USA). Similar assessment of attitudes could potentially be carried out worldwide via online questionnaires to determine whether perceptions of crime scene examiners, of the utility of forensic evidence types, or the sources of advice differ in Europe and further afield. This would highlight whether any jurisdictional (and legal) differences affected the attitudes towards forensic science, investigative personnel or forensic evidence types. Some work was recently carried out on the perceptions of fingerprint evidence, which showed great variation in opinions from different jurisdictions [394].

5.2.2. Longitudinal study

As previously identified, a number of restrictions were encountered during the case analysis part of this research which aimed to carry out a longitudinal study. Future work should try to finish this to determine the outcomes of tracking a given number of cases through the system for the investigation of volume crimes. Further research could be expanded to include other crime types (e.g. major crime) as well as other jurisdictions and other evidence types. Where possible, baseline data should be used to compare cases containing forensic evidence to cases which were solved using traditional policing methods. This would allow some evaluation to be made of the benefits of forensic evidence in specific cases.

Systematic review of specific crime types using process flowcharts could provide a better understanding of the value of evidence towards achieving investigative outcomes**.** Flowcharts of different stages of the investigation could provide valuable information relating to obtaining a detailed understanding of some of the difficulties faced in data collection; the further potential of this work must be explored in the future.

5.2.3. Other

The survey data utilised for this study was limited to the scope in which the questions were posed; therefore further, more in-depth analysis such as focus groups or structured interviews and inferences would be necessary to identify, address or begin to understand some of the underlying perceptions of the issues that were found.

Value of evidence

Further analysis into the perceptions of evidence between different investigative roles could be used to further identify the utility of forensic science in an investigation. A series of questions with case scenarios containing different evidence types could test whether respondents maintained their perceptions of evidence or whether it was case/scenario dependent. This could further distinguish if training had any effects.

Current methods in place which evaluate forensic evidence in relation to determining its prioritisation upon submission requires further analysis. The collation of empirical data which has tracked forensic evidence for a number of different crimes could help to determine guidelines to aid in establishing the forensic evidence which could provide the most useful information.

This could then be used to improve the understanding of the value of evidence and means that CSEs examiners may be able to make educated decisions on the collection of specific evidence types. With increasing demand on resources and continued restriction of budgets, developing a model (e.g. rules and discretion) which identifies the most useful evidence could affect resource allocation or distribution as well as decision making. In the absence of a clear understanding of value of specific evidence types, decisions are focused on the availability of technology rather than the contribution the evidence may make to the investigation.

The collection of data from police relating to the prevalence of evidence types collected from crime scenes, as well as data from laboratories which identify the evidence types which provide the best value compared with evidence that are less valuable is needed in order to determine whether the two are in agreement. More detailed analysis into the benefits of footwear mark and toolmark evidence could be used to encourage their use and increase their rates of collection.

Current data has demonstrated that timeliness of forensic analysis is less slow, and further in-depth research can ascertain where the delays occur. Calculating timeliness is various aspect of the investigation can be a useful indicator of performance but can also highlight areas of resource shortages, ineffective practices or bottlenecks. Similar method as established by SWIM to assess the performance in Scotland can be considered.

Training

Further analysis into training is required to explain the lack of variation in knowledge of evidence between training and non-trained individuals. There is a need to establish whether training currently received does focus on the value of evidence types. Or whether current policies regarding the collection of this evidence are limited or

focused on other evidence types. Or whether any other possible reasons currently not considered explain this variation.

Detailed analysis of training to determine what training has actually been received – how much, what kind, etc. before analysis of the effects this has on forensic knowledge and specifically on evidence perceptions. Analysis into how the perceptions and awareness of the value of these evidence types could be increased amongst different investigative roles (e.g. through changed training programmes, more publications, better knowledge transfer opportunities).

Cost-benefit analysis

Insight into cost benefit analysis (in terms of type of evidence which produces beneficial case outcome) could be provided by detailed assessment of the utility of forensic evidence by identifying the most effective and efficient means of utilisation. Studies similar to Roman *et al*. [99] and the Pathfinder Project [57] could help to evaluate the various costs of forensic analysis of evidence considering resource requirements and laboratory equipment costs. Better understanding of budget and cost-benefit analysis could provide evidence to establishing whether forensic evidence and forensic service provisions are aiding the effectiveness of the investigation of specific crimes. Linked to studies which consider the value of forensic evidence in the CJS, a more comprehensive understanding of the cost of forensic science could be achieved.

CSEs – roles and role perceptions

The differences in role expectations for different crime types requires further exploring. This could help to determine what subsequent effects this has on the role perceptions of CSEs.

The complexity of the role of CSEs in terms of the expectations of their tasks and responsibilities in the investigation of crimes requires further analysis to determine how they are currently being used by forces. Further evaluation could establish whether improved perceptions of CSEs could be the key to improving the integration between forensic service providers and police forces.

Detailed analysis how CSEs actually carry out scene investigations is required. Establishing what skills they use during scene investigation could determine actions to improve effectiveness.

References

1. Harrison, K., *Is Crime Scene Examination science, and does it matter anyway?* Science & Justice, 2006. **46**(2): p. 65-68.

2. Smith, M.J. and Tilley, N., eds. *Crime Science: New approaches to preventing and detecting crime*. 2005, Willan Publishing.

3. Jamieson, A., *A rational approach to the principles and practice of crime scene investigation: I. Principles.* Science & Justice, 2004. **44**(1): p. 3-7.

4. Hulme, J. and Twiss, A., *Scene it - done it. New technologies and approaches used at scenes.* Science & Justice, 2004. **44**(3): p. 187-193.

5. Bradbury, S.-A. and Feist, A., *The Use of Forensic Science In Volume Crime Investigations: A Review of the Research Literature.* Home Office Online Report, 2005. **43**: p. 86.

6. National Academy of Sciences, *Strengthening Forensic Science in the United States: A Path Forward*. 2009, The National Academies.

7. Inman, K. and Rudin, N., *The origin of evidence.* Forensic Science International, 2002. **126**(1): p. 11-16.

8. Horvath, F. and Meesig, R., *The Criminal Investigation Process and the Role of Forensic Evidence: A Review of Empirical Findings.* Journal of Forensic Sciences, 1996. **41**(6): p. 7.

9. Burrows, J. and Tarling, R., *Measuring the impact of forensic science in detecting burglary and autocrime offences.* Science & Justice, 2004. **44**(4): p. 217-222.

10. Kaye, D.H., *Identification, individualization and uniqueness: what's the difference?* Law, Probability and Risk, 2009. **8**(2): p. 85-94.

11. Fraser, J. and Ludwig, A., *Chapter 14: Forensic Science and Policing in Scotland*, in *Policing Scotland*, Donnelly, D. and Scott, K., Editors. 2010, Willan.

12. McCulloch, H., *Police use of forensic science.* Police Research Group: Police Research Series, 1996. **Paper 19**: p. 50.

13. Fraser, J. and Williams, R., *Handbook of Forensic Science*. 2009, Cullompton: Willan.

14. Tilley, N. and Ford, A., *Forensic Science and Crime Investigation.* Police Research Group: Crime Detection & Prevention Series, 1996. **Paper 73**: p. 66.

15. Williams, R., *The management of crime scene examination in relation to the investigation of burglary and vehicle crime.* Home Office Online Report, 2004. **24**: p. 58.

16. Ramsay, M., *The Effectiveness of the Forensic Science Service, Home Office Research Study 92*. 1987, HMSO: London.

17. Saulsbury, W., Hibberd, M., and Irving, B.L., *Using Physical Evidence: A Report of the Forensic Science Service and the Association of Chief Police Officers Joint Research Project*, Foundation, T.P., Editor. 1994.

18. Touche Ross Management Consultants, *Review of Scientific Support for the Police - Volume 3 (Scientfic Support in Police Forces and Common Issues)*. 1987, Home Office: London.

19. House of Commons Select Committee on Science & Technology, *Forensic Science On Trial*. 2005, HMSO: London.

20. Audit Commission, *Helping With Enquiries: Tackling Crime Effectively*. 1993, HMSO: London.

21. Roberts, P. and Willmore, C., *The Role of Forensic Science Evidence in Criminal Proceedings.*, in *Royal Commission on Criminal Justice Study 11*. 1993, HMSO: London.

22. Mennell, J., *The Future of Forensic and Crime Scene Science: Part II. A UK perspective on forensic science education.* Forensic Science International, 2006. **157**(Supplement 1): p. S13-S20.

23. Association of Chief Police Officers and Forensic Science Service, *Using Forensic Science Effectively*. 1996.

24. *Personal communication with SPSA FS*. 2010: Glasgow.

25. Taylor, F.W., *The principles of scientific managment*. 2nd ed. 1967, New York: Norton.

26. Senge, P.M., *The Fifth Discipline: The art and practice of the learning organization*. 2nd ed. 2006: Random House Business.

27. Johnson, R.A., Kast, F.E., and Rosenzweig, J.E., *Systems Theory and Management.* Management Science, 1964. **10**(2): p. 367-384.

28. Hoyle, D. *Systems and Processes - Is there a difference? (published for the Chartered Quality Institute)*. 2009 [cited 2011 July]; Available from: http://www.thecqi.org/Documents/community/South%20Western/Wessex%20Branch/Systems%20and%20Processes%20article%20by%20David%20Hoyle%20Oct09%20%282%29.pdf.

29. Bertalanffy, L.v., *General system theory: foundations, development, applications*. 1973: Braziller Inc.

30. Jenkins, G.M. and Youle, P.V., *A Systems Approach to Management.* Operational Research - Special Conference Issue, 1968. **19**: p. 5-21.

31. Cole, G.A., *Management Theory and Practice*. 6th ed. 2004, London: Thomson Learning.

32. McCann, J.E. and Ferry, L.D., *An approach for assessing and managing inter-unit interdependence.* Academy of Management Review, 1979. **4**(1): p. 113-119.

33. Bendoly, E., Bachrach, D.G., and Powell, B., *The Role of Operational Interdependence and Supervisory Experience on Management Assessments of Resource Planning Systems.* Production and Operations Management, 2008. **17**(1): p. 93-106.

34. Juran, J.M., *Juran on Quality By Design: The New steps for Planning Quality into Goods and Services*. 1992, New York: Maxwell Macmillan International

35. Davenport, T.H., *Process Innovation: Reengineering work through Information Technology*. 1993: Harvard Business School Press.

36. Kuykendall, J., *The criminal investigative process: Toward a conceptual framework.* Journal of Criminal Justice, 1982. **10**(2): p. 131-145.

37. Scientific Work Improvement Model, *Summary Report of the Scientific Improvement (SWIM) Package*, Office, H., Editor. 2007.

38. Jacobson, J., Maitland, L., and Hough, M., *The Reducing Burglary Initiative: investigating burglary*. 2003, Home Office Research Study 264.

39. Ribaux, O., Baylon, A., Roux, C., Delemont, O., Lock, E., Zingg, C., and Margot, P., *Intelligence-led crime scene processing. Part I: Forensic intelligence.* Forensic Science International, 2010. **195**: p. 10-16.

40. HMIC and Blakey, D., *Under The Microscope - Thematic Inspection Report on Scientific and Technical Support*, in *Her Majesty's Inspectorate of Constabulary (HMIC)*. 2000.

41. Jansson, K., *Volume crime investigations: a review of the research literature*, in *Home Office Online Report*, Office, H., Editor. 2005.

42. Burrows, J., Hopkins, M., Hubbard, R., Robinson, A., Speed, M., and Tilley, N., *Understanding the attrition process in volume crime investigations*, 295, H.O.R.S., Editor. 2005, Home Office Research, Development and Statistics Directorate.

43. Association of Chief Police Officers, *ACPO Investigation of Volume Crime Manual*, in *Association of Chief Police Officers of England, Wales and Northern Ireland*. 2002.

44. The Scottish Government, *Partners in Crime: Solving and Reassuring - A Thematic Inspection of Crime Management in Scotland*. 2003, Scottish Executive: Edinburgh.

45. Peterson, J., Sommers, I., Baskin, D., and Johnson, D., *The Role and Impact of Forensic Evidence in the Criminal Justice Process*, Justice, U.S.D.o., Editor. 2010, National Institute of Justice: Los Angeles.

46. Drucker, P.F., *The Effective Executive: The Definitive Guide to Getting the Right Things Done*. 2007, Oxford: Elsevier Ltd. .

47. Frazer, M., *Quality in Higher Education: An International Perspective*, in *What is Quality in Higher Education*, Green, D., Editor. 1994, Open University Press and Society for Research into Higher Education: Buckingham.

48. Vlăsceanu, L., Grünberg, L., and Pârlea, D., *Quality Assurance and Accreditation: A Glossary of Basic Terms and Definitions*, in *Papers on Higher Education*. 2007, UNESCO: Bucharest.

49. Wojtczak, A., *Glossary of Medical Educational Terms.* Medical Teacher, 2002. **24**.

50. Jamieson, A. and Arson Prevention Bureau, *Fire Investigation in Scotland*, in *An Arson Prevention Bureau publication by the Association of British Insurers*. 2004, The Forensic Institute.

51. Hales, C.P., *What Do Managers Do? A Critical Revew of the Evidence.* Journal of Management Studies, 1986. **23**(1): p. 88-115.

52. Trinder, L. and Reynolds, S., eds. *Evidence-Based Practice: A Critical Appraisal*. 2000, Blackwell Science Ltd. : Oxford.

53. Webb, B., Smith, C., Brock, A., and Townsley, M., *DNA fast tracking*, in *Crime Science: New approaches to detecting and preventing crime*, Smith, M.J. and Tilley, N., Editors. 2005, Willan: London. p. 197-190.

54. Tilley, N. and Burrows, J., *An Overview of Attrition Patterns* Home Office, Editor. 2005, Home Office Online Report 45.

55. Bond, J.W., *Maximising the opportunities to detect domestic burglary with DNA and fingerprints.* International Journal of Police Science & Management, 2006. **9**(9): p. 12.

56. Newburn, T., Williamson, T., and Wright, A., *Handbook of Criminal Investigation*. First ed, ed. Tim Newburn, T.W.a.A.W. 2007: Willan Publishing Ltd.

57. Burrows, J., Tarling, R., Mackie, A., Poole, H., and Hodgeson, B., *Forensic Science Pathfinder Project: evaluating increased forensic activity in two English police forces*, in *RDS Online Report 46/05*. 2005, Home Office: London.

58. Fraser, J., *SIPR Project Proposal*. 2007.

59. House of Commons Science and Technology Committee, *The Forensic Science Service - Seventh Report of Session 2010–12*. 2011, The Stationery Office Limited: London.

60. Home Office, *Review of the Forensic Science Service: Executive Summary*. 2003.

61. Home Office and McFarland, R., *Review of Forensic Science Service*. 2002, Home Office.

62. Home Office. *Forensic Science Regulator*. 2009 [cited 2010 January]; Available from: http://police.homeoffice.gov.uk/operational-policing/forensic-science-regulator/.

63. Crown Office and Procurator Fiscal Service. *Crown Office and Procurator Fiscal Service (COPFS)*. 2009 [cited 2009 June]; Available from: http://www.copfs.gov.uk/.

64. Scottish Police Services Authority. *Scottish Police Services Authority*. 2009 [cited 2009 June]; Available from: http://www.spsa.police.uk.

65. Scottish Police Services Authority Forensic Science. *About Us*. 2007 [cited 2011 March]; Available from: http://www.spsa-forensics.police.uk/about.

66. BBC News, *One-stop forensic service set up*, in *BBC News*. 2007.

67. Sweeney, C., *Behind the story: SPSA - a short but much troubled life*, in *The Sunday Times*. 2010.

68. Adams, L., *Policing 'crippled' by delays and errors*, in *The Herald*. 2010.

69. Scottish Policing Board. *Scottish Policing Board Minutes - 27 January 2010, 10:00 – 12:00pm*. 2010 [cited 2011 June]; Available from: http://www.scotland.gov.uk/Resource/Doc/254432/0098151.pdf.

70. Association of Chief Police Officers Scotland (ACPOS) and Scottish Police Services Authority (SPSA), *National Forensic Protocol: Accessing Forensic Science Services in Scotland*. 2008.

71. Scottish Police Serivces Authority Forensic Services, *Delivering Forensic Services to North and North-East Scotland: Addressing the Key Questions*. 2009.

72. Soanes, C. and Stevenson, A., eds. *Oxford Dictionary of English* 2005, OUP Oxford.

73. Association of Chief Police Officers Scotland, *Scottish Crime Recording Standard*. 2007.

74. Scottish Government. *Scottish Government*. 2010 [cited 2010 March]; Available from: http://www.scotland.gov.uk/Home.

75. Scottish Government, MacLeod, P., Page, L., Kinver, A., and Iliasov, A., *Scottish Crime & Justice Survey: First Findings 2008-2009*. 2009, Scottish Government Social Research, National Statistics.

76. Gill, M., Hart, J., Livingstone, K., and Stevens, J., *The Crime Allocation System: Police Investigations into Burglary and Auto Crime*, Office, H., Editor. 1996.

77. Stellfox, P. *The need for investigative strategy and the UK Murder Manual*. in *Skills & Good Practice In Crime Scene Investigation*. 2006. Krakow.

78. Connelly, C., *Law Basics: Student Study Guides - Criminal Law*. 2nd ed. 2002: W. Green & Son Ltd.

79. Nicol, C., Innes, M., Gee, D., and Feist, A., *Reviewing murder investigations: an analysis of progress reviews from six police forces*, in *Home Office Online Report*, Office, H., Editor. 2004.

80. National Crime Faculty and Committee, A.C., *Murder Investigation Manual*, Programme, N.S.D., Editor. 2000.

81. Tilley, N. and Townsley, M., *Forensic science in UK policing: strategies, tactics and effectiveness*, in *Handbook of Forensic Science*, Fraser, J. and Williams, R., Editors. 2009, Willan: Cullompton. p. 359-379.

82. Adderley, R. and Bond, J.W., *The Effects of Deprivation on the Time Spent Examining Crime Scenes and the Recovery of DNA and Fingerprints.* Journal of Forensic Sciences, 2008. **53**(1): p. 178-182.

83. Scottish Government, *Statistical Bulletin: Criminal proceedings in Scotland 2009-10*. 2011, A National Statistics Publication for Scotland.

84. Scottish Government, *Statistical Bulletin*, in *Criminal Justice Series*. 2007, A National Statistics Publication for Scotland.

85. Hale, C., *Fear of crime: A review of the literature.* International Review of Victimology, 1995. **42**(2): p. 79-150.

86. Ferraro, K.F. and Grange, R.L., *The Measurement of Fear of Crime.* Sociological Inquiry, 1987. **57**(1): p. 70-97.

87. Coupe, T. and Griffiths, M., *Solving Residential Burglaries*. 1996, Crime Detection and Prevention Series - Paper 77.

88. Tseloni, A. and Zarafonitou, C., *Fear of Crime and Victimization: A Multivariate Multilevel Analysis of Competing Measurements.* European Journal of Criminology, 2008. **5**(4): p. 387-409.

89. Levi, M. and Maguire, M., *Reducing and preventing organised crime: An evidence-based critique.* Crime, Law & Social Change, 2004. **41**: p. 397-469.

90. Maguire, M., *Criminal Investigation and Crime Control*, in *Handbook of Policing*, Newburn, T., Editor. 2003, Willan: Cullompton. p. 363-394.

91. Langan, P.A. and Levin, D.J., *Recidivism of Prisoners Released in 1994.* Bureau of Justice Statistics, 2002.

92. Nagin, D.S., *Criminal Deterrence Research at the Outset of the Twenty-First Century.* Crime and Justice, 1998. **12**: p. 1-42.

93. Fraser, J.G., *Acquisition and retention of DNA and Fingerprint Data in Scotland*, Government, T.S., Editor. 2008.

94. Amey, P., Hale, C., and Uglo, S., *Development and evaluation of a crime management model*, 18, P.R.S.-P., Editor. 1996.

95. Her Majesty's Inspectorate of Constabulary, *Study of the investigation of offences of burglary in dwellings*, in *Her Majesty's Inspectorate of Constabulary (HMIC)*. 1991.

96. Byford, L., *The Yorkshire Ripper Case - Review of the Investigation of the Case*. 1981, Home Office.

97. Burrows, J., *Burglary: Police Action and Victims' Views*. 1986, Home Office Research and Planning Unit Paper 37.

98. Briody, M., *The Effects of DNA Evidence on the Criminal Justice Process*, in *School of Sociology and Criminal Justice*. 2004, Griffith University: Brisbane. p. 175.

99. Roman, J.K., Reid, S., Reid, J., Chalfin, A., Adams, W., and Knight, C., *The DNA Field Experiment: Cost-Effectiveness Analysis of the Use of DNA in the Investigation of High-Volume Crimes*, in *U.S. Department of Justice*. 2008, Urban Institute Justice Policy Centre. p. 158.

100. Higgins, J.P.T. and Green, S., eds. *Cochrane Handbook for Systematic Reviews of Interventions*. 2008, Wiley-Blackwell.

101. Burrows, J. and Tarling, R., *Clearing Up Crime*, 73, H.O.R.-S., Editor. 1982, Home Office.

102. Stockdale, J.E. and Gresham, P.J., *Combating Burglary: An Evaluation of Three Strategies.* Police Research Group - Crime Detection and Prevention Series Paper 59, 1995.

103. Robson, C., *Interviews*, in *Real World Research*. 2002, Blackwel Publishing: Oxford.

104. Krueger, R.A. and Casey, M.A., *Focus Groups: A Practical Guide for Applied Research*. 2009, London: Sage Publications Inc.

105. Bryman, A. and Bell, E., *Business Research Methods*. 2nd ed. 2007, Oxford: Oxford University Pub. .

106. Babbie, E., *The basics of social research*. 4th ed. 2007, Canada: Thomson Wadsworth.

107. Bryman, A., *Social Research Methods.* Vol. 2. 2004, Oxford: Oxford University Press.

108. HMIC and Blakey, D., *Under The Microscope - Refocused*, in *Her Majesty's Inspectorate of Constabulary (HMIC)*. 2002.

109. Bedford, K., *Forensic science service provider models – Is there a 'best' option?* Australian Journal of Forensic Sciences, 2011. **43**(2-3): p. 147-156.

110. Baskin, D. and Sommers, I., *The influence of forensic evidence on the case outcomes of homicide incidents.* Journal of Criminal Justice, 2010. **In Press, Corrected Proof**.

111. Lawless, C., *A Curious Reconstruction? The Shaping of 'Marketized' Forensic Science* 2010, Centre for Analysis of Risk and Regulation, London School of Economics and Political Science: London.

112. Williams, R., *Policing and Forensic Science*, in *Handbook of Policing*, Newburn, T., Editor. 2007, Willan: Cullompton. p. 760-793.

113. Numprasertchai, S. and Igel, B., *Managing knowledge through collaboration: multiple case studies of managing research in university laboratories in Thailand.* Technovation, 2005. **25**(10): p. 1173-1182.

114. National Audit Office, *The Forensic Science Service*. 1998: London.

115. Atchison, T. and Bujak, J.S., *Cultural Factors: The Expert Culture and the Collective Culture*, in *Leading Transformational Change: The Physician-Executive Partnership*. 2002, Health Administration Press. p. 67-87.

116. Liddle, A.M. and Gelsthorpe, L.R., *Crime Prevention & Inter-Agency Co-Operation.* Police Research Group: Crime Prevention Unit Series, 1994. **Paper No. 53**.

117. Stockdale, J.E. and Gresham, P.J., *The Presentation of Police Evidence in Court.* Police Research Series: Paper Number 15, 1995.

118. Cope, N., *Intelligence Led Policing or Policing Led Intelligence?* British Journal Of Criminology, 2004. **44**: p. 16.

119. Roberts, P., *What Price A Free Market In Forensic Science Services? - The Organisation and Regulation of Science in the Criminal Process.* British Journal Of Criminology, 1996. **36**(1): p. 24.

120. Handy, C., *Understanding Organizations*. Vol. 4. 1993, London: Penguin Books.

121. Ericson, R.V. and Haggerty, K.D., *Policing the Risk Society*. 1997, Oxford: Oxford University Press.

122. Glomseth, R., Gottschalk, P., and Solli-Sæther, H., *Occupational culture as determinant of knowledge sharing and performance in police investigations.* International Journal of the Sociology of Law, 2007. **35**(2): p. 96-107.

123. Chan, J.B.L., *The technological game: How information technology is transforming police practice.* Criminal Justice, 2001. **1**(2): p. 139-159.

124. Treven, S., Mulej, M., and Lynn, M., *Impact of Culture on Organizational Behaviour.* Management, 2008. **13**(2): p. 2739.

125. Ting-Toomey, S., *Communicating Across Cultures*. 1999, New York: Guildford Press.

126. Khan, A., *Matching People with Organizational Culture*. 2005, Business Management Group, Inc.

127. Ashkanasy, N.M., Wilderom, C.P.M., and Peterson, M.F., eds. *Handbook of Organizational Culture & Climate*. 2000, Sage Publications, Inc. : Thousand Oakes, California.

128. Schein, E.H., *Organizational Culture and Leadership*. 3rd ed. 2004, San Francisco: John Wiley & Sons, Inc. .

129. Johnson, G. and Scholes, K., *Exploring Corporate Strategy: Text and Cases*. Fourth ed. 1997, Hemel Hempsted: Prentice Hall

130. Reiner, R., *The Politics of the Police*. Vol. 3rd Edition. 2000, Oxford: Oxford University Press.

131. Eldridge, J.E. and Crombie, A.D., *A Sociology of organisations*. 1974, London: Allen & Unwin.

132. Newburn, T., ed. *Policing: Key Readings*. 2005, Willan Publishing: Devon.

133. Hodges, S.P. and Hernandez, M., *How organizational culture influences outcome information utilization.* Evaluation and Program Planning, 1999. **22**(2): p. 183-197.

134. Harrison, R. and Stoakes, H., *Diagnosing organizational culture*. 1993, San Francisco: Pfeiffer.

135. Greenhalgh, T., *Change and the organisation: Culture and context.* The British Journal of General Practice, 2000: p. 340-341.

136. Drucker, P., *Managing in a time of great change*. 1995, New York: Truman Valley.

137. Haveman, H., *Ghosts of Managers Past: Managerial Succession and Organisational Morality.* Academy of Management Journal, 1993. **36**.

138. Tichy, N.M. and Cohen, E., *How Leaders Develop Leaders.* Training and Development, 1997. **5**.

139. Murphy, S.A., *Executive development and succession planning: qualitative evidence.* International Journal of Police Science & Management, 2006. **8**(4): p. 12.

140. Mnookin, J.L., Cole, S.A., Dror, I.E., Fisher, B.A.J., Houck, M.M., Inman, K., Kaye, D.H., Koehler, J.J., Langenburg, G., Risinger, D.M., Rudin, N., Siegel, J., and Stoney, D.A., *The need for a research cultture in the forensic sciences.* UCLA Law Review, 2011. **58**(3): p. 725-780.

141. Reiner, R., *The Politics of Police*. 1992: Wheatsheaf Pub.

142. Paoline, E.A., *Taking stock: Toward a richer understanding of police culture.* Journal of Criminal Justice, 2003. **31**(3): p. 199-214.

143. Chan, J., *Changing Police Culture.* British Journal of Criminology, 1996. **36**(1): p. 26.

144. Brown, A., *Organisational Culture*. 1995, London: Pitman Publishing.

145. Herbert, S., *Police Subculture Reconsidered.* Criminology, 1998. **36**(2): p. 28.

146. Miyazawa, A.S. and Bennett, T.F.G., *Policing in Japan: A Study on Making Crime*. 1992: Albany State University of New York Press.

147. Reuss- Ianni, E. and Ianni, F.A.J., *Street Cops and Management Cops: Two Cultures in Policing*, , in *Control in the Police Organisation*, Munch, M., Editor. 1983, MIT Press.

148. Reuss-Ianni, E., *Street cops vs. management cops: The two cultures of policies.* 1983, New Brunswick: Transaction Press;.

149. Fielding, N.G., *Joining Forces: Police Training, Socialization and Occupational Competence*. 1988, London: Routledge.

150. Reiner, R., *Policing the Police*, in *The Oxford Handbook of Criminology*, Mike Maguire, Rod Morgan, and Reiner, R., Editors. 1994, Oxford University Press: Oxford. p. 705-772.

151. Tyler, M.G., Kirby, L.T., Wood, S., Vernon, S., and Ferris, J.A.J., *Human blood stain identification and sex determination in dried blood stains using recombinant DNA techniques.* Forensic Science International, 1986. **31**: p. 267-272.

152. Saulsury, W., Mott, J., and Newburn, T., *Themes in Contemporary Policing*. 1996: William Saulsbury, Jo Mott & Tim Newburn (the collection).

153. Bordua, D.J. and Reiss, A.J., Jr., *Command, Control, and Charisma: Reflections on Police Bureaucracy.* The American Journal of Sociology, 1966. **72**(1): p. 68-76.

154. Guyot, D., *Bending granite: Attempts to change the rank structure of American police departments.* Journal of Police Science and Administration, 1979. **7**: p. 253-284.

155. Westley, W.A., *Secrecy and the police.* Social Forces, 1956. **34**: p. 254-257.

156. Perrow, C., *Complex Organizations: A Critical Essay*. 1986, New York: McGraw-Hill Inc. .

157. O'Neill, M., Marks, M., and Singh, A.-M., *Police Occupational Culture: New Debates and Directions*. Sociology of Crime Law and Deviance. Vol. 8. 2007, Oxford: Elsevier.

158. Manning, P.K., *Information Technology in the Police Context: The "Sailor" Phone.* Information Systems Research, 1996. **7**(1): p. 52-62.

159. Chan, J.B.L., *Police and New Technologies*, in *Handbook of Policing*, Newburn, T., Editor. 2003, Willan: Cullompton. p. 655-679.

160. Chan, J., Brereton, D., Legosz, M., and Doran, S., *E-policing: The Impact of Information Technology on Police Practices*. 2001, Queensland: Criminal Justice Commission.

161. Miller, S.L., *"Gender & Community Policing"* 1999: Northeastern University Press.

162. Assimakopoulos, D.G., *Technological Communities and Networks: Triggers and Drivers for Innovation*. 2007, London: Routledge.

163. Winsor, T.P., *Independent Review of Police Officer and Staff Remuneration and Conditions*. 2011.

164. Lander, P., *Single culture 'desirable'.* Police Professional, 2011. **245**(2): p. 8.

165. Manning, P.K., *Police Work: The Social Organisation of Policing*. 1977, Cambridge MASS: MIT Press.

166. Chan, J.B.L., *Changing police culture: policing in a multicultural society*. 1997: Cambridge University Press.

167. Doak, S.W., *The Relational Tacit Dimensions of Knowledge used within the Explicit Standardised Processes of Professional Practice in the Irish Forensic Science Laboratory*, in *Faculty of Humanities and Social Sciences, Newcastle University Business School*. 2008, Joint DBA programme between Newcastle University, UK & Grenoble Ecole de Management, France.

168. Udy, S.H., Jr., *"Bureaucracy" and "Rationality" in Weber's Organization Theory: An Empirical Study.* American Sociological Review, 1959. **24**(6): p. 791-795.

169. Doak, S. and Assimakopoulos, D., *How do forensic scientists learn to become competent in casework reporting in practice: A theoretical and empirical approach.* Forensic Science International, 2007. **167**: p. 201-206.

170. Brown, J.S. and Duguid, P., *Knowledge & Organisations: A Social-Practice Perspective.* Organization Science, 2001. **12**(2): p. 198-213.

171. Duguid, P., *"The Art of Knowing": Social and Tacit Dimensions of Knowledge and the Limits of the Community of Practice.* The Information Society: An International Journal, 2005. **21**(2): p. 109 - 118.

172. Sternberg, R.J. and Horvath, J.A., eds. *Tacit Knowledge in Professional Practice: Researcher and Practitioner Perspectives*. 1999, Lawrence Erlbaum Associates, Inc.: Mahaw.

173. Forensic Science Regulator, *Summary of the responses received for the Forensic Science Regulator's Consultation Paper on "A review of the options for the accreditation of forensic practitioners"*. 2009.

174. Evett, I.W., *Criminalistics: The Future of Expertise.* Journal of the Forensic Science Society, 1993(33): p. 173-.

175. Wenger, E., McDermott, R., and Snyder, W.A., *Cultivating Communities of Practice: A Guide to Managing Knowledge*. 2002, Boston: Harvard Business School Press.

176. Sternberg, R.J., Forsythe, G.B., Hedlund, J., Horvath, J.A., Wagner, R.K., Williams, W.M., Snook, S.A., and Grigorenko, E., *Practical Intelligence in Everyday Life*. 2000, Cambridge: Cambridge University Press.

177. National Institute of Justice, *Education and Training in Forensic Science: A Guide for Forensic Science Laboratories, Educational Institutions, and Students. Developed and Approved by the Technical Working Group for Education and Training in Forensic Science*, Justice, U.S.D.o.J.O.o.J.P.N.I.o., Editor. 2004, NIJ.

178. Weddell, R.J., *The way forward - raising educational standards for scientific support personnel in the UK.* Science & Justice, 1997. **37**(1): p. 9-14.

179. Houk, M.M., *An Investigation into the Foundational Principles of Forensic Science*, in *Department of Chemistry*. 2010, Curtin University of Technology: Perth & Syndey. p. 132.

180. Herbig, B., Büssing, A., and Ewert, T., *The role of tacit knowledge in the work context of nursing.* Journal of Advanced Nursing, 2001. **34**(5): p. 687-695.

181. Lawless, C.J., *Policing Markets: The Contested Shaping of Neo-Liberal Forensic Science.* British Journal of Criminology, 2011. **51**: p. 571=689.

182. Association of Chief Police Officers, *The Murder Manual*. 1999, Association of Chief Police Officers: London.

183. Robbins, S.P., *Organizational Behaviour*. 5th ed. 2005, Upper Saddle River, NJ: Pearsons Education Inc. .

184. Whaley, B.B. and Samter, W., eds. *Explaining Communication: Contemporary Theories and Exemplars*. 2007, Lawrence Erlbaum Associates Inc: Mahaw, New Jersey.

185. Matterlart, A. and Matterlart, M., *Theories of Communication: A Short Introduction*. 1999, London: Sage Publications Ltd. .

186. Choo, A.S., Linderman, K.W., and Schroeder, R.G., *Method and context perspectives on learning and knowledge creation in quality management.* Journal of Operations Management, 2007. **25**(4): p. 918-931.

187. CPS and ACPO, *Disclosure: experts' evidence and unused material. Guidance booklet for experts.* . 2006, Crown Prosecution Service & Association of Chief of Police Officers: London.

188. Home Office and Her Majesty's Inspectorate of Constabulary. *Improving Forensic Performance*. 2006 [cited 2009 June]; Available from: http://inspectorates.homeoffice.gov.uk/hmic/docs/ba2006frmwk/3d-fmwk-ba2006.pdf?view=Binary.

189. Her Majesty's Inspectorate of Constabulary for Scotland, *Thematic Inspection: Quality of service and feedback to users of police services in Scotland*, in *Her Majesty's Inspectorate of Constabulary for Scotland (HMICS)*. 2008.

190. Sachdeva, A.K., *Use of effective feedback to facilitate adult learning.* Journal of Cancer Education, 1996. **11**(2): p. 106 - 118.

191. House Of Commons, *Forensic Science on Trial: Government Response to the Committee's Seventh Report of Session*, in *House of Commons - Science & Technology Committee*. 2004-05.

192. Fisher, C.D., *Transmission of positive and negative feedback to subordinates: A laboratory investigation.* Journal of Applied Psychology, 1979. **46**(5): p. 533-540.

193. Dörfler, V., *Model of Learning Ability*, in *Department of Management Science*. 2005, University of Strathclyde: Glasgow. p. 324.

194. Lieberman, J.D., Carrell, C.A., Miethe, T.D., and Krauss, D.A., *Gold Versus Platinum: Do Jurors Recognize the Superiority and Limitations of DNA Evidence Compared to Other Types of Forensic Evidence?* Psychology, Public Policy, and Law, 2008. **14**(1): p. 27-62.

195. Burrows, M.H., *The processing of fingerprint evidence after the introduction of the National Automated Fingerprint Identification System (NAFIS).* Home Office Online Report, 2004. **23**: p. 37.

196. Bond, J.W. and Sheridan, L., *A novel approach to maximising the detection of volume crime with DNA and fingerprints.* International Journal of Police Science & Management, 2007. **10**(3): p. 12.

197. Milne, R., *Operation Bigfoot - a volume crime database project.* Science & Justice, 2001. **41**(3): p. 215-217.

198. Broeders, A.P.A., *Of earprints, fingerprints, scent dogs, cot deaths and cognitive contamination--a brief look at the present state of play in the forensic arena.* Forensic Science International, 2006. **159**(2-3): p. 148-157.

199. Cunningham, A., Walters, A., Hales, S., and Futers, C., *Meeting Report - Forensic Science and the Crime Scene.* Science & Justice, 2001. **41**(4): p. 279-286.

200. Fraser, J.G., *The application of forensic science to criminal investigation*, in *Handbook of Criminal Investigation*, Newburn, T., Editor. 2007, Willan: Cullompton.

201. Sanchez, R., *"Tacit Knowledge" versus "Explicit Knowledge": Approaches to Knowledge Management Practice*, in *Working Paper Series*. 2004, Department of Industrial Economics and Strategy, Copenhagen Business School: Frederiksberg.

202. Collins, J.D. and Hitt, M.A., *Leveraging tacit knowledge in alliances: The importance of using relational capabilities to build and leverage relational capital.* Journal of Engineering and Technology Management, 2006. **23**(3): p. 147-167.

203. Wyatt, J.C., *Management of explicit and tacit knowledge.* Journal of the Royal Society of Medicine, 2001. **94**: p. 6-9.

204. Koskinen, K.U., Pihlanto, P., and Vanharanta, H., *Tacit knowledge acquisition and sharing in a project work context.* International Journal of Project Management, 2003. **21**(4): p. 281-290.

205. Nichols, A. and Badger, B., *An investigation of the division between espoused and actual practice in infection control and of the knowledge sources that may underpin this division.* British Journal of Infection Control, 2008. **9**(4): p. 11-15.

206. Doak, S. and Assimakopoulos, D., *How forensic scientists learn to investigate cases in practice.* R&D Management, 2007. **37**(2): p. 113-122.

207. Polanyi, M., *The Tacit Dimension*. 2nd ed. 1983, London: Routledge & Kegal Paul.

208. Doak, S. and Assimakopoulos, D., *Tacit Knowledge: A Needed Addition to SOPs in a Forensic Science Environment.* Forensic Science Policy & Management, 2009. **1**(4): p. 171-177.

209. Mitri, M., *Applying tacit knowledge management techniques for performance assessment.* Computers & Education, 2003. **41**(2): p. 173-189.

210. Epstein, R.M., *Mindful Practice.* JAMA: The Journal of the American Medical Association, 1999. **282**(9): p. 833-839.

211. Wagner, R.K., *Tacit Knowledge in Everyday Intelligent Behavior.* Journal of Personality and Social Psychology, 1987. **52**(6): p. 1236-1247.

212. Wenger, E.C. and Snyder, W.M., *Communities of practice: The organizationalfrontier.* Harvard Business Review, 2000. **78**(1): p. 139-145.

213. Lanzara, G.F. and Patriotta, G., *Technology and the courtroom: an inquiry into knowledge making in organisation.* Journal of Management Studies, 2001. **38**(7): p. 943-72.

214. Baumard, P., *Tacit knowledge in organizations*. 1999, London: Sage.

215. Goldblatt, D., ed. *Knowledge & the social sciences: theory, method & practice*. 2nd ed. 2000, Routledge: London.

216. Brown, S. and Willis, S., *Research & Development in Forensic Science: A Providers Perspective*, in *Forensic Science Research and Practice Conference*. 2009: Strathclyde University, Glasgow.

217. Nonaka, I. and Takeuchi, H., *The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation*. 1995, Oxford University Press: New York.

218. Fernie, S., Green, S.D., Weller, S.J., and Newcombe, R., *Knowledge sharing: context, confusion and controversy*. International Journal of Project Management, 2003. **21**(3): p. 177-187.

219. Allen, T.J., *Communication networks in R & D Laboratories.* R&D Management, 1970. **1**(1): p. 14-21.

220. Gherardi, S., Nicolini, D., and Odella, F., *Toward a social understanding of how people learn in organizations.* Management Learning, 1998. **29**(3): p. 273-297.

221. Brown, J.S. and Duguid, P., *The Social Life of Information*. 2000, Boston: Harvard Business School Press.

222. Her Majesty's Inspectorate of Constabulary for Scotland, ™*Training Matters*, Office, H. and (HMICS), H.M.s.I.o.C.f.S., Editors. 2002, Home Office.

223. Roux, C. and Robertson, J., *The development and enhancement of forensic expertise: higher education and in-service training*, in *The Handbook of Forensic Science*, Fraser, J. and Williams, R., Editors. 2009, Willan Publishing: Cullompton. p. 572-602.

224. Buckley, R. and Caple, J., *The Theory & Practice of Training*. 5th ed. 2007, London: Kogan Page

225. Robertson, J., *The future of crime scene investigation*, in *The practice of crime scene investigation*, Horswell, J., Editor. 2004, CRC Press. p. 399-406.

226. National Policing Improvement Agency. *Crime Scene Investigation Training*. 2011 [cited 2011 May]; Available from: http://www.npia.police.uk/en/6461.htm.

227. National Policing Improvement Agency. *Courses, Exams and Professional Development: SIO Courses*. 2010 [cited 2011 March]; Available from: http://www.npia.police.uk/en/1305.htm.

228. Roux, C. and Robertson, J., *The development and enhancement of forensic expertise: higher education and in-service training*, in *Handbook of Forensic Science*, Fraser, J. and Williams, R., Editors. 2009, Willan Publishing.

229. National Policing Improvement Agency. *NPIA: National Policing Improvement Agency*. 2010 [cited 2010 May]; Available from: http://www.npia.police.uk/en/5151.htm.

230. National Policing Improvement Agency, *NPIA Business Plan 2008-2011*. 2008.

231. Small, D., *Forensics21: challenging, enabling and improving forensic science*. Police Professional, 2009.

232. National Policing Improvement Agency. *Forensics21*. 2009 [cited 2009 June]; Available from: http://www.npia.police.uk/en/10432.htm.

233. National Policing Improvement Agency, *NPIA Business Plan 2010-2013*. 2010.

234. Home Office, *Policing in the 21st Century: Reconnecting police and the people (Government Consultation)*. 2010.

235. Neyroud, P., *Review of Police Leadership and Training*. 2011.

236. National Policing Improvement Agency. *Volume Crime Scene Investigator (VCSI) Conversion Course*. 2010 [cited 2011 January].

237. Williams, R., Johnson, P., and Martin, P., *Genetic Information & Crime Investigation - Social, Ethical and Public Policy Aspects of the Establishment, Expansion and Police Use of the National DNA Database*. 2004, University of Durham.

238. Tilley, N., Robinson, A., and Burrows, J., *The Investigation of high-volume crime*, in *The Handbook of Criminal Investigation*, Newburn, T., Williamson, T., and Wright, A., Editors. 2007, Willan Publishing Ltd: Portland.

239. Franklin, S., Dixon, G., and Williamson, A., *Process Management and Improvement: CSI Tasking*. 2009, National Policing Improvement Agency,.

240. Crown Prosecution Service and Association of Chief Police Officers, *Disclosure: experts' evidence and unused material. Guidance booklet for experts.* . 2006, Crown Prosecution Service & Association of Chief of Police Officers: London.

241. Innes, M. and Clarke, A., *Lets Get Physical: Contact trace Materials in the Crime Investigation Process*. 2002, Home Office: London.

242. Williams, R., *The Grammar of Forensic Investigation (Unpublished)*. 2004, University of Durham.

243. Her Majesty's Inspectorate of Constabulary for Scotland, *Thematic Inspection: Productivity of police officers*, in *Her Majesty's Inspectorate of Constabulary for Scotland (HMICS)*. 2008.

244. Coupe, T. and Griffiths, M., *Police Investigation Into Residential Burglary*, in *British Criminology Conference*. 1998, British Society of Criminology: Loughborough University.

245. Crispino, F., *Nature and place of crime scene management within forensic sciences.* Science & Justice, 2008. **48**(1): p. 24-28.

246. Fraser, J.G., *Delivery and Evaluation of Forensic Science.* Science & Justice, 2003. **43**(4): p. 4.

247. Innes, I., Fielding, N., and Cope, N., *The Appliance of Science? The Theory and Practice of Crime Intelligence Analysis.* British Journal Of Criminology, 2005. **45**: p. 19.

248. Fraser, J.G., *Not Science...Not Support: Forensic solutions to investigative problems.* Science & Justice, 2000. **40**(2): p. 4.

249. Newiss, G., *Responding to and investigating street robbery*. 2002.

250. Bond, J.W., *Value of DNA Evidence in Detecting Crime.* Journal of Forensic Sciences, 2007. **52**(1): p. 128-136.

251. Heffernan, L., *Scientific Evidence: fingerprints and DNA*. 2006, Dublin: First Law.

252. Bond, J.W., *The value of fingerprint evidence in detecting crime.* International Journal of Police Science & Management, 2009. **11**: p. 77-84. .

253. Peterson, J.L., Mihajlovic, S., and Gilliland, M., *Forensic evidence and the police: The effects of scientific evidence on criminal investigations*. 1984, US Government Printing Office: Washington DC.

254. Peterson, J.L., Ryan, J.P., Houlden, P.J., and Mihajlovic, S., *The Uses and Effects of Forensic Science in the Adjudication of Felony Cases.* Journal of Forensic Sciences, 1987. **32**(6): p. 1730-1753.

255. Greenwood, P.W., Chaiken, J.M., and Petersilia, J., *The Criminal Investigation Process*. 1977, Lexington: D C Heath and Co.

256. Scottish Criminal Records Office, *McKie Report*. 2006.

257. Greenwood, P.W., *An analysis of the apprehension activities of the New York City Police Department* 1970, New York: Rand.

258. Brandl, S.G. and Frank, J., *Relationship between evidence, detective effort, and the disposition of burglary and robbery investigations.* American Journal of Police, 1994. **13**(3).

259. Sanders, W.B., *Detective Work: A Study of Criminal Investigations*. 1977, New York: Free Press.

260. Briody, M., *The Effects of DNA Evidence on Property Offences in Court.* Current Issues in Criminal Justice, 2006. **17**(3): p. 380-396.

261. Briody, M.J. and Prenzler, T., *DNA Databases and Property Crime: A False Promise?* Australian Journal of Forensic Sciences, 2005. **37**: p. 73-86.

262. Human Genetics Commission, *Nothingto hide, nothingto fear? Balancing individual rights and the public interest in the governance and use of the National DNA Database*. 2009.

263. Hedberg, K. and Albertson, J., *The National DNA Database in Sweden: A Survey about Legislative Procedures, Changes and effects from 1999 to 2003*. 2003.

264. Busher, L., *The use of the UK National DNA Database to support an intelligence-led approach to the investigation of crime.* Journal of Forensic Medicine, 2002: p. 21-25.

265. Bowman, J. and Wilson, J.P., *Different roles, different perspectives: perceptions about the purpose of training needs analysis.* Industrial and Commercial Training, 2008. **40**(1): p. 38-41.

266. Kaye, D.H., *The good, the bad, the ugly: The NAS report on strengthening forensic science in America*, in *The 5th Triennial Conference of the European Academy of Forensic Science*. 2010, Science & Justice: Glasgow. p. 8-11.

267. Ludwig, A. and Hill, L., *Forensic Science Research and Practice — Meeting report, Joint meeting of the Scottish Institute for Policing Research and the Centre for Forensic Science, Strathclyde University, Glasgow, July 2009.* Science and Justice, 2009. **49**: p. 230-230.

268. Brown, S. and Willis, S., *Complexity in Forensic Science.* Forensic Science Policy & Management, 2009. **1**(4): p. 192-198.

269. Murphy, E., *What "Strengthening Forensic Science" today means for tomorrow: DNA exceptionalism and the 2009 NAS Report.* Law, Probability and Risk, 2010. **9**(1): p. 7-24.

270. Turvey, B.E., *The NAS report on forensic science: A forensic scientist's response.* Crime Reconstruction, 2009.

271. European Network of Forensic Science Institutes, *One Day One Subject Meeting on NAS Report*. 2009: Wiesbaden, Germany.

272. Mnookin, J.L., *The Courts, the NAS, and the Future of Forensic Science.* Brooklyn Law Review, 2010. **75**(4): p. 1-67.

273. Gottfredson, M.R. and Hindelang, M.J., *A study of behavior of law.* American Sociological Review, 1979. **44**(1): p. 3-18.

274. Scottish Government, *Fraser Report on Retention of DNA and fingerprint data: Government's response*, Government, S., Editor. 2009.

275. Wheate, R., *The importance of DNA evidence to juries in criminal trials.* International Journal of Evidence and Proof, 2010. **14**(2): p. 129-145.

276. Adderley, R. and Bond, J.W., *Predicting Crime Scene Attendance.* Policing: An International Journal of Police Strategies & Management, 2006. **31**(2): p. 14.

277. House of Commons Home Affairs Committee, *The National DNA Database*. 2010, The Stationery Office Limited: London.

278. Home Office, *Keeping the right people on the DNA Database: Science and Protection*. 2009, Home Office,.

279. Walsh, S.J., Buckleton, J.S., Ribaux, O., Roux, C., and Raymond, T., *Comparing the growth and effectiveness of forensic DNA databases.* Forensic Science International: Genetics Supplement Series, 2008. **1**(1): p. 667-668.

280. Melson, K.E., *President's Editorial - The Journey to Justice.* Journal of Forensic Sciences, 2003. **48**(4): p. 1-3.

281. Home Office and Her Majesty's Inspectorate of Constabulary, *HMIC Baseline Assessment Framework Specific Grading Criteria*. 2006.

282. McCartney, C., *The DNA Expansion Programme and Criminal Investigation.* British Journal of Criminology, 2006. **46**(2): p. 175-192.

283. Rix, B. and Home Office, *The Contribution of Shoemark Data to Police Intelligence, Crime Detection and Prosecution*, in *Research, Development and Statistics Directorate*. 2004.

284. Fraser, J. and Williams, R., *The contemporary landscape of forensic science*, in *The Handbook of Forensic Science*, Fraser, J. and Williams, R., Editors. 2009, Willan Publishing: Cullompton. p. 1-20.

285. Mennell, J. and Shaw, I., *ACPO Future Forensics: Towards a strategy for forensic science*. 2009, Northumbria University.

286. Koehler, J.J., *Forensic science reform in the 21st century: a major conference, a blockbuster report and reasons to be pessimistic.* Law, Probability and Risk, 2010. **9**(1): p. 1-6.

287. Audit Commission, *Effective Policing: Performance Review in Police Forces*. 1990, HMSO: London.

288. DeForest, P., *Proactive Forensic Science.* Science and Justice, 1998. **38**: p. 1-.

289. Stockdale, J.E. and Gresham, P.J., *Tackling Street Robbery: A Comparative Evaluation of Operation Eagle Eye*, 87, C.D.a.P.S.P., Editor. 1998, Home Office.

290. Forensic Science Service. *Chartered Forensic Practicioner Status*. 2011 [cited 2011 July]; Available from: http://www.forensic-science-society.org.uk/Qualifications/CompetenceTesting?Print=1.

291. Silverman, B., *Research and Development in Forensic Science: a Review*. 2011.

292. Becker, W.S., Dale, W.M., and Pavur, E.J., *Forensic Science in Transition: Critical Leadership Challenges.* Forensic Science Policy & Management: An International Journal, 2009. **1**(4): p. 214 - 223.

293. Saunders, M.N.K., Lewis, P., and Thornill, A., *Research Methods for Business Students*. 3rd. ed. 2004, Harlow: Prentice Hall.

294. Robson, C., *Real World Research*. 2nd ed. 2002, Oxford: Blackwell Publishing.

295. Frazer, L. and Lawley, M., *Questionnaire Design and Administration: A Practical Guide*. 2001, New York: Wiley.

296. Fink, A.G., *How to Conduct Surveys: A Step-by-Step Guide*. 4th ed. 2008, California: Sage Publications, Inc. .

297. Fink, A.G., *How To Ask Survey Questions*. 2nd ed. 2003, California: Sage Publications, Inc.

298. Oppenheim, A.N., *Questionnaire Design, Interviewing and Attitude Measurement*. 1992, London: Pinter Publishers.

299. Neuman, W.L., *Social Research Methods: Qualitative and Quantitative Approaches*. 6th ed. 2009: Pearson Education.

300. Babbie, E., *The Practice of Social Research*. 8th ed. 1998, Belmont: Wadsworth Pub. Comp. .

301. Veal, A.J., *Research Methods for Leisure and Tourism: A Practical Guide*. 3rd ed. 2006, London: Prentice Hall.

302. Tourangeau, R. and Smith, T.W., *Asking sensitive questions: The impact of data collection mode, question format, and question context.* Public Opinion Quarterly, 1996. **60**(2): p. 275-304.

303. Brace, I., *Questionnaire Design: How to Plan, Structure and Write Survey Material for Effective Market Research*. 2004, London: Market Research in Practice Series.

304. Carifio, J. and Perla, R., *Resolving the 50-year debate around using and misusing Likert scales.* Medical Education, 2008. **42**(12): p. 1150-1152.

305. Carifio, J. and Perla, R.J., *Ten Common Misunderstandings, Misconceptions, Persistent Myths and Urban Legends about Likert Scales and Likert Response Formats and their Antidotes.* Journal of Social Sciences, 2007. **3**(3): p. 106-116.

306. Corder, G.W. and Foreman, D.I., *Nonparametric Statistics for Non-Statisticians: A Step-by-Step Apprach*. 2009: Wiley Blackwell.

307. Lucy, D., *Introduction to Statistics for Forensic Scientists*. 2005, Chichester, West Sussex: John Wiley & Sons Ltd.

308. Aitken, C. and Taroni, F., *Statistics and the evaluation of evidence for forensic scientists*. Statistics in Practice. 2004, Chichister: Wiley.

309. Higgins, J.J., *Introduction to Modern Nonparametric Statistics*. 2003: Duxbury Press.

310. Greenhalgh, T., *How to read a paper- the basics of evidence-based medicine*. 3rd ed. BMJ books. 2006, Oxford: Blackwell.

311. Griffiths, D., Stirling, W.D., and Weldon, K.L., *Understanding Data: Principles & Practices of Statistics*. 1998, Milton, Queensland: John Wiley & Sons Australia Ltd. .

312. Lani, D.J. *Statistics Solutions: Dissertation Consultation and Research Support for Doctoral Students, Thesis Students and Researchers*. 2009; Available from: http://www.statisticssolutions.com/.

313. Scottish Government, *Criminal Proceedings in Scottish Courts, 2008-2009*. 2010, A National Statistics Publication for Scotland.

314. Scottish Government, *Recorded Crime in Scotland, 2008-09*, Scotland, A.N.S.P.f., Editor. 2009, Statistical Bulletin Crime and Justice Series.

315. Scottish Government, *Volume/Types of Crime Recorded & Crimes Cleared Up*. 2008, A National Statistics Publication for Scotland.

316. Association of Chief Police Officers Scotland (ACPO), Her Majesty's Inspectorate of Constabulary for Scotland (HMICS), Scottish Police Services Authority (SPSA), and Government, S., *Scottish Police Performance Framework 2008-2009*. 2009.

317. Scottish Police Services Authority, *SPSA Annual Plan 2008-2009*. 2008-09.

318. Lothian & Borders Police, *Lothian and Borders Police Annual Report & Force Statistics*. 2008-2009.

319. Strathclyde Police, *Strathclyde Police Annual Report & Force Statistics*. 2009-2010.

320. Lothian & Borders Police. *L&B Police Recruitment - Entrance Criteria*. 2011 [cited 2010 March]; Available from: http://www.lbp.police.uk/recruitment/entrance-criteria.asp.

321. The Forensic Science Society, *Certificate/Diploma in Crime Scene Examination: Curriculum and guidelines for applicants 2011*. 2010.

322. Scottish Police College, *SPC Prospectus 2010-11*, SPSA, Editor. 2010.

323. Bramley, P., *Evaluating Training*. 2nd ed. 2006, London: Chartered Institute of Personnel and Development.

324. Brightman, R., *Education and Training for the Future*. 2005, NIFS Australian Forensic Science.

325. Scottish Police Serivces Authority. *Scottish Police College - Tulliallan*. 2011 [cited 2010 April]; Available from: http://tulliallan.police.uk/.

326. Quinones, M.A. and Ehrenstein, A., eds. *Training for a Rapidly Changing Workplace: Applications of Psychological Research*. 1997, American Psychological Association: London.

327. Warr, P., Allan, C., and Birdi, K., *Predicting three levels of training outcome.* Journal of Occupational and Organizational Psychology, 1999. **72**(3): p. 351-375.

328. Greenhalgh, T., *Change and the individual 1: Adult learning theory.* British Journal of General Practice, 2000: p. 76-77.

329. Davie, H.T.O. and Nutley, S.M., *Developing learning organisations in the new NHS.* BMJ, 2000. **320**(7240): p. 998-1001.

330. Mabey, C. and Iles, P., *Managing Learning*. 1999: Open University Press/Thomson.

331. Argyris, C., *On Organizational Learning*. 2nd ed. 1999, Oxford: Blackwell Publishers.

332. Calvert, G., Mobley, S., and Marshal, L., *Grasping the Learning Organization.* Training and Development, 1994. **48**(6): p. 40-43.

333. Honey, P. and Mumford, A., *The Manual of Learning Styles*. 2nd ed. 1986, Maidenhead: Peter Honey.

334. Kolb, D.A., *The Process of Experiential Learning*, in *Experiential learning: experience as the source of learning and development*. 1984, Prentice Hall: Englewood Cliffs, NJ.

335. Burrows, J. and Tarling, R., *The Investigation of Crime in England and Wales.* British Journal of Criminology, 1987. **27**: p. 229-.

336. Horswell, J., *Education and training of police in the forensic sciences: an Australian perspective.* Science & Justice, 1995. **35**(1): p. 15-18.

337. Ribaux, O., Girod, A., Walsh, S.J., Margot, P., Mizrahi, S., and Clivas, V., *Forensic intelligence and crime analysis.* Law, Probability and Risk, 2003. **2**: p. 47-60.

338. Ribaux, O., Walsh, S.J., and Margot, P., *The contribution of forensic science to crime analysis and investigation: Forensic intelligence.* Forensic Science International, 2006. **156**(2-3): p. 171-181.

339. Thompson, W.C., *Tarnish on the "Gold Standard": Understanding Recent Problems in Forensic DNA Testing.* National Association of Criminal Defense Lawyers (NACDL) - The Champion, 2006.

340. Lynch, M., *God's signature: DNA profiling, the new gold standard in forensic science.* Endeavour, 2003. **27**(2): p. 93-97.

341. Schroeder, D.A. and White, M.D., *Exploring the Use of DNA Evidence in Homicide Investigations.* Police Quarterly, 2009. **12**(3): p. 319-342.

342. Nichols, R.G., *Defending the Scientific Foundations of the Firearms and Tool Mark Identification Discipline: Responding to Recent Challenges.* Journal of Forensic Sciences, 2007. **52**(3): p. 9.

343. National Research Council, *The Evaluation of Forensic DNA Evidence*. 1996, Washington D.C.: National Academy Press.

344. Kaye, D.H., *DNA Evidence: Probability, Population Genetics and the Courts.* Harvard Journal of Law and Technology, 1993. **7**: p. 101-.

345. Pyrek, K.M., *Forensic Science Under Siege*. 2007, London: Elsevier Inc. .

346. Koppl, R., *How To Improve Forensic Science.* European Journal of Law And Economics, 2005.

347. Stelfox, P., *Criminal Investigation: An introduction to principles and practice*. 2009, Cullompton: Willan Publishing.

348. House Of Commons, *Science and Technology - Seventh Report*. 2005, Science and Technology Committee Publications.

349. Napier, T.J., *Scene linking using footwear mark databases.* Science & Justice, 2002. **42**(1): p. 39-43.

350. *Police and Criminal Evidence Act (PACE)*. 1984.

351. Nuffield Council on Bioethics, *The forensic use of bioinformation: ethical issues*. 2007.

352. Williams, R. and Johnson, P., *Inclusiveness, effectiveness and intrusiveness: issues in the developing uses of DNA profiling in support of criminal investigations.. .* Journal of Law, Medicine & Ethics, 2005. **333**: p. 13.

353. National Policing Improvement Agency. *National Footwear Reference Collection*. 2010 [cited 2010 June]; Available from: http://www.npia.police.uk/en/14141.htm.

354. Jackson, G., Jones, S., Booth, G., Champod, C., and Evett, I.W., *The nature of forensic science opinion-a possible framework to guide thinking and practice in investigation and in court proceedings.* Science & Justice, 2006. **46**(1): p. 33-44.

355. Ribaux, O. and Margot, P., *Inference structures for crime analysis and intelligence: the example of burglary using forensic science data.* Forensic Science International, 1999. **100**(3): p. 193-210.

356. Tilley, N., *SIPR Fourth Annual Lecture: Discipline and Discretion*. 2010: University of Strathclyde, Glasgow.

357. Goldstein, J., *Police Discretion Not to Invoke the Criminal Process: Low-Visibility Decisions in the Administration of Justice.* The Yale Law Journal, 1960. **69**(4): p. 543-594.

358. Brown, J.S. and Duguid, P., *Organizational learning and communities-of-practice: Toward a unified view of working, learning, and innovation.* Organization Science,, 1991. **2**(1): p. 40-57.

359. Scottish Police Serivces Authority, *Scene Examiner Role Profile (unpublished)*. 2010.

360. Conklin, J., *Wicked Problems & Social Complexity*, in *Dialogue Mapping: Building Shared Understanding of Wicked Problems*. 2005, John Wiley & Sons.

361. Handy, C., *The Age of Paradox*. 1994, Boston: Harvard Business School Press.

362. Zheng, W., Yang, B., and McLean, G.N., *Linking organizational culture, structure, strategy, and organizational effectiveness: Mediating role of knowledge management.* Journal of Business Research, 2010. **63**(7): p. 763-771.

363. Henri, J.-F., *Organizational culture and performance measurement systems.* Accounting, Organizations and Society, 2006. **31**(1): p. 77-103.

364. Manning, P.K., *Information Technologies and the Police.* Crime and Justice: Modern Policing, 1992: p. 349-98.

365. Wyatt, J., *Management of explicit and tacit knowledge.* J R Soc Med, 2001. **94**(1): p. 6-9.

366. Boulding, K.E., *General Systems Theory: The Skeleton of Science.* Management Science, 1956. **2**(3): p. 197-208.

367. Field, A., *Discovering Statistics Using SPSS*. 2005, London: Sage.

368. Association of Chief Police Officers and Centrex, *Practice Advice on Core Investigative Doctrine*, in *Produced on Behalf of ACPO by the National Centre for Policing Excellence*. 2005, ACPO & Centrex.

369. Scott, J., *Rational Choice Theory*, in *Understanding Contemporary Society: Theories of The Present*, Browning, G., Halcli, A., and Webster, F., Editors. 2000, Sage Publications. p. 126-138.

370. Helsloot, I. and Groenendaal, J., *Naturalistic Decision Making in Forensic Science: Toward a Better Understanding of Decision Making by Forensic Team Leaders.* Journal of Forensic Sciences, 2011. **56**(4): p. 890-897.

371. Brodeur, J.-P. and Shearing, C., *Configuring Security and Justice.* European Journal of Criminology, 2005. **2**(4): p. 379-406.

372. Jones, B.D., *Bounded Rationality.* Annual Review of Political Science, 1999. **2**: p. 297-321.

373. Donnelly, D. and Scott, K.B., *Police Accountability in Scotland: (1) The New Tripartite System.* The Police Journal, 2002. **75**(1): p. 3-15.

374. Scottish Police Services Authority, *Pilot Project - Scene Examination Unit Satellite Office (Govan Police Station)*. 2009, SPSA Forensic Services: Glasgow.

375. Linacre, A., *The UK National DNA Database.* 2003, 2003. **361**: p. 2.

376. Fugate, B.S., Stank, T.P., and Mentzer, J.T., *Linking improved knowledge management to operational and organizational performance.* Journal of Operations Management, 2009. **27**: p. 247-264.

377. Prime, R. and Hennelly, L., *Effects of the Processing of DNA Evidence*. 2003, Home Office: London.

378. Johnson, P. and Williams, R., *DNA and Crime Investigation: Scotland and the 'UK National DNA Database'.* Scottish Journal of Criminal Justice Studies, 2004. **10**: p. 9.

379. Tilley, N., *Thinking about Crime Prevention Performance Indicators.* Police Research Group: Crime Detection & Prevention Series, 1995. **Paper 57**: p. 46.

380. Loveday, B., *Policing performance: The impact of performance measures and targets on police forces in England and Wales.* International Journal of Police Science & Management, 2006. **8**(4): p. 282–293.

381. Gottschalk, P., *Stages of knowledge management systems in police investigations.* Knowledge-Based Systems, 2006. **19**(6): p. 381-387.

382. Horswell, J. and Edwards, M., *Development of quality systems accreditation for crime scene investigators in Australia.* Science & Justice, 1997. **37**(1): p. 3-8.

383. Fraser, J.G., *Partners In Crime.* Forensic Science, 2008: p. 1.

384. Cook, R., Evett, I.W., Jackson, G., Jones, P., and Lamber, J.A., *A model for case assessment and interpretation.* Science & Justice, 1998. **38**: p. 151-156.

385. Welsh, C., *Partnership - the Key to Success*, in *The Standard - Focus on Forensic Science*. 2008, JSSC - Skills for Justice.

386. Ribaux, O., Baylon, A., Lock, E., Delémont, O., Roux, C., Zingg, C., and Margot, P., *Intelligence-led crime scene processing. Part II: Intelligence and crime scene examination.* Forensic Science International, 2010. **199**(1-3): p. 63-71.

387. Argote, L., McEvily, B., and Reagans, R., *Managing Knowledge in Organizations: An Integrative Framework and Review of Emerging Themes.* Management Science, 2003. **49**(4): p. 571-582.

388. Feist, A. and Newiss, G., *Watching the Detectives: Analysing hard-to-solve homicide investigations*. 2001, Home Office.

389. Barclay, D., *Using forensic science in major crime inquiries*, in *Handbook of Forensic Science*, Fraser, J. and Williams, R., Editors. 2009, Willan: Cullompton. p. 337-358.

390. Fraser, J. and Williams, R., *The future(s) of forensic investigation*, in *Handbook of Forensic Science*, Fraser, J. and Williams, R., Editors. 2009, Willan Publishing (UK).

391. Damelio, R., *The Basics of Process Mapping*. 1996: Productivity Press.

392. Her Majesty's Inspectorate of Constabulary for Scotland, *PNC Inspections: National overview report*. 2009, HMICS.

393. Cooper, A. and Mason, L., *Forensic resources and criminal investigation*, in *The Handbook of Forensic Science*, Fraser, J. and Williams, R., Editors. 2009, Willan Publishing: Cullompton.

394. Hamilton, I., *Fingerprint identification and science : a comparative study of attitudes of criminal justice sector professions*, in *Deptartment of Pure and Applied Chemistry*. 2010, University of Strathclyde: Glasgow.

Appendix 1: The investigation of volume crimes involving forensic science

The investigation of a crime (whether volume or major) requires the collection and analysis of evidence (samples or objects) from a scene. After a report is made to the police by a member of the public, victim or witness, the area is secured and the forensic process will begin with the analysis of the scene and the recovery of evidential items which may be able to clarify the sequence of events or provide intelligence towards identifying the offender. A number of errors can occur at this early stage of the investigation which could result in evidence being contaminated or lost. Quality failures at this stage of the investigation can often not be rectified and result in the loss of information for the case [268]. A great deal of focus has been placed on ensuring that personnel attending the crime scene are aware of the potential dangers and limitation of scene investigations and that they have received substantial training.

Specific stage of the process	**Details of actions and description of where issues can arise.**
Crime notified to police call centre	- When the crime is notified to the police, it is often the first contact between police and the public (victim or witness). It occurs when it is discovered and reported to a call handler. - Call handlers gather information by recording relevant details to determine whether (or how urgently) police (and/or crime scene examiner) attendance is required. They also offer guidance/reassurance to the caller about how to best preserve forensic evidence. - Therefore, it is vital that call handler have an adequate understanding of forensic evidence. Inefficient management here can affect the investigation adversely. Inexperienced or untrained call handlers may delay scene attendance or inadvertently contaminate the scene.

Police and Scenes of Crime Units respond	- Initial decisions made by officers are crucial as they could result in serious consequences affecting the rest of the investigation should a lack of understanding of evidential value occur. - Poor scene management can lead to missed or contaminated evidence which cannot be rectified by laboratory. The delicate nature of crimes scenes, time restrictions and further cases often do not permit a scene to be revisited for collecting additional evidence. - Crime scene examiners (CSEs) also attend scene to identify, preserve and collect physical material which may provide critical intelligence relating to the circumstances of the case or the perpetrator of the criminal activity.
CSE collect evidence	- CSE utilise a range of techniques using an established sequence of examination which considers the context and circumstances of that case. Identifying evidence which may be of forensic importance to specific offence is difficult when knowledge or training has been ineffective. - CSEs may primarily look for specific evidence types (e.g. DNA and fingerprints) which can help identify the offender. Secondary focus is on corroborative evidence (e.g. footwear marks) to strengthen the case. Footwear marks are recovered from approximately 10% of all crime scenes visited by CSEs, relatively low compared to the rate of fingerprint recovery (32.7%) [283]. - Evidence is collected and packaged according to protocols and contamination or loss of evidence credibility is minimised.
Evidence submitted to the laboratory and analysed	- Packaged items collected from the crime scene are submitted for laboratory examination containing a lab submission form. Often laboratory scientists have very few other details (e.g. information regarding other evidence which was recovered but not submitted). - Laboratory submission forms allow scientists: to check the integrity of submitted items; to receive brief information relating to the case circumstance; to assess the needs of police investigations in terms of the desired outcomes of the requested analyses; and to calculate the time required to complete the

	analysis [23]. - Interpretation of evidence is restricted to the accuracy and relevance of the data provide, where data is the representation of current information. When information changes, the data produced is of lesser value and sometimes becomes completely irrelevant (or inaccurate) which wastes time and resources. - Analysis within forensic laboratories follows very strict protocols with previously approved, accredited and standardised working procedures (SOPs). These are tried and tested procedures, which have previously eliminated as many errors as possible to ensure the outcome of the analysis is reproducible and accurate within the given parameters. - Forensic analysis is often includes detailed and intricate procedures to obtain accurate results from (sometimes) very minute traces of evidence, therefore contamination factors are taken seriously and measures are in place to ensure this is controlled rigorously.
Results are interpreted in context of case and a is report produced	- The profiles obtained (DNA or fingerprints) are searched against information of known offenders held on a database. - If a match is found (identification), the details of the individual identified are passed onto the investigating police officers to make further enquiries or arrests [252]. - All results obtained by forensic scientists are communicated back to the police once they have been interpreted with the details know by the scientists of the case. - A report is produced which is sent to the police and which forms part of the investigative case report.

Appendix 2: Search strategies utilised in this study

Search terms:

- Crime management
- Crime scene investigation/Crime Scene Examiners/ Scenes of crimes officers
- Criminal investigation
- DNA + DNA database + Innocence Project
- Evidence +
    - Collection
    - Detection
    - Evaluation
    - Submission
- Evidence types – DNA, fingerprints, footwear marks, toolmarks, glass & CTM,
- Fingerprints/IDENT1/NAFIS
- Forensic +
    - Evidence
    - Investigation
    - Science
- Forensic Science Service
- Investigation
- Investigative process/techniques
- Management of criminal investigation
- Major/Serious crime
- Police + forensic science
- Robbery/burglary/theft/Vehicle or car crime investigation
- Scene attendance/detection levels
- Volume crime

Information sources:

- Academic Journals
    - British Journal Of Criminology
    - Forensic Science International
    - International Journal of Police Science & Management
    - Journal of Forensic Science
    - Science & Justice
- Association of Chief Police Officers + (Scotland)
- Athens: ISI Web of Knowledge
- European Network of Forensic Science Institutes (ENFSI)
- FBI website
- Home Office
    - Police Research
    - Science & Research
    - House of Commons
- Internet search engine – google.
- National Institute of Justice (NIJ)
- National Police Improvement Agency (NPIA)
- National Statistics Publication for Scotland
- Scientific Working Groups - SWGMAT/TREAD
- Scottish Government
    - Scottish Statistical Bulletin
    - Scottish Police Performance Framework
- Scottish Police Services Authority (SPSA)
    - SPSA Forensic Science Service
- Science Direct
- University of Strathclyde Library

Appendix 3: Overview of studies carried out in England & Wales and utilised in this report

Date	Title/Author	Publisher Report type	Research objectives/aims	Sample summary	Methodological approach	Outcomes	Weaknesses
1981	*"The Yorkshire Ripper Case"* L. Byford [96]	HMIC Case Review	To assess errors made in case and identify main criticisms of police.	Case analysis Eight police districts	- Police interviews - Examination of original documents, interviews and media files	Suggested improvements: - Standardization of procedures/documents - Computerization - Need for intelligence units	Review based on one case. Focus on how problems occurred rather than why.
1982	*"Clearing Up Crime"* J. Burrows & R. Tarling [101]	Home Office Research Paper	Examine variety of factors affecting clear-up rates.	Crime statistics were obtained from 41 forces, one year's statistics.	- Analysis of crime statistics - Data relating to forces e.g. number of officers from police - Use of socio-demographic data.	- Clear up rate - Clear up rate without TICs and other clearances without proceedings - Relative clear-up rate (relative to clear-ups per offender/crime rate).	Snap shot in time (one year). Focused on one aspect of the process only – police clear up rates.
1987	*"Review of Scientific Support"* Touche Ross Management Consultants [18]	Home Office Review	Assess main management issues within Scientific support services and police forces.	Police forces in E&W excluding the Met Police 6 Forensic laboratories	- Data analysis of staffing levels and crime rates 1984-86 (recorded, solved, detected) - Review of previous published work	- Requirement for national fingerprint system (AFR) - Need to improve quality of evidence collection - Implementation of SSMs - Development of genetic profiling	No statistical analysis undertaken.
1987	"*The Effectiveness of the FSS*" M. Ramsay [16]	Home Office Research Study	Examine the effectiveness and use of the FSS in England & Wales.	600 personal/ property crimes. Cases taken from 2 FSS labs in E&W. 6 police forces	Data collection - 593 case files - 887 police and scientist questionnaires - Follow up interviews	- Data analysis - Officer opinions/viewpoints on effectiveness - Turn-around times of cases from different forensic labs	Focused solely on the FSS.

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
1996	*"Using Forensic Science Effectively"* FSS & Association of Chief Police Officers (ACPO) [23]	FSS & ACPO Steering Group Research Study	Assess current investigative procedures. Provide models, information, and guidelines to improve use.	12 police forces 190 interviews. 2 other forces used in pilot.	- Documentary evidence from project between 1994–1995 - Semi-structured interviews - Workshops	- Staff attitudes (practitioners and suppliers) - Methods of forensic use (reactive or proactive) - Several issues affecting use of forensic science	Limited statistical analysis
1995	*" Combating burglary: an evaluation of three strategies"* J. Stockdale & P. Gresham [102]	Home Office Police Research Group	To evaluate police operations designed to tackle burglary and to identify good practice.	3 forces where operations implemented 169 interviews	- Interviews with police officers - Analysis of operations documentation	- Level of crime and detections - Police perspective and support of operations/additional benefits and drawbacks.	No raw data on which interpretations of strategies are based on.
1996	*"Forensic science and crime investigation"* N. Tilley & A. Ford [14]	Home Office Police Research Group	Evaluate police use of forensic science. Assess relevance of forensic provision.	Twelve forces 189 interviews	- semi-structured interviews - statistical information - review of major reports since 1981	- service supplier analysis - Opinions of practitioners and service suppliers which is backed up with documentary evidence.	Use of forensic science only analysed in investigative stage, does not consider effects on the CJS.
1996	*"Police use of forensic science"* H. McCulloch [12]	Home Office Police Research	Assess use of forensic science. Identify best-practice for collecting statistic.	11 forces Control group: 2 forces which did not use database	- Analysis of data extracted from the police database in year 1994	- submissions/tests - cost analysis - service supplier analysis - case/test timeliness - value of forensic tests	Focused on whether forces used SOCIMS. Forces input incomplete data, bias the results.

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
1996	"*Development and evaluation of a crime management model*" P. Amey; C. Hale & S. Uglow [94]	Home Office Police Research	Evaluation of a specific crime management model for proactive management of resources.	Preliminary work: nationwide survey of police forces in E&W 2 two sites pilot site	- Survey of existing crime management arrangements - Analysis of recorded crime figures and detections rates - Activity analysis - Staff survey	- Recorded crime - Detection rates - Staff attitudes - Victim satisfaction high.	Snapshot of time – 1 year. Work based on attitudes – staff, victims.
1996	"*The crime allocation system: police investigations into burglary and auto crime*." M. Gill, J. Hart, K. Livingstone & J. Stevens [76]	Home Office Police Research	Examine crime allocation systems Assess performance contribution (successful outcomes analysis)	9 forces chosen from postal survey, observed for 3 days 655 interviews in 3 forces	- Postal survey to all forces - Observations of police work - Semi-structured interviews with police officers	- Case allocation structures - Perceived effectiveness of investigations - Investigative actions and outcomes - Levels of victim reassurance.	No attempt made to link investigative actions with its results (cause & effect)
1996	"*Solving residential burglary*" T. Coupe & M. Griffiths [87]	Home Office Police Research Group	Analysis of the progress of burglary cases. Evaluate investigative actions to solve burglaries.	2 divisions, single UK force 704 burglary cases (256 detected, 448 randomly selected undetected cases)	- Questionnaire - Analysis of police statistics - Crime report analysis - Site observations - Victim interviews.	- Detection rate - Timeliness - Time spent at scene - A low number of residential studies were solved (6%) - Varied victim satisfaction.	Snapshot in time – 6 month period in 1994. No statistics of significance of findings.

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
2000	"*Under the Microscope*" Her Majesty's Inspectorate of Constabulary (HMIC) [40]	Home Office Research Study	Evaluate scientific support by police	43 forces: 6 inspection visits, semi-structured interviews, focus groups,	- audit of support activity - audit of 100 CJ DNA samples, 30 DNA & 30 fingerprint ident. - interviews - focus groups	- DNA, fingerprints, footwear management - Technical support - Training analysis - Performance - Timeliness - Budget constraints.	Data collected via checklists A follow-up from 1996 UFSE, to be followed up in the future.
2002	"*Investigating burglary*" J. Jacobson, L. Maitland & M. Hough [38]	Home Office Research Study	Assess process of burglary investigations. Identify key components of investigation and develop general principles for improving their effectiveness	3 three UK policing areas 2 forces: main variances in demographics and geography.	- Review of police practices - Case file analysis - 24 interviews, focus groups with officers - Officer shadowing	- The complexity of burglary investigations requires the adoption of systematic procedures. - A clear characterisation of the minimum activities to be undertaken is required.	Limited number of forces. Case reviews based on level of completion of paperwork.
2002	"*Under the Microscope: Refocused*" Her Majesty's Inspectorate of Constabulary (HMIC) [108]	Home Office Research Study (follow up to 2000 report)	Assess response to UTM, 2000. Assess rate of change and implementation of recommendations since 2000.	10 forces Target: Chief Officer responsible for Scientific Support, SSM and a nominated BCU commander.	- self assessment questionnaire	- poor implementation of recommendations since 2000 - some improvements in fingerprint and DNA management - generally limited effect of evidence on outcomes	Questionnaires completed based on self assessment – not a reliable means of measurement for change.

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
2004	"*The management of crime scene examination in relation to the investigation of burglary and vehicle crime*" R. Williams [15]	Home Office Research Study	Identify the factors (contextual & organisational) influencing scientific support performance levels.	7 forces 26 Semi-structured Unstructured interviews within one force only	- Data analysis - semi-structured interviews (individual/group) - other unstructured interviews - focus groups	- assess management of different resource levels - crime scene attendance policies - scene examination processes - performance outcomes	No statistical work carried out to assess the strength of evidence/data
2004	"*Measuring the impact of crime scene examination in relation to the investigation of burglary and vehicle crime*" R. Burrows & J. Tarling [9]	Science and Justice Research Paper	Investigated the forensic process across 8 paired basic command units Focused on attendance rates for specific crime types	7 police divisions Information from 5 forms of forensic material: fingerprints, SGM+ DNA, LCNDNA, footwear and toolmarks.	- Data analysis - semi-structured individual/group interviews - CSE attendance rates	- Measure relationship between rates of attendance and DNA hits and fingerprint identifications.	Results bases on estimates from two forces and the data has been applied to national statistics to calculate results.
2004	"*Reviewing murder investigations: an analysis of progress reviews from six police forces*" C. Nicol, M. Innes, D. Gee & A. Feist [79]	Home Office Review	Identify means of good reviews of the investigative process Identify recurrent themes in unsolved murder reviews. Assess the role of the review in any improvements of investigative performance.	Contents of 34 review documents analysed	- inspection survey data - qualitative analysis of 34 review documents - review of academic literature - interviews with six senior officers	- increased focus on tackling gaps in force policy on major crime - more encouragement for the adherence to existing policies (force and ACPO) - the recognition of the importance of disseminating good practice.	Reviews self-administered – potential for bias. Based on homicides – preference for resources than for VC.

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
2005	"*The Use of Forensic Science In Volume Crime Investigations: A Review of the Research Literature*" S. A. Bradbury & A. Feist [5]	Home Office Review	To collate and summarise previous research. To identify how forensic science is used and how it contributes to the detection/conviction of volume crimes.	50 previously published studies	- Systematic literature review	- the proportion of offences detected by forensic science is relatively small - change of evidence from corroborative evidence to inceptive purposes helped increase the proportion of detections	Review based on other people's work. No independent data collection or analysis to provide further evidence for their claims.
2005	"*Understanding the Attrition Process in Volume Crime*" J. Burrows, M. Hopkins, R. Hubbard, A. Robinson, M. Speed & N. Tilley [42]	Home Office Research Develop. and Statistics Directorate	To assess what solves crimes, why the attrition rate for volume crimes is so high and why the rate of detection varies across forces. To assess the policies /processes applied during investigation.	8 police BCUs Tracking of 3000 volume crime cases from crime to disposal Focus on two BCUs – one high rate of detections, the other low.	- Random sample selection for detected and undetected cases - File analysis - Interviews	- Factors other than attrition are affecting the rate of detection of volume crimes: the priority (of detection), the approach (to investigations) and the management of volume crimes, level of resources, attendance rate	Variations in collection of data from different police forces affects how complete the sample and the how complete the results were.
2005	"*Forensic Science Pathfinder Project: evaluating increased forensic activity in two England police forces*" J. Burrows, R. Tarling, A. Mackie, H. Poole & B. Hodgson [57]	Home Office Research Online Report	To reduce crime, tackle 'attrition' (and increase public confidence in the criminal justice system by assessing the effectiveness of applying enhanced forensic science techniques to scenes of volume crime	7 police divisions which hosted the Pathfinder Project in GMP and Lancashire	- Data were collected5 for 2 periods: - 1 year prior project (June '99- May 2000); - 1 year during projects (June 2000- May 2001).	- *LCN DNA:* potential for wider use vehicle crime. Cost major factor of police forces. - *Footwear:* mixed results. Collection of FW from crime scenes increased by 18%. Same for control division. - *Toolmarks:* widespread scepticism. Recoveries increased, low at 1.6. crime scenes.	

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
2005	"*Forensic Science On Trial*" House of Commons Select Committee on Science & Technology [19]	House of Commons Science & Tech. Committee Report	To investigate effects if the FSS is becomes a GovCo or a public-private partnership. To examine the quality of forensic science training, the levels of investment; and the general use of forensic science.	Assessment of the FSS	- five oral evidence sessions - 34 written submissions received in response to our call for evidence and requests for supplementary information.	- A number of recommendations identified - training of expert witnesses in the general principles of presentation of evidence to courts and the legal process is essential	No focus on the use of evidence but the impact of changing the status of FSS. Limited impact determined for databases and daily routines of forensic services
2006	"*Maximising the opportunities to detect domestic burglary with DNA & Fingerprints*" J. Bond [55]	International Journal of Police Science & Management Research Paper	To assess the impact of DNA and fingerprint evidence on the detection and reduction of domestic burglary. To assess if blanket attendance at crime scenes/increased timeliness of evidence processing affects outcomes.	Prioritisation of forensic resources over 6 months Northamptonshire Police Force FSS & National DNA Database facilities	- Cases analysis of performance against predetermined targets	- The increase in primary detections derived from DNA and fingerprints is significant. - Does affect the crime levels on a short term basis; however, levels of detection and crime levels return to per-assessment levels after study.	Snapshot in time and located at one force only. Broader, national analysis needs to be carried out to determine if regional differences can be established.
2007	"*Summary Report of the Scientific Improvement Package*" Scientific Working Improvement Model (SWIM) [37]	Home Office & Police Standards Unit Research Study	To assist in the delivery of scientific support in England and Wales. To assess systems and process, as well as individual force performance	41 police forces	- Development of a model for identification and detections processes - a systematic 4 step forensic process analysis & improvement frame work, process flowcharting and modelling	- Identifies performance gaps - Provides recommendations to forces to address them - Identify means of improving policing performance	Snapshot in time

Appendix 4: Overview of studies carried out elsewhere

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
1977	*"The Criminal Investigation Process"* P. Greenwood; J. Chaiken & J. Petersilia [255]	Report	Describe and assess investigative roles and practices. Reveal if staffing and procedural differences affect investigative outcomes.	Survey sent to 300 departments 153 responses 4 dep. chosen for detailed study. Relevant FBI stats and data relating to all dep. also used.	- A national survey - Police stats and case file analysis. - Official FBI stats/data for 296 deps.	- Crimes reported - Clearance rates - Arrest related measures - How crimes are solved - Quality of details given to prosecutors	Assessed clearance of crimes, do not consider that clearances occur by means other than arrests, or remain unsolved
1984	"*Forensic evidence and the police: The effects of scientific evidence on criminal investigations"* J.L. Peterson, S. Mihajlovic & M. Gilliland [253]	US Departme nt of Justice Report	Describe the various uses of physical evidence in criminal investigations. Assess the effects of evidence on the solution of serious crimes and the apprehension and prosecution of offenders.	Four jurisdictions Two types of cases– 1600 cases with forensic evidence and 1100 cases without. Additional cases containing just fingerprints or just suspected of drug offences	- Random case sampling of the initial case report which were reviewed from the four jurisdictions - Court reports were also reviewed	- There is a need for crime laboratories to establish policies defining the types of physical evidence which should be collected from crime scenes - Physical evidence makes substantial difference to case outcomes	Limited statistical analysis of results Limited to four jurisdictions
1987	*"The Uses and Effects of Forensic Science in the Adjudication of Felony Cases"* J.L. Peterson, J.P. Ryan, P.J. Houlden and S. Mihajlovic [254]	Journal of Forensic Sciences Research Paper	Investigate the uses and effects of forensic and other evidence on the judicial processing of criminal cases: decisions to charge, to determine guilt or innocence, and to decide the severity of sentences.	All the crime labs were contacted via a mail survey. Random sampling of several thousand felony case filings in six jurisdictions Exit surveys of several hundred jurors.	- Surveys of lab staff - Interviews - Hypothetical case scenarios, - Exit surveys jurors - Review of felony case filings.	- Confessions were the principal form of evidence influencing decisions to convict or acquit defendants. - Forensic science has greatest impact at time of sentencing. - Defendant imprisoned, longer where scientific evidence is presented.	

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
1994	*"Relationship between evidence, detective effort, and the disposition of burglary and robbery investigations"* S.G. Brandl & J. Frank [258]	American Journal of Police Research Paper	Evaluate the relationships between time spent on follow-up investigations, strength of evidence available and case outcome.	Case file analysis.	- Data was obtained from 1 medium size police dep. - All burglary and robbery cases with follow-up invest. from July 90-1. - 609 cases.	- Case closure status- arrest vs. no arrest.	Snapshot of one year. Single municipal police department.
1996	"*The Criminal Investigation Process and the Role of Forensic Evidence*" F. Horvath & R. Meesig [8]	Journal of Forensic Science Research Paper	To determine the role played by forensic evidence in the investigative process.	Review of findings from empirical studies on the effects of forensic analyses on criminal cases.	- Review of previous published work	- Most cases do not use physical evidence. - Value of evidence rarely recognised if available. - Evidence predominantly used to strengthen case in order to gain confession from suspect.	Based on review of literature. No own research carried out, therefore no data available for analysis.
2003	*"Partners in Crime: Solving & Reassuring: A Thematic Inspection of Crime Management in Scotland"* Scottish Government & HMICS [44]	HMICS Thematic Inspection	To assess the management of volume crime. To focus on incident handling, crime recording, investigation, police reporting, use of technology, and victim needs.	Data from British Crime Survey Collaboration with all Scottish Police Forces Inspection March – May 2003	- Review of procedures from all 8 forces via a inspection. - Review of procedures from 8 English & Welch forces. - Completion of comprehensiv e 73 question protocol.	- Greater focus on the management of crime scenes as affected crime rates. - Greater focus on victims of crime has positive impact on fear of crime. - Technological advances have been beneficial to crime management.	Lack of statistical analysis. Limited raw data.

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
2004	*"The Effects of DNA on the Criminal Justice Process"* M. Briody [98]	PhD Thesis Unpub.	To examine the effects of DNA evidence on the investigative process and subsequent decision in court.	750 cases referred by police for prosecution (½ with DNA, ½ with other evidence) Offences divided into: sexual offences, serious assault, homicides and property crime.	- Quantitative analysis on primary data - Secondary data and literature used to assess strategic impact of forensic intelligence	- DNA evidence had positive impact on cases going to court for the three serious offences, as well as providing a power influence on jury decisions. - DNA had no real effect on cases going to court for property crimes, however significant impact on guilty pleas.	PhD thesis carried out in Australia: technically unpublished work
2004	*"Fire Investigations Scotland"* A. Jamieson [50]	Arson Prevention Bureau Research Study	To assess current fire investigation procedures in Scotland. Recommend improvements for the future.	All major stakeholders: PF, Police, Fire Service, H&S Executive, insurers, Local Authorities, etc.	- Analysis of previously published studies and consultation interviews with stakeholders and policy makers	- To create a national unit specifically to analyse fire-related data - A need to develop recognised professional standards	Focused on fire investigation, not directly linked to volume crime investigations.
2008	"*Acquisition and Retention of DNA and Fingerprint Data in Scotland*" J. Fraser [93]	Scottish Gov. Review of Consultation Paper	To review the operation and effectiveness of the legislative regime governing police powers regarding the acquisition, use and destruction of forensic data.	Mains stakeholders of forensic science Scottish police forces	- Interviews with main stakeholders - Analysis of data from stakeholders	- Data relating to the governance and management of forensic databases are to be freely available - Urgent review is required of the current governance arrangements for forensic databases (DNA & Fingerprint)	General analysis of the implications of the retentions of evidence rather than direct effect on the investigative process.

Date	Title/Author	Report	Research aims	Sample size	Methodology	Outcomes	Weaknesses
2008	"*The DNA Field Experiment: Cost-Effectiveness Analysis of the Use of DNA*" J. Roman, S. Reid, J. Reid, A. Chalfin, W. Adams & C. Knight [99]	US Dep. of Justice Research Study	To test the different approaches to the use of DNA as a tool in the investigations of property crimes. To assess the cost-effectiveness of DNA in the investigation of burglary crimes.	8 police forces throughout the US November 2005 – July 2007 500 crime scenes	- Randomised study in five experimental sites - Impact analysis of the estimated differential outcomes between treatment and control area	- DNA evidence at property crimes results in 2x as many suspects identified and arrested, 2x as many cases accepted for prosecution than other evidence. - DNA is 5x more likely to identify offender than fingerprints. - Suspect identified using DNA had twice as many prior arrests	Snapshot from the expanded use of DNA, focused effort on evidence and crime type so could bias results.
2009	"*Strengthening Forensic Science in the Unites States*" National Academies of Science [6]	National Research Council Research Report	To assess the resource needs of the forensic science community; to maximise technology to solve crimes; to promote accredited training programmes and to disseminate best practice.	Committee made up of members of the forensic science, community, the legal community, and diverse group of scientists. Also, consolations were had with experts.	- Review and consultation with experts and committee members.	- Need to establish standards for the mandatory accreditation of forensic science labs and scientists - Need for more control, - More research to address issues of accuracy, reliability, and validity - Need for more training	Sometimes deemed over critical.
2011	"*The Role and Impact of Forensic Evidence in the Criminal Justice Process"* J. Peterson, I. Sommers, D. Baskin & D. Johnson [45]	National Institute for Justice Research Report	To estimate frequency of evidence collection; To track the use and attrition of evidence; To identify the types of evidence which contribute most frequently to successful case outcomes.	A total of 4,205 cases sampled: 859 aggravated assaults, 1,263 burglaries, 400 homicides, 602 rapes 1,081 robberies. Descriptive and impact data collected.	- Prospective analysis of official record data that followed criminal cases in five jurisdictions	- *Aggravated Assaults* - collection of physical evidence was + predictor of arrest. - *Burglary* – witness reports and physical evidence = + predictor for arrest - *Homicide* - Cases with evidence 21x times more likely to be charged.	

Appendix 5: Cover Letter for survey "The Use of Forensic Science in Scotland"

Dear all,

As part of my PhD research being undertaken at the University of Strathclyde Centre for Forensic Science, I would like to invite you to take part in a short survey. As well as exploring available published literature in this area, the project above is interested in the views of everyone involved in Scottish criminal justice sectors (forensic science, police, law, scene examination, lab technician, academia, etc.).

The focus of the survey is based on volume crimes and encompasses crimes of dishonesty: including theft by housebreaking (dwelling, non-dwelling, business), all attempted theft by housebreaking, theft of a motor-vehicle and theft by opening–lockfast–place (motor vehicle and non-motor vehicle).

The survey is completely anonymous (the provision of contact email address is voluntary) and comprises of seventeen short tick-box questions. It should take no longer than 10 minutes to complete.

There are no right or wrong answers and all information collected will be kept confidential. It will not be possible to identify anyone from the results of this survey. The results will be used to compile a summary of the views of the use of forensic science across different professions and levels of experience. Please answer all questions within the questionnaire (to the best of your knowledge).

Please return the questionnaires not later than the 30th of June 2009 to the representative at your organisation who will return them in the stamped, self-addressed envelopes provided (postage covers the return of a maximum of twenty questionnaires per envelope). If you have any queries or comments or would like further information, please do not hesitate to contact me.

Thank you very much for your time,

Anika Ludwig

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Appendix 6: Survey "The Use of Forensic Science in Scotland"

Introduction

- We would like you to take part in a survey based at the University of Strathclyde, studying the attitudes towards the use of forensic science among people working in the Scottish criminal justice sectors.
- The focus of the survey is based on the category of 'volume crimes'. In Scotland, this encompasses various crimes of dishonesty: including theft by housebreaking, theft of a motor-vehicle, and theft by opening–lockfast–place (OLP); in England and Wales this includes robbery, burglary-dwelling/non-dwelling, TWOC and theft of a motor vehicle.
- There are no right or wrong answers. We are carrying out this research to discover your views on the use of forensic science within specific sectors of the criminal justice system. Please answer all questions within the questionnaire (to the best of your knowledge).
- All information collected will be kept confidential and your answers will only be used for research. Only members of the research team will have access to the completed surveys. It will not be possible to identify anyone from the results of this survey. If you are willing to be contacted by a member of the research team, please provide an email address: _____.

Your Details

Gender: *MALE* ☐ *FEMALE* ☐ **Age:** _____ *YEARS*

What is the name of the organisation you work for?: _____

What is your current rank/job title/grade? _____

Total Years of Service: _____

What is the highest academic qualification you have attained? *(tick one only)***:**

None ☐ *Secondary School* ☐

Undergraduate/Bachelors' Degree ☐ *(Subject(s) studied and level)* _____

Postgraduate Degree ☐ *(Subject(s) studied and level)* _____

Other qualification (Subject(s) studied and level): _____

Training and Knowledge

Q1. – Have you received any specific forensic training? *YES* ☐ *NO* ☐

Q1(a). – Please indicate the type of training you received:

Formal training (e.g. Police College) ☐ *Coaching/Shadowing* ☐

On the job training ☐ *Reading material (e.g. best practice guide)* ☐

Other (please specify) ☐ _____

Q1(b). – Please estimate the total amount of training you received:

_____*HOURS/DAYS/WEEKS/MONTHS (Delete as appropriate)*

Q2. – How frequently are you involved in decisions about the following:

	Never	Rarely	Sometimes	Regularly	Always
Crime scene attendance	☐	☐	☐	☐	☐
Evidence recovery	☐	☐	☐	☐	☐
Lab Submission	☐	☐	☐	☐	☐

Q3. – Please rate the following types of forensic materials in terms of their value to volume crime investigations in providing **intelligence** to further an investigation:

Forensic Material	No Value 1	Limited Value 2	Some Value 3	Valuable 4	Great Value 5
DNA	☐	☐	☐	☐	☐
Fingerprints	☐	☐	☐	☐	☐
Footwear marks	☐	☐	☐	☐	☐
Glass traces	☐	☐	☐	☐	☐
Tool-marks	☐	☐	☐	☐	☐

Q4. – Please rate each type of the following forensic materials in terms of their **maximum strength of evidence** in establishing a link between a suspect and a crime scene:

Forensic Material	Limited support 1	Some Support 2	Strong Support 3	V. Strong Support 4	Conclusive Link 5
DNA	☐	☐	☐	☐	☐
Fingerprints	☐	☐	☐	☐	☐
Footwear marks	☐	☐	☐	☐	☐
Glass traces	☐	☐	☐	☐	☐
Tool-marks	☐	☐	☐	☐	☐

Communication & Information

Q5. – The following questions (Q.5a – Q.5d) contain a list of personnel involved in the investigative process from whom it may be possible to seek advice from. Please indicate who you seek advice from and indicate using the tick boxes below.

Q5 (a). – Assessing the potential value of attending a specific crime scene:			
Colleagues in same role	☐	*More experienced colleague in same role*	☐
Immediate supervisor	☐	*SSM or CSM*	☐
SIO	☐	*Forensic Scientist*	☐
Detective Officer	☐	*Crime Scene Examiner (CSE)*	☐
None of these	☐	*The Forensic Gateway*	☐
Other (please specify)	☐	_____	
Q5 (b). – Assessing the potential value of evidence at a scene:			
Colleagues in same role	☐	*More experienced colleague in same role*	☐
Immediate supervisor	☐	*SSM or CSM*	☐
SIO	☐	*Forensic Scientist*	☐
Detective Officer	☐	*Crime Scene Examiner (CSE)*	☐
None of these	☐	*The Forensic Gateway*	☐
Other (please specify)	☐	_____	
Q5 (c). – Deciding what forensic materials to recover:			
Colleagues in same role	☐	*More experienced colleague in same role*	☐
Immediate supervisor	☐	*SSM or CSM*	☐
SIO	☐	*Forensic Scientist*	☐
Detective Officer	☐	*Crime Scene Examiner (CSE)*	☐
None of these	☐	*The Forensic Gateway*	☐
Other (please specify)	☐	_____	
Q5 (d). – Deciding what forensic samples to submit for laboratory examination:			
Colleagues in same role	☐	*More experienced colleague in same role*	☐
Immediate supervisor	☐	*SSM or CSM*	☐
SIO	☐	*Forensic Scientist*	☐
Detective Officer	☐	*Crime Scene Examiner (CSE)*	☐
None of these	☐	*The Forensic Gateway*	☐
Other (please specify)	☐	_____	

Skills & Knowledge

Q6. – This is a list of statements related to the skills, knowledge, experience and availability of a wide range of personnel who may be involved in investigations of volume crime. Please indicate how much you agree or disagree with each statement using the tick boxes below:

Q6 (a). – Having a skilled and experienced investigating officer is of great importance in ensuring a positive outcome from an investigation.

Strongly Disagree ☐ *Disagree* ☐ *Neither Dis/Agree* ☐ *Agree* ☐ *Strongly Agree* ☐

Q6 (b). – The availability of experts/expert advice is of great importance in a criminal investigation.

Strongly Disagree ☐ *Disagree* ☐ *Neither Dis/Agree* ☐ *Agree* ☐ *Strongly Agree* ☐

Q6 (c). – National intelligence databases (i.e. DNA database) are very useful in obtaining positive outcomes during investigations.

Strongly Disagree ☐ *Disagree* ☐ *Neither Dis/Agree* ☐ *Agree* ☐ *Strongly Agree* ☐

Q7. – In your opinion, the role of crime scene examiner is best described as?

Evidence collector ☐ Forensic Investigator ☐ Specialist advisor ☐

Systems & Procedures

Q8. – Does your organisation operate a tasking policy for attending volume crime scenes by CSEs?

YES ☐ *(if yes continue to Q8a & Q8b)* *NO* ☐ *DON'T KNOW* ☐

Q8 (a). – Does this policy require blanket or selective attendance for the following crimes?:

	Blanket	**Selective**
Theft	☐	☐
Theft by housebreaking (dwelling)	☐	☐
Theft by housebreaking (non-dwelling)	☐	☐
Theft by housebreaking (business)	☐	☐
All attempted theft by housebreaking	☐	☐
Theft from motor vehicle	☐	☐
Theft by opening – lockfast – place	☐	☐
Attempted theft by opening – lockfast – place	☐	☐

Q8 (b). – Are there any other priorities for volume crime scene attendance policies?

YES ☐ *(please specify)* _____ *NO* ☐

Appendix 7: Codebook used in SPSS for questionnaire responses

	Variables	SPSS Name	Coding Instructions	
1	**Sex**	*Sex*	1-Male	2-Female
2	**Age**	*Age*	Years	
3	**Total Years of Service**	*Yos*	Years	
4	**Place of Work**	*PoW*	1-SPSA Edin 3-SPSA Dundee 5-COPFS 7-L&B Police	2-SPSA Glasgow 4-SPSA Aberdeen 6-Strath Police
5	**Current Rank**	*Rank*	1-Scientist 3-FP Examiner 5-Detective Cons. 7-Detective Serg. 9-Chief Inspector 11-Chief Super	2-CSE 4-Police Const. 6-Police Serg. 8-Inspector 10-Super
6	**Degree**	*Degree*	1- None 3-Undergrad Degree 5-PhD	2-Secondary School 4-Masters Degree 6-Other
7	**Specialist Training**	*Trai1*	1-Yes	2-No
8	**Type of Training**	*Trai2*	1-Formal Training 3-On the job 5-Other 7-FT & OTJ 9-CS & OTJ 11-OTJ & R 13-FT, C & R 15-All	2-Coach/ Shadowing 4-Reading 6-FT & CS 8-FT & RM 10-CS & RM 12-FT, C& OTJ 14-C, OTJ&R 16-FT, OTJ&R
9	**Total years/hours/days**	*Trai3*	Time	
10 11 12	**DM CSE attendance** **DM evidence recovery** **DM lab submission**	*DM1* *DM2* *DM3*	1-Never 3-Sometimes 5-Always	2 - Rarely 4 - Regularly
13 14 15 16 17	**Intelligence DNA** **Intelligence FP** **Intelligence FW** **Intelligence Glass** **Intelligence TM**	*Intel 1* *Intel 2* *Intel 3* *Intel 4* *Intel 5*	1-No value 2 - 3-Indifferent 4- 5-Great Value	

18 19 20 21 22	**Linking DNA** **Linking FP** **Linking FW** **Linking Glass** **Linking TM**	*ValDNA* *ValFP* *ValFW* *ValGlass* *ValTM*	1 - Limited Support 2 - 3 - Strong Support 4 - 5 - Conclusive	
23	**Skilled IO is important** **Availability of expert** **National databases**	*IO* *Exp.* *NDNAD*	1-Strongly Disagree 3-Neither 5-Strongly Agree	2-Disagree 4-Agree
24	**CSE role**	*CSE role*	1-Evidence Collector (EC) 3-Specialist Advisor (SA) 5-EC & SA 7-All	2-Forensic Investigator (FI) 4-EC & FI 6-FI & SA
25	**Formal policy**	*FormP*	1-Yes 3-Don't know	2-No
26	**Other priorities**	*Oth.Pol*	1-Yes	2-No
27	**Advice sources** (Experienced) Colleague Immediate supervisor SSM/CSM SIO Forensic Scientist Detective Officer CSE Forensic Gateway None/other	 *Col.* *ImSup* *CSM* *SIO* *FS* *IO* *CSE* *FG* *None*	1-Yes	2-No
28	**Attendance Policy** Attendance theft Attendance theft HB (D) Attendance theft HB (ND) Attendance theft HB (B) All attempted theft HB Theft from MV Theft OLP Attempted theft OLP	 *AT1* *AT2* *AT3* *AT4* *AT5* *AT6* *AT7* *AT8*	1-Blanket	2-Selective
29	**Other attendance policies**	*AttPol*	1-Blanket 3-Don't Know	2-Selective

Appendix 8: Kendal's Tau table of correlation coefficients

Key to tables:

Label in table	Description of variable
1. Age	Age in years
2. Years of Service	Number of years worked in specific role
3. Place of work	Name of SPSA branch or Police Force
4. Role	Current role description
5. Quali.	Highest qualification obtained
6. Train.	Whether specific forensic training has been received.
7. Type Train.	Type of training received
8. Am. Train.	Amount of training received (number of hours, days, weeks, months)
9. F1 10. F2 11. F3	Frequency of decision making regarding … : *... scene attendance* *... evidence collection* *... laboratory submission.*
12. Intel. DNA 13. Intel. FP 14. Intel. FW 15. Intel. Glass 16. Intel. TM	Value of … as intelligence to further investigations. *... DNA* *... fingerprints* *... footwear marks* *... glass fragments* *... tool-marks*
17. Weight DNA 18. Weight FP 19. Weight FW 20. Weight Glass 21. Weight TM	Maximum weight of … evidence in establishing a link between a suspect and a crime scene. *... DNA* *... fingerprints* *... footwear marks* *... glass fragments* *... tool-mark evidence*
22. Adv. Source 1 23. Adv. Source 2 24. Adv. Source 3 25. Adv. Source 4	Personnel from whom advice is sought from when…: *Assessing the value of attending a specific crime scene* *Assessing the potential value of evidence at a scene* *Deciding what forensic materials to recover* *Deciding what samples to submit for examination*
26. IO	Importance of a skilled investigating officer for ensuring a positive outcome from an investigation.

27. Expert	Importance of the availability of experts or expert advice in a criminal investigation.
28. NDNAD	Value of national intelligence databases (i.e. DNA database) in obtaining positive investigative outcomes
29. CSE	How the role of the CSE best described.
30. Formal Policy	Is there a tasking policy for attending volume crime scenes
31. Other Policies	Are there any other crime scene attendance policies
	Type of attendance policy for … (blanket or selective):
32. AT1	*... Theft*
33. AT2	*... Theft by housebreaking (dwelling)*
34. AT3	*... Theft by housebreaking (non-dwelling)*
35. AT4	*... Theft by housebreaking (business)*
36. AT5	*... All attempted theft by housebreaking*
37. AT6	*... Theft from motor vehicle*
38. AT7	*... Theft by opening – lockfast – place*
39. AT8	*... Attempted theft by opening – lockfast – place*

Table 16: Kendal's Tau correlation coefficient calculations

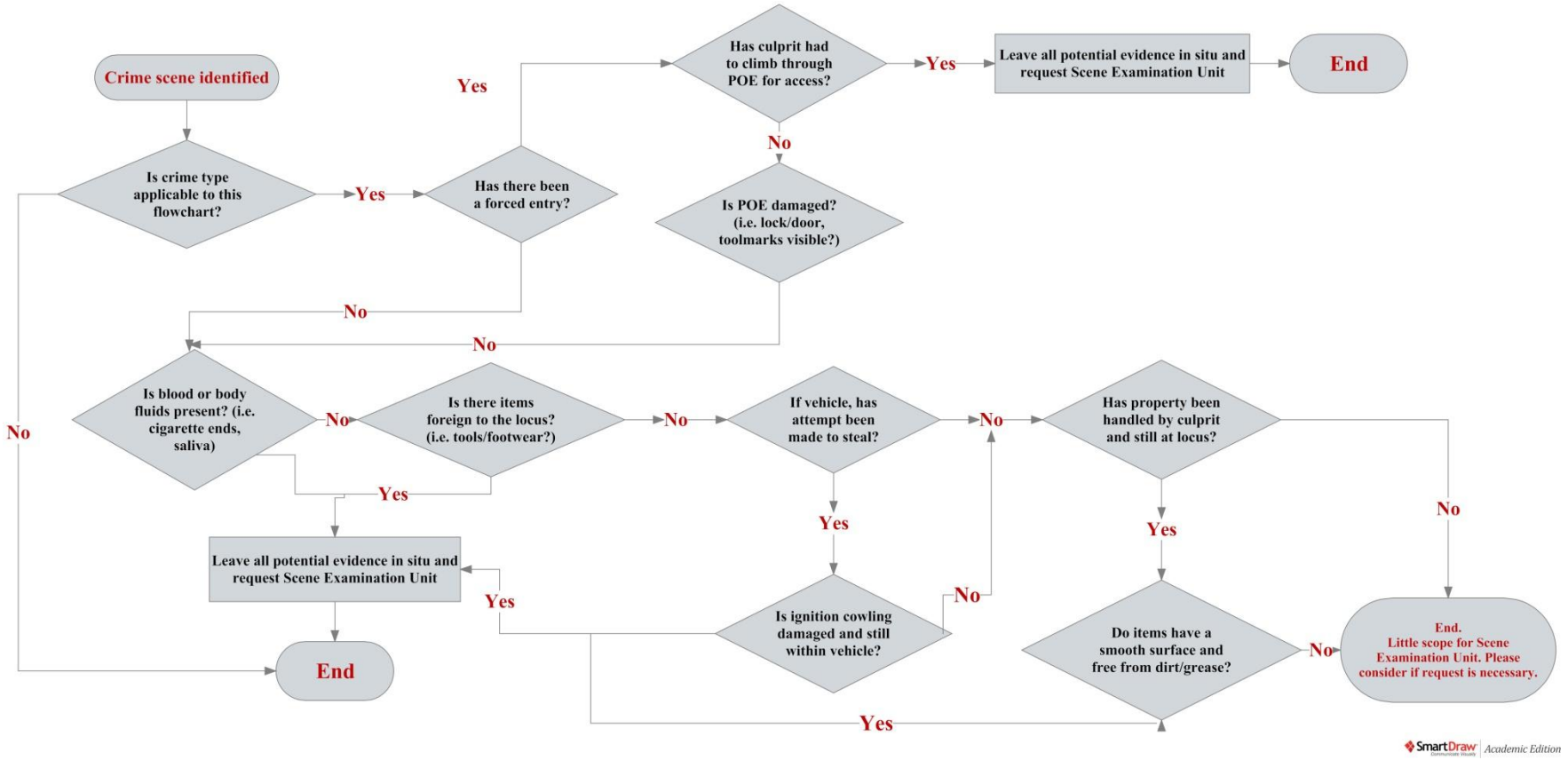
Kendall's Tau Correlation		POW	Role	Quali.	Train.	Type train	Amount train	F1	F2	F3	Intel DNA	Intel FP	Intel FW	Intel Glass	Intel TM	Weight DNA	Weight FP	Weight FW	Weight Glass	Weight TM	AS1	AS2	AS3	AS4	Skilled IO	Experts	NDNAD
YoS	Correlation	.191**	.310**	-.107*	-.066	.000	-.010	.293**	.171**	.221**	.078	.094	.011	-.027	.057	.064	.031	.066	-.012	.034	-.106*	-.146**	-.093*	-.049	.107*	.007	.067
	Sig. (2-t)	.000	.000	.025	.197	.993	.852	.000	.000	.000	.121	.060	.823	.575	.237	.210	.545	.167	.803	.474	.017	.001	.036	.275	.028	.890	.182
	POW		.651**	-.266**	.286**	.012	-.403**	.301**	.175**	.206**	.012	-.004	-.163**	.097	-.032	.146**	-.035	-.137**	.069	-.019	-.174**	-.200**	-.211**	-.206**	.043	-.088	.079
			.000	.000	.000	.810	.000	.000	.000	.000	.828	.944	.002	.060	.535	.008	.522	.007	.180	.706	.000	.000	.000	.000	.414	.102	.140
		Role		-.314**	.285**	.097*	-.399**	.321**	.143**	.159**	.022	.033	-.135**	.060	.012	.222**	.048	-.113*	.073	-.007	-.175**	-.202**	-.184**	-.173**	.058	-.040	.116*
				.000	.000	.047	.000	.000	.004	.001	.688	.539	.009	.243	.821	.000	.383	.027	.158	.888	.000	.000	.000	.000	.270	.455	.031
			Quali.		-.160**	-.050	.091	-.114*	-.034	-.038	-.039	-.035	-.002	-.101	-.026	-.150**	-.061	.025	-.059	.021	-.022	.015	-.032	-.050	-.023	.068	-.071
					.005	.319	.125	.026	.502	.457	.489	.525	.971	.057	.623	.008	.276	.631	.267	.696	.650	.760	.510	.310	.664	.217	.198
				Train.		.460**	-.046	.084	.023	.056	-.048	-.047	-.074	.115*	.025	.128*	-.031	-.063	.144*	.025	-.119*	-.118*	-.094	-.124*	-.091	-.068	.025
						.000	.479	.131	.682	.309	.420	.429	.194	.045	.667	.035	.605	.267	.012	.653	.024	.026	.076	.019	.117	.252	.677
					Type train		.220**	.085	.040	.046	.108*	.109*	.031	.106*	.066	.079	.075	.008	.049	-.046	-.118*	-.104*	-.083	-.093*	-.017	.037	.019
							.000	.082	.413	.342	.043	.040	.543	.038	.194	.140	.160	.868	.337	.363	.012	.027	.077	.047	.738	.484	.715
						Amount train		-.207**	-.185**	-.125*	.030	.059	.096	.052	.010	-.128*	-.074	.059	-.041	-.006	.101	.115*	.116*	.113*	.033	.188**	-.052
								.000	.001	.032	.635	.358	.113	.391	.871	.049	.250	.332	.500	.919	.074	.042	.039	.045	.597	.003	.417
							F1		.729**	.654**	.127*	.119*	-.035	-.073	-.065	.171**	.013	-.052	-.050	-.089	-.263**	-.315**	-.351**	-.304**	-.052	-.139**	.078
									.000	.000	.019	.028	.496	.161	.204	.002	.811	.309	.335	.082	.000	.000	.000	.000	.317	.010	.147
								F2		.728**	.122*	.089	.004	-.111*	-.091	.140*	-.031	-.056	-.111*	-.118*	-.219**	-.289**	-.339**	-.275**	-.045	-.092	.118*
										.000	.024	.098	.936	.032	.075	.010	.573	.271	.031	.021	.000	.000	.000	.000	.384	.085	.028
									F3		.108*	.074	-.013	-.051	-.035	.073	-.076	-.039	-.097	-.086	-.233**	-.275**	-.313**	-.280**	-.082	-.055	.096
											.045	.169	.800	.321	.493	.180	.166	.445	.059	.090	.000	.000	.000	.000	.117	.303	.075
											Intel DNA	.564**	.072	.015	-.032	.254**	.134*	-.074	-.065	-.139*	-.074	-.047	-.015	.002	.079	.113	.310**
												.000	.195	.791	.569	.000	.023	.182	.242	.011	.152	.361	.776	.964	.166	.054	.000
												Intel FP	.247**	.048	.091	.070	.246**	.096	.028	.014	-.019	-.066	-.008	.040	.045	.031	.106
													.000	.390	.099	.232	.000	.082	.618	.799	.713	.197	.874	.440	.428	.598	.068
													Intel FW	.415**	.519**	-.037	.053	.417**	.255**	.350**	.059	.016	.023	.062	.049	.097	.032
														.000	.000	.512	.342	.000	.000	.000	.229	.746	.634	.210	.358	.080	.565
														Intel Glass	.578**	.018	-.017	.134*	.389**	.291**	-.009	.045	.031	-.008	.069	.131*	-.010
															.000	.749	.758	.010	.000	.000	.863	.368	.529	.870	.204	.019	.862
															Intel TM	-.029	.016	.276**	.303**	.478**	.036	.050	.059	.034	.072	.038	.037
																.604	.773	.000	.000	.000	.468	.310	.233	.494	.182	.489	.500
																Weight DNA	.546**	.070	.090	-.044	.003	-.008	.002	.007	.123*	.111	.251**
																	.000	.207	.109	.429	.955	.880	.977	.887	.032	.060	.000
																	Weight FP	.256**	.160**	.106	.029	.025	.074	.138**	.069	.063	.117*
																		.000	.004	.056	.585	.625	.154	.009	.228	.285	.048
																		Weight FW	.494**	.562**	.140**	.097*	.068	.121*	-.011	.027	-.024
																			.000	.000	.004	.047	.165	.014	.831	.621	.658
																			Weight Glass	.650**	.048	.047	-.005	.056	.061	.127*	.027
																				.000	.329	.344	.921	.258	.261	.022	.626
																				Weight TM	.098*	.126**	.063	.121*	.085	.082	.033
																					.043	.010	.195	.013	.111	.136	.548
																					AS1	.645**	.554**	.531**	.056	.047	.045
																						.000	.000	.000	.262	.360	.382
																						AS2	.736**	.672**	.036	.094	.011
																							.000	.000	.474	.067	.833
																							AS3	.703**	.052	.073	.027
																								.000	.299	.157	.600
																								AS4	.075	.127*	.036
																									.133	.014	.490
																									Skilled IO	.475**	.342**
																										.000	.000
																										Expert	.331**
																											.000

Correlation significant p<0.01

Correlation significant p<0.01 not useful

Correlation significant p<0.05

Appendix 9: Flowchart process for crime scene call outs for thefts OLP and theft HB



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