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Solving Violent Crime: Targeting Factors that Predict Clearance of Non-Domestic Violent Offences

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Abstract

This study aims to identify factors which indicate clearance of non-domestic violent crime, and determine whether there are factors that policing agencies can target to improve clearance rates, whilst assessing the inter-variable effects of suspect information, before designing a predictive model and comparing the accuracy of this statistical model to the existing West Midlands Police experiential allocation model. It uses all cases of violent crime reported to West Midlands Police between 1st March 2012 and 31st December 2013, which amounts to 29105 cases. This dataset is split randomly into two. The first half (n=14553) is used to identify factors and build the predictive model, which is then tested against the second half of the dataset.

A wide range of variables was obtained for each case in the dataset and these were first analysed using chi-squared tests, t-tests, aoristic analysis and effect size analysis to identify twenty-five solvability factors, including forensic investigator attendance which is an underused but powerful indicator, and thirteen case-limiting factors. Some factors changed direction of prediction based on elimination or inclusion of cases with suspect information. Researchers will need to consider inter-variable effects when conducting solvability analysis.

The majority of these factors were used in a logistic regression which was reverse-engineered to provide a formula for prediction of case outcome. The cut-off point was adjusted to minimise the impact of incorrectly filed reports and additional opt-in factors were included to reduce the reputational risk to policing agencies. The new model was

tested against the existing allocation model, and predictive accuracy was 11.62% better with the new statistical model. This provides an argument for policing agencies to adopt statistical allocation models and develop use of forensic examination for violent crimes.

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Introduction

Violent crime is recognised by the World Health Organisation (1997) as being a serious international health concern, causing death and suffering on a global scale. Interpersonal violence is a major contributor to disability, personal injury and illness. Sivarajasingam and colleagues (2012) estimate that over 250,000 people sought urgent medical treatment following violence in 2012 and that this was worst amongst young people. The physical effects of violent crime such as injury are clear. However, violent crime has also been associated with psychiatric disorders such as post-traumatic stress disorder (Brewin et al., 1999; O'Brien, 1998). Whilst clearly an estimation, and with some methodological weaknesses such as the removal of people who valued violent crime reduction at zero, the value per incident of intangible effects of crime are estimated, by surveys of how much victims would be willing to pay to avoid being victims, at £5,282 for common assault and £35,844 for serious wounding (Atkinson et al., 2005). This demonstrates that violence has a large economic impact which only increases when pain, suffering and fear of crime are taken into account (Dolan and Peasgood, 2007; Dolan et al., 2005). Violent crime accounts for about a quarter of all crimes in volume but is estimated to account for fifty-eight percent of the tangible costs of all crime (Brand and Price, 2000). In terms of overall impact, violent offences could be considered the power few (Sherman, 2007) offences that, if improved, may make a massive difference in terms of community safety, fear of crime and demand on police resources. This is the case despite police records tending to underestimate violence levels (Clarkson et al., 1994; Mayhew, 2014).

The police have a duty to maintain order, prevent harm to people and property, and are the organisation responsible for investigating violent crime and ensuring that violent offenders are subject to appropriate justice. Detection of violent crime is important, as it is likely to reinforce public opinion that police are able to maintain order, and may create a deterrent effect on potential offenders or reduce offences through incarceration (Von Hirsch et al., 1999). However, detection rates have remained at around 40% between 2008 and 2013 (Smith et al., 2013) and Shepherd (1997, p.208) argues that "violence which results in the need for hospital treatment is often not investigated by police and assailants are rarely brought to justice."

Solvability factors, or identification of factors which correlate with successful outcomes, have been researched for many crime types including burglary, vehicle crime, robbery and homicide. However, minimal work has examined violent crime other than homicide, and there have been no large-scale analyses of solvability factors for violent crime which would provide sufficient statistical power to identify factors which are significant but play only a small part in clearance of violent crime. This research will expand upon the work of other solvability studies, using a large-scale population of offences to address solvability of violent offences. It has been suggested (Skogan and Antunes, 1979) that violent offenders are more likely to be described or identified, which in turn assists the investigation. This research will also examine whether investigative factors show differential impact on solvability in the presence or absence of suspect information.

West Midlands Police (WMP) uses a Crimes Service Team (CST) to record and screen crime offences. The screening tool assesses initial investigative evidence in relation to offender identity, forensic opportunities, CCTV, vehicle details, availability of witnesses and other factors. This means that WMP gathers more data relating to solvability than many other forces which makes it ideal for conducting research of this sort. However, whilst screening crimes is likely to result in a more sensible allocation of investigative resources, the screening tool was based upon officer experience and intuition, rather than analysis of solvability. This poses a risk that cases are incorrectly allocated or filed, which may waste resources or cause victims to be let down whilst offenders escape justice. Kahneman (2011, p.224) identified that prediction formulae are frequently superior to human decision makers. In times of austerity and public and political pressure on police agencies, it is imperative that any screening tools used are as accurate as possible. However, even in the area of burglary where the majority of solvability research has been conducted, there is a lack of research involving examination of extensive datasets to design and test a predictive model. As in research conducted by Paine (2012), where predictive models are proposed, they have often been tested on the dataset used to design them.

This thesis reviews the existing literature in relation to solvability, paying specific attention to research which has examined violent offences and homicide. Following this, the limitations of previous research are identified and research aims are laid out to expand upon prior research. The methodology is then laid out for the study of 29105 cases of violent crime to identify factors which are more prevalent in detected cases than undetected cases for non-domestic violent crime. The results of individual factor analyses

using chi-squared tests and t-tests are then presented individually and in an effect size analysis to identify factors which indicate clearance of non-domestic violent offences and which can be developed by UK police agencies, with consideration given to the impact of factors in the presence and absence of suspect information. Finally, through use of logistic regression, a predictive model is designed and tested on a separate dataset to indicate the extent to which clearance of violent crime can be predicted and to develop current solvability models. This thesis then tests this predictive model against the current WMP allocation mechanism. The outcomes are then discussed and compared to existing research along with the practical and policy implications of these findings.

Literature Review

This literature review commences with a description of the difficulties and benefits of detecting violent crimes and then reviews the background behind identification of factors that indicate whether offences are solved. It examines initial work by the RAND Corporation (Chaiken et al., 1976) which suggested that crimes were solved based on circumstances and initial investigation, rather than subsequent investigative work. This is contrasted with Eck's (1983) Triage Hypothesis which suggests that, whilst some cases may seem to solve themselves and others may be un-solvable, there are cases that can be solved if the right work is put in. Most solvability research has examined volume crimes. The mechanisms by which solvability has been studied and the results of these investigations are then scrutinised before the previous research into violent crime solvability is discussed. Homicide is violent crime with the most serious outcome. Despite this research not including homicide offences, the literature in relation to homicide detection provides a larger pool of research into factors which is examined in detail. The role of case screening and the mechanisms by which solvability has been predicted is then scrutinised to review what is known about prediction of detection. The literature review then identifies how this research will target gaps in current evidence and how it aims to increase knowledge of solvability.

Benefits and Difficulties of Solving Violent Crime

Violent crime is a serious issue which has both a physical impact upon the lives of people affected by it through injury or inability to work and intangible effects such as pain, suffering and fear of crime (Dolan et al., 2005). There may be serious under-reporting of

violence, as both the 2009/10 and 2010/11 British Crime Surveys estimated there were in excess of 2 million violent incidents against adults each year in England and Wales, with under half that number recorded by police in the same periods (Flatley et al., 2010; Chaplin et al., 2011). Detecting crime may encourage reporting, help to deter potential offenders (Maguire, 2003), and may reduce crime through incapacitation of offenders who might otherwise commit further crime (Jansson, 2005; Levitt, 2004).

Clearance rate may be a sign of police effectiveness (Cordner, 1989; Litwin, 2004). Perceptions of police effectiveness may impact upon trust in police (Tankebe, 2008; Tyler and Fagan, 2008) so detecting crime, thus demonstrating that police agencies are able to bring offenders to justice, is important. Low clearance rates may damage trust in police (Regoeczi et al., 2000) and officer morale (Riedel and Jarvis, 1998). Violent crimes are often more solvable than other offences where victims do not come into contact with offenders as violent offences involve a greater likelihood that victims will be able to identify their attackers (Burrows and Tarling, 1982; Smit et al., 2004; Thanassoulis, 1995). However, national figures for detection of violent offences demonstrate that only 44% of total violent offences were detected in 2010/11 and 2011/12, although the detection rate for murder reached 95% in 2011/12 (Taylor and Bond, 2012; Taylor and Chaplin, 2011).

Ousey and Lee (2010, p.152) argue that low clearance rates may "increase the sense of insecurity among the general public." It has also been suggested that uncleared crimes may traumatise victims or increase fear of victimisation (Riedel and Jarvis, 1998). With citizens being co-producers of services they receive, (Whitaker, 1980) therefore being necessary

for the investigative process, insecurity amongst the public may result in less cooperation from victims and witnesses, which may impact on solvability. Riess (1971, p.69) comments that “the citizenry has enormous power to subvert the system by its decisions to call the police or not.” Violent offences have an added complication in relation to other crime types as the offender has already demonstrated that they are willing to harm, therefore witnesses may not co-operate with police due to fear of retaliation (Myers, 2000).

However, as Gill and colleagues (1996, p.44) state, “Members of the public are probably the greatest investigative resource available to the police” and so, whilst lack of information may place upper bounds on police ability to solve other crimes (Skogan and Antunes, 1979), the prevalence of witnesses in violent crime aids investigators and provides a basis upon which other investigative factors can be built. It also provides scope for detection of violent crime to increase through effective allocation of cases for investigation.

Initial Work

Isaacs (1967) examined 1905 crimes of which only 336 (18%) resulted in an arrest, and found that the suspect being named by the victim was key. Of the 1905 crimes, 1556 did not have named suspects and 88% of these cases were not solved. Of the 349 cases with named suspects, 86% were solved.

Greenwood (1970) examined burglary, robbery and grand larceny crimes and found that a suspect being named was associated with arrest likelihood than where only a description or other evidence was available.

The RAND Corporation (Greenwood et al., 1975) built upon these earlier studies by using case assignment files to examine how detectives used their time and analysis of cleared crimes to describe how they were solved. They argued that there are two types of investigation; cases which do not result in a clearance but take a substantial amount of time and resources, and cases which are solved with little work but require substantial effort once solved. They also found that most solved cases involved either an arrest at the scene (around 22%), identification of an offender at the time of reporting (around 44%), or actions they describe as being "routine" for investigators (around 34%) such as showing mug-shot albums to witnesses. They state that "investigative special action" by detectives, such as comparison of fingerprints based on modus operandi, only accounted for about 3% of clearances (Greenwood et al., 1975, p.ix). They concluded that "case solutions reflect activities of patrol officers, members of the public and routine clerical processing more than investigative techniques" (Chaiken et al., 1976, p.1) and that the information the victim provides to the initial responding officer is the most important factor (Greenwood and Petersilia, 1975).

The RAND study was dubious about the investigative value that detectives add, stating that the circumstances of the crime are more important than any subsequent investigation and that the overwhelming majority of case solutions are due to factors that are immediately

available to responding officers or to an arrest being made at the scene. Detectives were perceived by the authors as spending most of their time reviewing cases that would never be solved or preparing files for court. In support of these findings, general follow-up investigations by detectives were found to be ineffective in non-homicide investigations by Weisburd and Eck (2004) and other researchers have found that the majority of detections were due to the actions of the attending officer at the scene (Coupe and Griffiths, 1996; Brandl and Frank, 1994).

The RAND study (Greenwood et al., 1975) made multiple findings and lengthy recommendations. However, these were based upon a methodology with a low response rate and small sample size. For example, only ten instances of detected aggravated assault were examined, all of which were solved through initial investigation. Sherman (2003) has advised that it is dangerous to produce misleading evidence about the conclusions of any study or to make overstated claims about the generalizability of the conclusions. Over 35 years later, Telep and Weisburd (2011) argued that there was still insufficient evidence in relation to the work of detectives to assess their effectiveness. Therefore the RAND conclusions were likely to have been overstated. However, the suggestion that most cleared cases would be solved regardless of secondary investigative actions was later labelled as the circumstances-result hypothesis (Eck, 1983), a theory somewhat supported by colloquialisms of homicide investigators who describe cases as self-solvers where officers obtain prosecutions easily, and whodunits which have “a more problematic and extended search” to identify a suspect (Innes, 2003, p.197).

Eck's Triage Hypothesis

Eck (1983) argued that there are likely to be differences between crime types and that by putting them all together, as in the RAND study, the true impact of factors may not be demonstrated. Therefore Eck (1983) focussed entirely on burglary and robbery investigations. Eck concluded that the key finding of the RAND study was too severe and that secondary investigations did impact on clearance of crimes.

Eck (1983) drew on two sets of contrasting findings and labelled them; those of Greenwood and colleagues (1975) were called the circumstance-result hypothesis, and those of Folk (1971) who stated that investigative effort determined the outcome of cases, regardless of leads, were described as the effort-result hypothesis. Eck then presented a further hypothesis which he called the triage hypothesis.

The triage hypothesis posits that there are three types of cases. The first are those which practically solve themselves and where little to no detective work is required. Second came the suggestion of a new group of cases where there are leads and the cases are solvable, but solution of these cases relies on investigative work. Thirdly, there are cases which may never be solved, and which certainly cannot be solved using a reasonable level of resourcing. The triage hypothesis presented a set of cases where, if investigative effort is concentrated, it may be possible to improve the chance of solving cases. The argument for this was made through analysis of burglaries and robberies where Eck (1983) identified that some information found during the initial investigation was predictive of whether an

arrest was made. However, this finding also applied to the presence of actions performed by detectives following on from the initial investigation.

It has been suggested that the groupings of cases are not as clean cut as Eck (1983) describes, with some cases, which would be predicted to remain unsolved, being solved and some self-solvers remaining undetected (Coupe, 2014b). Whilst there may be slight blurring of groups, Eck's triage hypothesis provides an explanation for solvability of offences which fits with most available evidence and provides scope for improvements in investigative efficiency. Technology available to investigators has improved dramatically over that available in 1983. Therefore Bradbury and Feist (2005) note that investigative factors such as availability of analysable forensic evidence may have changed the proportions of these groups by moving cases from being unsolvable to being solvable with reasonable effort. In times of austerity we must find out what works and not throw money at things which do not (Bueerman, 2012). If it is possible to identify solvability factors which identify cases in this group, it may be possible to greatly improve police investigative efficiency, especially given improvements in evidence gathering techniques.

Identification of Solvability Factors

Solvability factors are items of information, including leads, which are components of the crime or are available for investigators to act upon, and when examined together are determinant of the likelihood of solving a crime. As Coupe (2014a) discussed, two types of studies have examined solvability factors; solvability studies examining multiple factors have mainly considered burglary and robbery, and studies of clearance and detection have

considered the effects of various factors on other crime types such as assault, rape and homicide (Ousey and Lee, 2010; Paré et al., 2007; Roberts, 2008; Wellford and Cronin, 1999). Both types demonstrate that there are characteristics of investigations which are differentially present in solved and unsolved cases. Because the majority of solvability studies have examined volume crime, these are considered first, followed by violence and finally murder. This is to demonstrate how factors are identified before assessing specific discoveries in relation to violent offences.

Paine (2012) conducted a large-scale descriptive analysis in Thames Valley Police which was expanded upon by Paine and Ariel (2013). Data was obtained for 128 variables for each of 14306 recorded burglary and attempt-burglary offences. 57 variables were useful for comparison between solved and unsolved cases. These useful variables included information relating to stolen property, location characteristics, presence of witnesses, temporal characteristics, forensic evidence and speed of response. Paine (2012) identified solvability factors by comparing differences in presence of factors between solved and unsolved cases using Chi-squared tests. Fourteen factors were identified as solvability factors as they had the highest effect sizes. The predictive accuracy of 12 of these is stated to be over 80% for each variable. However, this may be due to low solvability rate for burglary. If no burglaries at all were investigated, given the Thames Valley burglary detection rate of 10.68% (Paine, 2012, p.34), 89.32% of cases would be correctly allocated, although no crimes would be detected.

Whilst unable to create a predictive model, Paine (2012) was able to identify factors, such as identification of footwear impressions, with low prevalence in the dataset but which were shown to be strong indicators of solvability. Paine (2012) discusses the limitations of such a large sample, as it prevented close examinations of the cases to establish the origin and reliability of the data and also prevented identification of other variables that were not electronically recorded but argues that he has avoided a pitfall faced by some studies, where factors are not identified due to low statistical power (Weisburd and Britt, 2007), through having such a large sample of cases. This is consistent with Baskin and Sommers' (2010; 2012) argument that research into the impact of forensic evidence is frequently limited by small sample size.

Consistent with other studies (Burrows et al., 2005; Coupe and Griffiths, 1996; Eck, 1979; Eck, 1983; Stevens and Stipak, 1982), Paine and Ariel (2013) found that on-scene capture of suspects and suspect identity information are factors which are most likely to relate to an arrest. This has been found consistently across a range of crime types including non-residential burglary (Coupe and Kaur, 2005), robbery (Newiss, 2002) and vehicle crime (Burrows et al., 2005). Paine and Ariel's (2013) findings that footprints, fingerprints and DNA were important in prediction of solvability for burglary are consistent with some other authors (Bond, 2007; 2009; Coupe and Griffiths, 1996), whilst others have disputed their value (Burrows et al., 2005). Despite findings and policy documents that suggest the value of forensic evidence (ACPO, 1996; Bradbury and Feist, 2005), Robinson and Tilley (2009) demonstrated that use of forensic techniques was inconsistent.

Despite these findings relating to volume crime, a number of factors have been identified which may also impact on violent crime. These are the presence of proactive policing methods (Robb et al., 2014), the offence being witnessed (Donnellan, 2011; Paine, 2012), availability of CCTV (Robb, 2012), offence commission during daylight hours (Coupe and Blake, 2006), availability of resources (Coupe and Griffiths, 2000) and reporting early in commission of offence (Coupe and Blake, 2005). Speed of response has been suggested as being linked to solvability (Blake and Coupe, 2001; Clawson and Chang, 1977) but this may only be the case if the crimes are reported immediately (Bieck and Kessler, 1977) or within five minutes of the offence (Spelman and Brown, 1981).

This provides an overview of factors which should be considered when examining clearance of violent crime, in addition to those identified in the next section which scrutinises previous research into assault solvability.

Solvability Factors for Assault

Greenberg and colleagues (1977) found it difficult to identify solvability factors for violent offences. Since then, few studies have examined solvability of non-lethal violent crime, and even fewer with large enough samples to identify factors with low prevalence.

However, Roberts (2008) used logistic regression to examine the effect of incident and contextual characteristics on arrest for non-lethal violence and found that for robbery and aggravated assault, incidents with multiple victims or with concomitant offences were

more likely to be cleared. Consistent with other research (D'Alessio and Stolzenberg, 2003), victim injury was associated with higher solvability.

Having a known offender has also been associated with greater likelihood of clearance (Eitle et al., 2005; Peterson et al., 2010), and Tilley and colleagues (2007) concluded that eyewitness reports which provide suspect information or facilitate the offender being caught nearby are the most indicative factor in relation to whether a violent offence will be solved. This is consistent with Baskin and Sommers' (2012) findings that victim and witness accounts were significantly linked with solvability. Eitle and colleagues (2005) also found that offences which occurred in dwellings were more likely to be solved. However, this may be linked to an offender being known. There is some conflict over the benefit of forensic evidence in relation to clearance of violent offences. Baskin and Sommers (2012) found no link whilst Peterson and colleagues (2010; 2013) demonstrated clear links between collection and analysis of physical evidence and arrest of suspects.

A number of factors have been observed to be associated with reduced likelihood of clearance of violent crime. Use of a firearm in commission of the offence and time elapsed since the offence were also factors which Roberts (2008) showed to be less likely to be found in correspondence with solved crimes. Incidents between strangers are also associated with lower clearance levels for robbery and assault (D'Alessio and Stolzenberg, 2003; Snyder, 1999).

This review demonstrates how sparse the evidence is in relation to solvability of non-lethal violence. Whilst it is possible and necessary to draw upon the findings of studies relating to non-violent crime, it is also beneficial to examine crimes which are closely associated, such as homicide.

Solving Homicide

Whilst murder investigations are often treated very differently from other investigations, they involve a violent offence with a more serious outcome and, in most, the victim is unable to provide an account of what has occurred. As Gottfredson and Hindelang (1979) argue, the most serious offences often gain a greater response from police and the legal system. This is consistent with the detection rates in England and Wales for murder being much higher than for assault. This section shows an overview of the factors which have been identified as being determinant of murder solvability and are considered in this research.

Roberts (2007) examined 1579 murder incidents and identified factors which were more likely to be associated with cleared cases. As with a number of other studies, Roberts found that crimes with a female victim (Regoeczi et al., 2000) or with a younger victim (Addington, 2006; Litwin, 2004; Mouzos and Muller, 2001; Puckett and Lundman, 2003; Regoeczi et al., 2000; Roberts, 2014; Wolfgang, 1958) were associated with greater solvability. The latter finding may be due to children being more likely to have a guardian with them or be hurt by someone they know (Cardarelli and Cavanagh, 1992). Victims involved in drug- or gang-related activity were more likely to be associated with solved cases, a finding which is

consistent with Litwin and Xu (2007) but not with Lee (2005). Roberts (2007) also demonstrated that witnesses and physical evidence were key indicators of solvability, along with offenders who were under the influence, non-stranger offenders, contact-type weapons and concomitant serious offences, although the presence of concomitant offences has been argued to act in the opposite direction by others (Litwin, 2004; Riedel and Rinehart, 1996; Wellford and Cronin, 1999). Use of firearms in the offence was found to limit solvability, possibly due to reduced evidence transfer between offender and victim (Geberth, 1996).

Many studies of homicide clearance rate have utilised a multivariate approach with homicide clearance as the dependent variable, and characteristics of the incident and victim as predictors. Similar to Alderden and Lavery (2007), most have used logistic regression to examine links between their identified characteristics and clearance. Use of contact weapons such as knives consistently indicates increased solvability (Addington, 2006; Mouzos and Muller, 2001; Puckett and Lundman, 2003). As with Roberts (2007), firearm usage is associated with lower solvability in some studies (Litwin, 2004; Ousey and Lee, 2010), though not in others (Riedel and Rinehart, 1996; Wellford and Cronin, 1999). The victim-offender relationship is an important factor (Brown and Keppell, 2012; Lee, 2005; Litwin and Xu, 2007; Roberts, 2014). This may link to findings that homicides inside dwellings are more solvable (Litwin, 2004; Regoeczi et al., 2008; Wellford and Cronin, 1999), and that crimes with offenders who are strangers are associated with lower clearance rates (Lee, 2005; Mouzos and Muller, 2001; Ousey and Lee, 2010). Lee (2005)

also found that cases with more than one victim or which elicited interest from The New York Times were more likely to be cleared.

As with other crimes, eyewitness testimony appears key in whether homicides are cleared (Corwin, 1997; Geberth, 1996; Riedel and Rinehart, 1996; Wellford and Cronin, 1999). This may explain some of the effect observed by Alderden and Lavery (2007) where late night (00:00 to 05:59hrs) homicides were less likely to be solved, and that presented by Wellford and Cronin (1999) where crimes occurring in good weather conditions showed higher solvability. Presence of physical evidence has been linked to increased likelihood of clearance in homicide (Briody, 2004), child abduction homicide (Brown and Keppell, 2012) and cold cases (Davis et al., 2014). However, as with other crime types, some studies have failed to show this, potentially due to low sample size (Peterson et al., 2010) or inferior DNA testing capability for old crimes (Baskin and Sommers, 2010).

Greenwood and colleagues (1975) argument that skill of detectives was unimportant conflicts with findings of Marché (1994) and Puckett and Lundman (2003), who found that investigator experience appears to aid detection of homicides, especially those with low solvability. Similar to findings from other crime types (Burrows and Tarling, 1982; Tilley and Burrows, 2005), high officer workload (Roberts, 2014) and lower numbers of detectives per case (Wellford and Cronin, 1999) have been argued to correspond with lower likelihood of clearing cases. Keel and colleagues (2009) also found that self-reported caps, or approval requirements, on overtime were associated with lower homicide clearance rates. These findings demonstrate that it is possible to identify solvability factors for even the most

violent of offences, and that failure to use these factors to guide the allocation of investigative resources may result in fewer crimes being solved.

Case Screening and Prediction of Solvability

The Association of Chief Police Officers (ACPO, 1989, p.6) defined crime screening as "a structured system to help target investigative resources on crimes most likely to be detected. This requires an objective assessment of the nature and number of solvability factors available at the time of the initial investigation or subsequently." Her Majesty's Inspectorate of Constabulary (HMIC, 2012) stated that the process of screening, allocation and finalisation of crimes is required to facilitate effective investigation. Whilst it is important to consider the political ramifications and effects on public confidence that may be associated with perceived service reductions (Denis et al., 2007), the fact that labour accounts for a large percentage of restricted police budgets means that, if some resources are not wasted on unsolvable investigations, "it seems logical that detectives would have a better chance of clearing the smaller number of remaining solvable cases" (Williams and Sumrall, 1982, p.112).

Formal case screening occurs in many police forces (BBC News, 2013), and where it does not officers will frequently screen cases informally to concentrate on those they view as most promising (Waegal, 1982; Brandl and Frank, 1994; Coupe and Griffiths, 1996). However, formal screening mechanisms are predominantly based on officer perceptions, experiences and public interest assessments (Gill et al., 1996; Robinson and Tilley, 2009). These mechanisms vary between forces which may result in inconsistencies (Coupe and

Griffiths, 1996). Cawley and colleagues (1977) identified that cases can be screened based upon weighted or un-weighted criteria. WMP uses an un-weighted inclusion model where the presence of any factor dictates that the case is allocated. The factors were identified by officers as dictated by experience and perception, then combined with public interest factors and mandatory offences. As statistical judgements are frequently more accurate than those of even the most experienced practitioners (Kahneman, 2011, p.224), it is important to consider whether case screening should be based upon experiential or statistical judgements of weighted or un-weighted factors.

Greenberg and colleagues (1973) performed a discriminant analysis of 2000 burglaries to identify solvability factors, of which they identified six, which they then combined to create a case screening model. This model was then tested against a disparate sample of 500 burglaries using information from the primary investigation. Each solvability factor was weighted based upon its predictive capability. Greenberg and colleagues (1973) predicted case clearance to between 67 and 92 percent accuracy.

Eck (1979) replicated the above research and found that it was possible to predict investigative outcome accurately in 85% of cases. Eck (1983) found that six percent of solvable cases were incorrectly screened out, resulting in the potential for victims to be let down, and that nine percent were incorrectly screened in which potentially wastes resources but to a much lesser degree than if no screening is performed.

Eck's (1983) triage hypothesis suggests that application of investigative effort to a smaller number of solvable cases should increase clearance rate. Williams and Sumrall (1982) found that filing cases identified as unsolvable resulted in an increased clearance rate without additional resourcing. However, this was a simple before-after design so only reaches level 1 on the Maryland Scale (Sherman et al., 1998) and lack of randomisation or other scientific rigour means that it cannot identify causality (Sherman, 2010).

Targeting allows prioritisation of scarce resources, so it is important to consider whether investigative resources can be allocated through prediction of the outcome following the initial investigation. This author has been unable to find a direct comparison between a predictive allocation model and an experiential model and Sherman (2013) states that as of 2012 it was still difficult to find a police agency that used a statistical model of solvability to allocate investigative resources. Therefore there is much to be gained from identifying solvability factors and building a predictive model which can be compared to an experiential model using a large dataset.

Aims of this Research

Due to the limited literature investigating factors affecting solvability of violent offences and the lack of research into prediction of violent crime solvability, this research seeks to expand our knowledge of solvability factors for violent crime as follows:

First, in relation to violent crime, there is little evidence of the factors that contribute to case solvability and much of the available research has involved smaller samples than may

be necessary to identify significant factors. This research uses an extensive dataset from a Force with high data quality to identify factors that indicate solvability of non-domestic violent offences.

Second, under fifty percent of violent crimes are solved in most UK forces whilst solvability is much higher for murder where investigative opportunities are maximised. This research identifies factors which contribute towards violent crime clearance that can be developed by UK policing agencies to facilitate increases in clearance rate.

Third, as suspect information has been shown to be an extremely strong factor in most studies (Burrows et al., 2005), it may skew the impact of other variables on solvability. This research examines and identifies areas where solvability factors differ between cases where suspect information is available to investigators and cases where it is not.

Fourth, there are few research papers which have designed a usable statistical predictive model, and most predictive tools have been tested against the dataset used to design them, limiting their external validity (Hagan, 2006). A predictive model for clearance of non-domestic violent crime is designed, presented and then tested using a large separate dataset to assess the extent to which case solvability can be predicted by factors identified in this research.

Finally, WMP uses an un-weighted allocation model based on officer perceptions and experience. It is clear from previous research that efficiencies may be gained from using

weighted models (Eck, 1979), but direct comparisons have not been conducted between experience-based models and weighted statistical models for violent crime. This research compares the current WMP model to the predictive model prepared in this paper and examines the accuracy with which they each predict case solvability following initial investigation.

Methods

It is possible that other studies have failed to identify important solvability factors due to insufficient sample sizes and lack of statistical power. To obtain the maximum possible statistical power within this study and reduce the risk of failing to identify solvability variables (Weisburd & Britt, 2007), this research maximises the size of the available dataset, whilst ensuring that maximal homogeneity is retained to reduce some of the pitfalls that large studies can face (Weisburd et al., 1993). Due to the fact that there has been insufficient examination of violent crime solvability, this research addresses the identification of factors which indicate clearance, before moving the research forward in a practically usable manner by producing a predictive model, and contrasting this with an experiential model of case allocation. The research questions addressed by this thesis are laid out, and the outcome measure defined, before the data selection process is explained and the variables that were obtained and used are described. The mechanism for splitting the dataset is then demonstrated before data accuracy is addressed. The analytical procedures used are then laid out before a discussion of difficulties faced by, and limitations of, this research

Research Questions

This research sets out to improve our understanding of non-domestic violent offence solvability by addressing the following questions:

1. What factors indicate clearance (solvability) of non-domestic violent offences?
2. Are there investigative factors that contribute towards violent crime solvability which can be developed by UK policing agencies?

3. Are there factors which affect clearance of violent crime differently dependent upon whether there is suspect information available?
4. To what extent can case clearance be predicted by factors identified in this research?
5. How does the current WMP case screening mechanism compare to the factors identified in this research when predicting case solvability?

For investigation of these research questions, it is necessary to define the outcome measure, before other variables can be obtained and examined.

Defining Clearance

There have been a number of different outcome measures used in solvability studies. Studies in the US may use arrest in the same way that detection is used in the UK (Paine, 2012) as it requires a prosecutor to approve the outcome. However, in the UK, arrest is simply based upon reasonable grounds to suspect that the person has committed an offence. Therefore there are many suspects who are arrested but are never formally sanctioned.

Williams and Sumrall (1982) suggested that conviction rate could be used. However, there are numerous factors and agencies, other than the evidence in the case, which can prevent conviction. Sanction detection is the clearance of a crime through imposition of a sanction on the offender. This has been used by numerous UK studies (Burrows et al., 2005; Donnellan, 2011; Paine, 2012) but it may miss out a small amount of cases where sanction

is not imposed but the same evidential threshold is met. Clearance by non-sanction detection has previously been thought open to "manipulation" (Bloch & Bell, 1976, p.7) and "bias" (Greenwood, 1970, p.5). However, Home Office (2011, p.15) demonstrates that non-sanction detections now only include cases where there is sufficient evidence to charge and either the defendant is deceased or a decision is made not to prosecute despite having the capability of doing so. The evidential standard that is required is the same in each case. The Home Office, as of April 2014, now records solved offences as offences having positive outcomes. This includes all outcomes which are based on the evidential standard above, both sanction and non-sanction, and is the mechanism for measurement of police clearances in the UK. Therefore clearance is measured in this research by positive crime outcome as this provides the most accurate, most complete, outcome measure available.

Data Selection

A preliminary examination of WMP data relating to violence against the person was completed for all relevant offences that were reported between January 2010 and May 2014. The time to detect these offences was measured as the time between offence commencement and detection in days. The minimum was 1 day and maximum 1,026 days. The mean was 31.8 days. The predicted accuracy of detection, or likelihood that the crime would be filed within a given period, was calculated based upon these data. This assumes a similar detection pattern for the offences used in this study which is likely due to the fact that this is a large population of the same offence types. It is predicted that 97 percent of

violent crimes that are detected will be detected within 155 days and 99 percent will be detected within 221 days.

The Crimes Service Team (CST) was implemented throughout West Midlands Police by 27th February 2012. Therefore, 1st March 2012 was selected as a start point for data that were examined as the CST improved data collection, data quality and homogeneity of crime recording. The data that were examined in this research were all violent crimes reported between 1st March 2012 and 31st December 2013. The start date ensured that all crimes were recorded through the CST. It would have been possible to increase the size of the dataset by including earlier offences but this is likely to have increased variation in the dataset. The end date was determined to allow enough time before analysis for the cases to be cleared, as the accuracy of this research would be eroded massively by errors in determining the outcome of the cases. The dataset was downloaded during May 2014, which meant there were just over four months between the last recorded crimes and the download date. It was predicted that 96.8% of cases would be finalised by this point. To increase this further the outcome variable, whether the cases were cleared or not, was re-downloaded on 12th September 2014, prior to the final analysis. This means that even the offences recorded on the last day of the data period had a 99.3% chance of being finalised.

Exclusion Rules

All crimes with special interest markers for Child Abuse, Vulnerable Adult and Domestic Violence were then removed. Due to their intra-familial nature and relationships between offenders and victims, these crimes may be inherently different in terms of solvability. The

Home Office Counting Rules (Home Office, 2014) were examined and a number of offences were discounted from the overall research. Murder and manslaughter are not included as they differ from other violence by virtue of the victims being unable to provide any evidence, and receive substantially more resources for investigation, being investigated by a stand-alone department in WMP. Attempted murder of a victim under one year old was discounted as children are nearly always killed by someone known to them (Regoeczi et al., 2008), so these may have a different detection pattern.

Driving-related violent offences and public order offences were removed as these would introduce additional heterogeneity and may detract from the aims of this research. Conspiracy offences were removed as they can involve suspects who were not at the original incident. Finally, all offences relating to police, PCSOs, detention staff, prison staff, and any offences committed whilst resisting arrest, were removed as these are likely to have been committed in the presence of a public official and therefore generally have higher detection rates (Jansson et al., 2005; Smith et al., 2013). Paine (2012) suggested removal of offences that are taken into consideration (TIC) as they can incorporate no solvability factors. This would have been completed but there were none of these present in the dataset.

Use of these dates and exclusion rules provided 29,105 cases for analysis which are broken down by offence in table 1, over double that used to identify solvability factors for burglary by Paine (2012) and nearly ten times that used by Robinson and Tilley (2009).

Table 1: Crime Types

Offence Type	Count
Common Assault	7285
Racially/Religiously Aggravated Common Assault	496
Assault Occasioning Actual Bodily Harm (ABH)	13250
Attempt Malicious Wounding	3
Malicious Wounding	3779
Racially/Religiously Aggravated ABH and Malicious Wounding	520
Attempt to Inflict Grievous Bodily Harm (GBH) without Intent	3
Inflicting GBH without Intent	1556
Racially/Religiously Aggravated Inflicting GBH without Intent	22
Attempt to Cause GBH with Intent to do GBH	273
Cause GBH with Intent to do GBH	1874
Attempt Murder - Victim 1 Year Old or Over	44
Grand Total	**29105**

Figure 1 shows the percentage of cleared and uncleared cases in the overall dataset. For the period between 1st March 2012 and 31st December 2013, there were 29,105 violent offences of which 43.41% (12635) were cleared by positive outcome. Figure 2 shows the method by which these cases were solved.

Figure 1: Clearance Rate

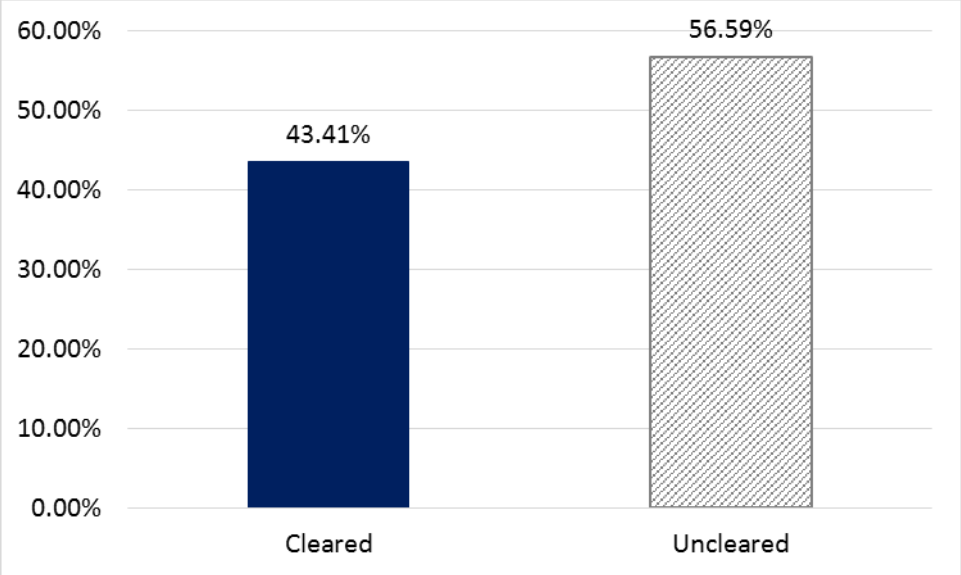
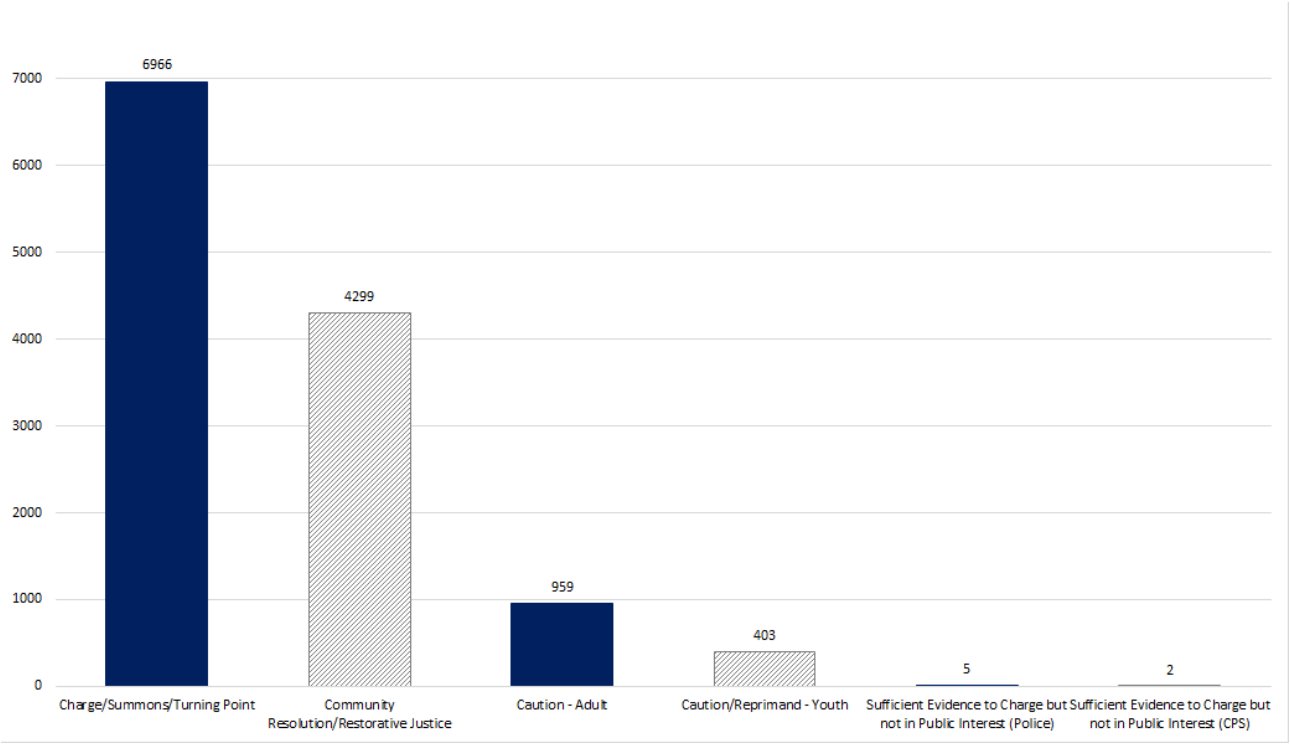


Figure 2: Clearance Method



Data Sources and Variables Examined

There is a wealth of information recorded by police services. When considering whether factors will be useful in predicting solvability of violent crime, the literature does not provide many to include. However, when combined with factors identified for other crime types, as identified in the literature review, a comprehensive list is created. This list is contained in Appendix 1 which also demonstrates the systems that data were obtained from.

Whenever a crime is recorded, the CST officer asks a series of solvability questions. These questions comprise a yes or no answer and a notes field to expand on the answers. These

fields provide information about some traditionally described solvability factors. These questions relate to: whether there is any suspect information available during the initial investigation, whether officers have identified forensic opportunities, if the crime is part of a series, whether there has been identifiable or hazardous material stolen, any vehicle details that have been identified, any outstanding traceable witnesses, whether there is potential or usable CCTV, and anything else the officer thinks may help solve the crime. All of these fields were downloaded. This allowed examination of the information currently available for solvability calculations.

In addition, data were retrieved from a number of different WMP systems via the data warehouse: offence details, report method, locations, temporal information, case member details, details of weapons, modus operandi and outcome information were recovered from Crimes and the Crimes Update Portal; details of all scanned documents relating to these offences were gathered from Crimescan; details of allocation and investigation movement from Docutrak; information concerning the attendance of forensic scene investigators and recovery of physical evidence were downloaded from Socrates.

The data were downloaded in multiple different formats from the WMP data warehouse and were then reformatted into Microsoft Excel in order that each case could be reconciled with information available for other cases. Because one of the desired end-results of this research is to provide a model which can be utilised by police services to screen cases for allocation, it is necessary for any variables which are used by a prediction model to be stored electronically so that an automated computer model can draw upon the necessary

data. Therefore dummy variables were created, consistent with those used by other researchers (Litwin, 2004; Puckett and Lundman, 2003), such as whether the offence occurred in a private indoor location (Riedel and Boulahanis, 2007). The entire list of variables examined is provided in Appendix 2. Lists of the factors which make up the dummy variables in Appendices 3 and 4.

Splitting the Dataset

Each case was given a unique reference number. Due to the large number of cases available in the data, it was possible to build the model using one half of the data and then test on the other half, thus avoiding an over-fitting of the data. To facilitate this, the data was split into two groups. This was done using the Random.Org Random Sequence Generator. Random allocation avoids sample selection bias (Heckman, 1979) and greatly assists external validity (Campbell and Stanley, 1963) by maintaining the capability to generalise the findings to the whole population.

It is important to establish that the groups, despite being randomly allocated, are equivalent (Hagan, 2006). Therefore, descriptive analysis was conducted with both groups. Table 2 demonstrates that they are equivalent in terms of offence types whilst Table 3 demonstrates that they are equivalent in terms of clearance.

Table 2: Group Comparison – Offence

Offence	Analysis	Predictive	Grand Total
Common Assault	3667	3618	7285
Racially/Religiously Aggravated Common Assault	229	267	496
Assault Occasioning Actual Bodily Harm (ABH)	6726	6524	13250
Attempt Malicious Wounding	2	1	3
Malicious Wounding	1824	1955	3779
Racially/Religiously Aggravated ABH and Malicious Wounding	258	262	520
Attempt to Inflict Grievous Bodily Harm (GBH) without Intent	1	2	3
Inflicting GBH without Intent	757	799	1556
Racially/Religiously Aggravated Inflicting GBH without Intent	8	14	22
Attempt to Cause GBH with Intent to do GBH	144	129	273
Cause GBH with Intent to do GBH	913	961	1874
Attempt Murder - Victim 1 Year Old or Over	24	20	44
Grand Total	**14553**	**14552**	**29105**

Table 3: Group Comparison – Clearance

	Analysis	Predictive	Grand Total
Cleared	6363	6272	12635
Uncleared	8190	8280	16470
Grand Total	14553	14552	29105

These groupings were assessed using t-tests to ensure that they are not significantly different. These groups are not significantly different in terms of offence type, $t(22)=0.000$, $p=0.0833$, or clearance, $t(2)=0.000$, $p=1.000$. Therefore it is appropriate to use these two groups to identify factors and build a model with one group, before testing it on the other group. This avoids issues that other researchers such as Paine (2012) have had when testing predictions against the group used to make the predictions.

Data Accuracy

The accuracy of the dataset is variable, ranging from extremely accurate data in terms of attendance of forensic scene investigators as these are all recorded, to unknown accuracy

levels for officer-recorded items. However, due to the CST acting as a gatekeeper (HMIC, 2014), all offences have the solvability questions applied which ensures completeness of the dataset.

Accuracy of WMP data was assessed as follows by HMIC: “The force had a strategy for capturing crime and incident data, and HMIC found that the basic information recorded on incidents and crimes complied to an excellent level with the NCRS. The quality of incident and crime records was high; samples indicated that incident records contained good quality data and that crime classifications were being recorded correctly” (HMIC, 2012, p.3).

Analytical Procedures

Each potential solvability factor was analysed individually to start with, using appropriate methods for each independent variable to analyse differences where the dependent variable is whether the case is cleared. For variables with two independent groups, independent samples t-tests were used with continuous data that follows a normal probability distribution. For categorical variables, chi-squared tests were used. Yates’ (1934) correction for continuity was used to compensate for overestimation of the chi-squared value when examining a 2x2 table.

It was not possible to obtain information relating to the workload of officers. Therefore, to assess the effects of workload and whether peak offence times are associated with lower solvability, aoristic analysis was performed to provide an indication of the likelihood that

the offence occurred during a defined temporal period (Ratcliffe, 2000). This allows a more accurate examination of offence times when there is a time range recorded. For offences where we know the precise time, this will not reduce accuracy. The strength of the aoristic approach has been demonstrated for identifying high risk offence times (Ashby and Bowers, 2013; Ratcliffe and McCullagh, 1998) but this use, for application of high demand times to solvability research, is a novel one. An independent samples t-test was used to examine the overall aoristic risk score for cleared and uncleared cases.

Each of the variables examined in the first analyses were then assessed using the Campbell Collaboration Effect Size Calculator, which is based upon work by Lipsey and Wilson (2001), to provide an indication of the impact that each variable exerts independently upon whether a case is cleared or not.

The combination of results from these first analyses allow the author to answer the first research question: what factors indicate clearance (solvability) of non-domestic violent offences?

Each of the variables that were significant at the $p<0.05$ level in the earlier tests, or were believed to be of tactical value with information not covered by other factors, were assessed for prevalence by examining the percentage of cases they were present in and identifying solvability factors that have low prevalence in order that they can be developed to make more use of them. This allows the second research question to be addressed: are

there investigative factors that contribute towards violent crime solvability which can be developed by UK policing agencies?

To examine the third research question, are there factors which affect clearance of violent crime differently dependent upon whether there is suspect information available, all of the variables assessed above were then examined using the same analyses as above, but only for cases without suspect information.

To answer research question four, to what extent can case clearance be predicted by factors identified in this research, all variables that were significant at the $p<0.05$ level in the earlier tests, or which were believed to be of tactical value with information not covered by other factors, were then examined for inter-variable correlation using Pearson tests of correlation. To avoid multicollinearity, combinations with Pearson's $r>0.9$ were removed before remaining variables were included in a logistic regression, using whether the case was cleared or uncleared as the dichotomous dependent variable. The sample size assumption for multiple regression (Pallant, 2001) was satisfied, as there are 26 variables in the model, which would require over 258 cases ($N>50+8*26$) according to Tabachnick and Fidell (1996, p.132), and the sample size in this case is 14553. Each variable makes sense on a priori grounds, based on previous findings (Howell, 2004), and has been checked for singularity.

Allison (1984) considers that dichotomising the dependent variable may cause loss of information. However, the information lost does not detract from the aim of this research,

which is to predict the same dichotomous variable in other datasets. As logistic regression is used to find the best fitting, interpretable, model to describe a useful relationship (Hosmer et al., 2013), the output of the logistic regression was then used as the basis to design a statistical weighted predictive model. The design process is included in the results section of this thesis, as it makes more sense in terms of order.

This model was then applied to the second, randomly sampled, dataset to assess its accuracy of prediction. The current WMP allocation model was also applied to the second dataset to compare the two models and answer research question five: how does the current WMP case screening mechanism compare to the factors identified in this research when predicting case solvability?

Difficulties and Limitations of Data

Data download tools utilised by WMP are not designed for research. Gathering data was extremely time-consuming and produced errors, including content of the detection column including undetected crimes, which meant that sections of data had to be re-downloaded following cleansing and entirely re-analysed at one stage. This also meant that individual forensic results are not examined as they would have had to be downloaded by an external consultant or retrieved one at a time.

These data were collated for investigative purposes rather than specifically for research and therefore there are likely to be some data that are overwritten thus preventing identifiable times of occurrence for data. Whilst this does not affect the suspect

information variable, it does prevent use of offender details which are attached to the investigation log, which is similar to the issue experienced by Paine (2012, p.40). In addition, the data is not coded in a manner which allows research to be conducted without significant data cleansing and coding. Bachmann & Schutt (2007, p.403) identify a "major disadvantage" with use of secondary data, as the data has already been collected and the collection model cannot be altered in any way.

Despite these difficulties and limitations, this research has produced a large-scale detailed dataset, with which it has conducted a detailed examination of numerous potential factors. This author believes that this is of greater practical and intellectual value than a smaller more in-depth examination would be.

Results

This section starts by presenting results of identification of individual solvability factors, using independent samples t-tests, chi-squared tests, aoristic analysis and effect size analysis to answer the first research question: what factors indicate clearance (solvability) of non-domestic violent offences?

Prevalence of factors is then presented for consideration alongside the strength of factors to answer the second research question: are there investigative factors that contribute towards violent crime solvability which can be developed by UK policing agencies?

Next analysis of individual variables is presented for cases where suspect information is not present to answer the third research question: are there factors which affect clearance of violent crime differently dependent upon whether there is suspect information available?

The results of logistic regression analysis are then presented, allowing the fourth question to be answered: to what extent can case clearance be predicted by factors identified in this research? This is used as the basis for design of a predictive model which is presented and applied to the second half of the dataset providing a further answer to the fourth question.

This new predictive model is then tested against the WMP allocation model, allowing the final research question to be answered: how does the current WMP case screening mechanism compare to the factors identified in this research when predicting case solvability?

Identification of Solvability Factors

This section presents the results of analyses of individual variables and how they differ between cleared and uncleared cases. These results therefore identify factors that may act individually as indicators of clearance, or solvability factors.

West Midlands Police (WMP) bases case allocation on fourteen factors that were identified through officer experience and intuition. These are measured when officers record crimes and this is done by the CST operator asking whether these factors are present. Suspect information is present if any level of suspect information is known, ranging from descriptions to names. Witness outstanding is confirmed if the officer is aware of witnesses who may have evidence to provide but have not given a statement.

The CST records whether the crime is mandatory for investigation, this includes, but is not limited to, most serious violent offences and hate crimes. The officer then records whether the crime relates to a critical incident, whether it has elicited media attention or is linked to community tension issues, whether it has had a major financial impact and whether it is a high profile case.

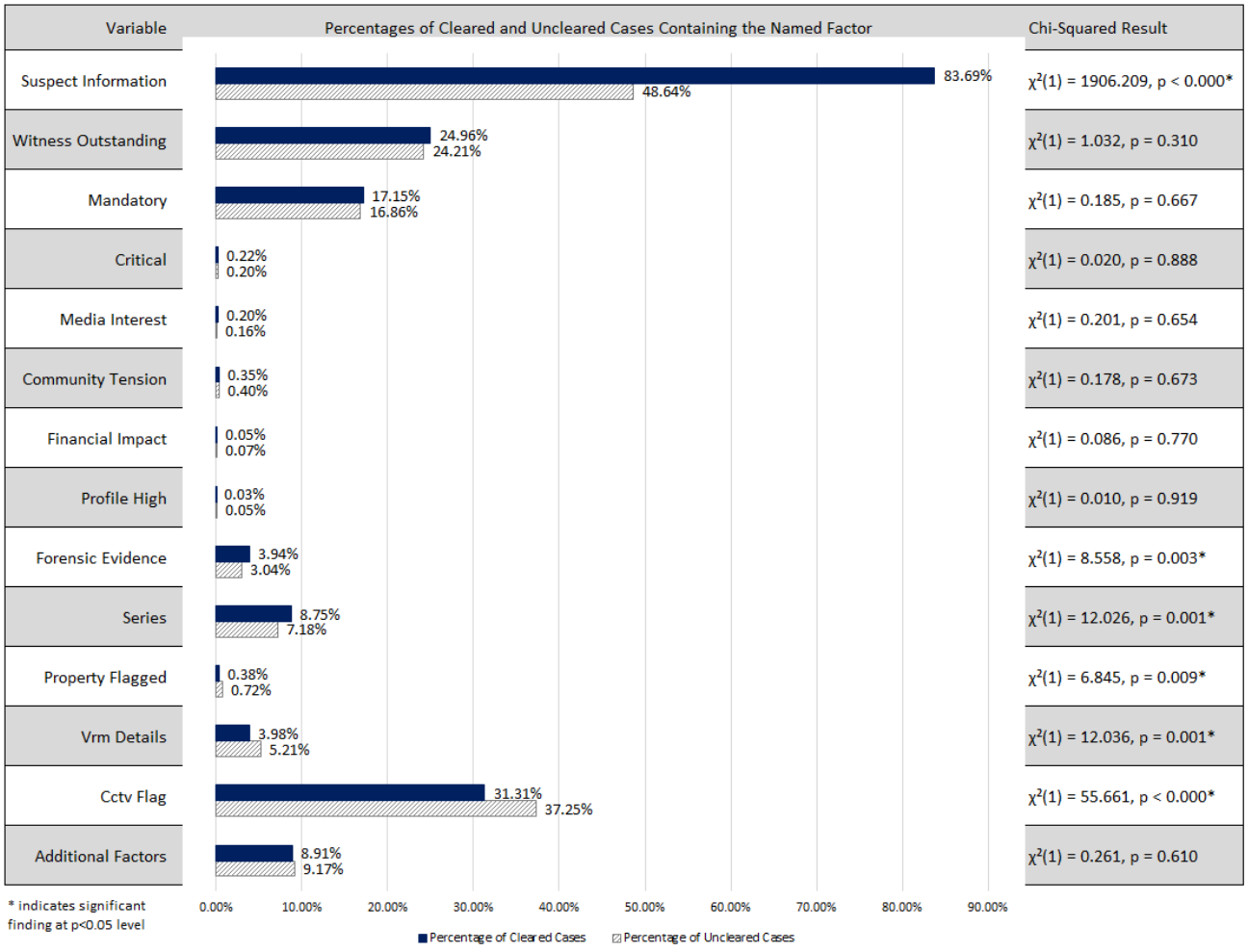
Forensic evidence is recorded based on the officer deciding whether they believe there are any forensic opportunities. The officer then records whether are aware of the case being part of a series and whether any flagged or marked property has been taken. VRM details records whether the recording officer has any vehicle details which will assist in investigation of the offence and CCTV Flag is confirmed if the recording officer states that

there is potentially CCTV present, they do not have to have viewed it. The officer is then asked whether they are aware of any other information that could assist with solving the crime.

There is a further factor which asks whether the case is already resolved. Unfortunately it is not possible to measure the prevalence of cases that were actually resolved before recording occurred as all solved crimes are recorded as resolved so it appears that this updates once an outcome is entered. Therefore this is not included in these analyses.

Figure 3 shows the results of chi-squared tests for prevalence of WMP-identified variables for cleared and uncleared offences.

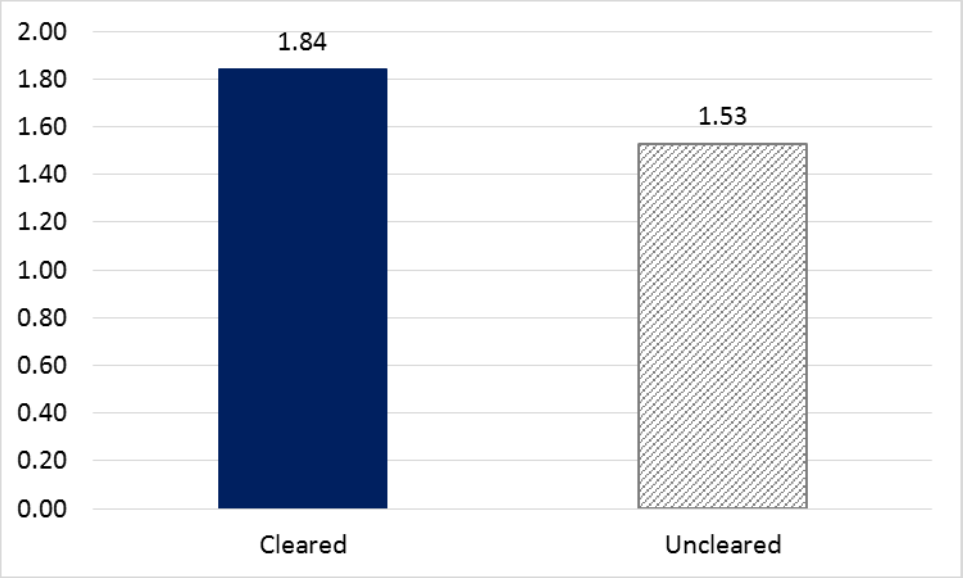
Figure 3: Results of Chi-Squared Tests – WMP Factors



Of the fourteen factors that WMP uses to predict solvability, only suspect information, officer identified forensic opportunities and the offence being part of a series are positive indicators when analysed individually. Potential for CCTV and recorded VRM details are both more prevalent in uncleared cases than cleared cases. Witnesses being identified as outstanding, offence types that WMP deem mandatory for investigation and cases that involve critical incidents, media interest, community tension, financial impact or are high profile do not differ significantly in prevalence between cleared and uncleared cases.

Figure 4 presents the mean total number of WMP identified solvability factors for cleared and uncleared cases, not including whether the case is resolved.

Figure 4: Mean Total WMP Solvability Factors

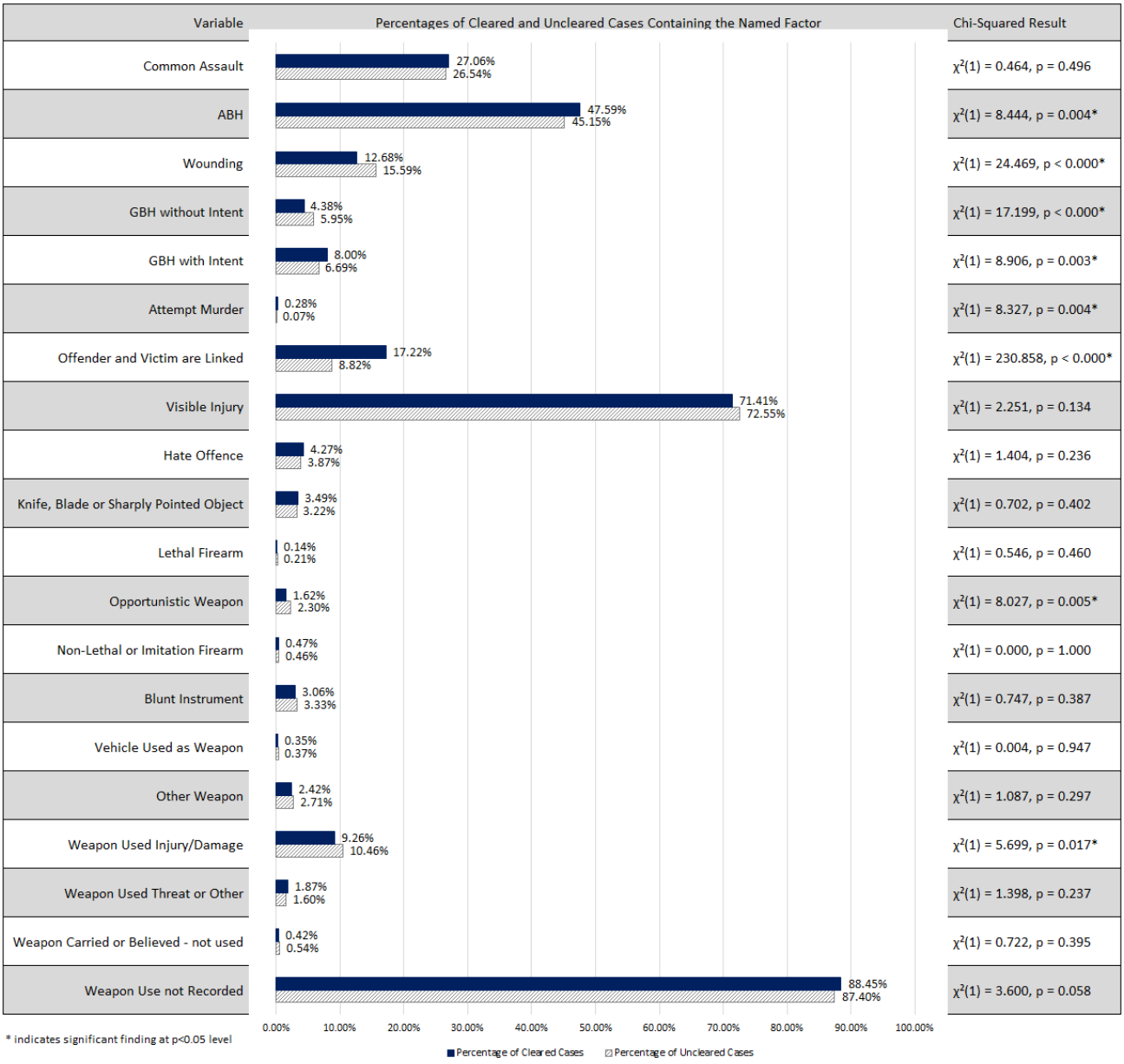


The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p<.001$). Therefore results are presented for an unequal variances t-test (Welch, 1947). The mean of total WMP-model solvability factors present was significantly higher for cleared cases, $t(13721.782)=16.746$, $p<0.001$.

Data that has been obtained for all cases from other parts of the WMP data warehouse will be examined next. These data are not currently accessed by the WMP allocation model. Due to the amount of data that is stored electronically in the WMP data warehouse, there are a large number of different variables covering a range of potential solvability factors. Figure 5 shows the results of chi-squared tests for prevalence of variables relating to

offence type, victim-offender link, injury, weapon type, and weapon usage in cleared and uncleared cases.

Figure 5: Results of Chi-Squared Tests – New Factors



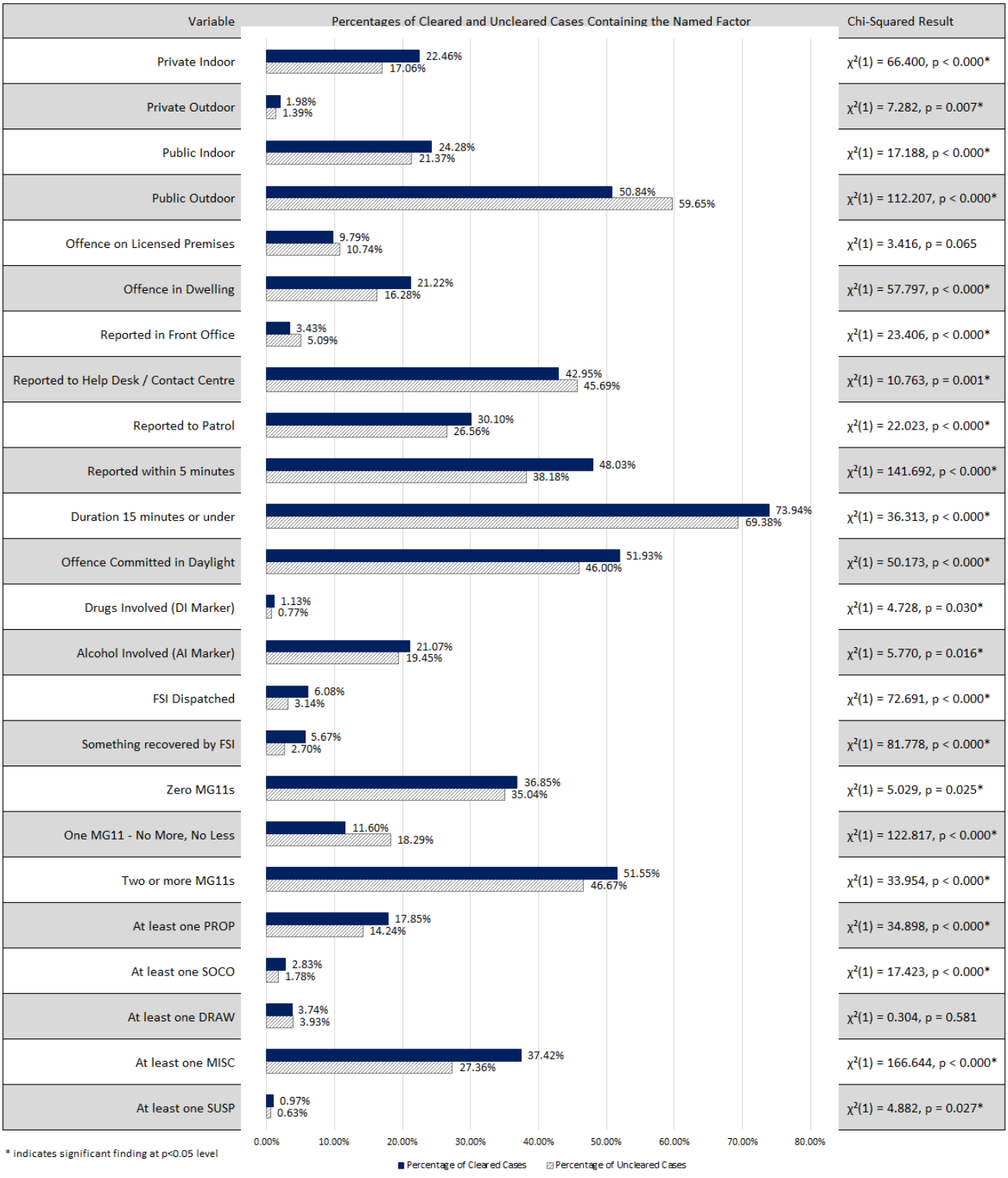
In terms of offence type; there is no significant difference in the percentage of offences that are common assaults. Actual bodily harm, wounding and GBH without intent each form a significantly larger percentage of uncleared cases than of cleared cases, whilst GBH

with intent and attempt murder make up a significantly greater percentage of cleared cases. Attempted offences are counted with their substantive counterparts. Links between victim and offender are associated significantly more with cleared cases, whereas neither the presence of a visible injury as measured by offence classification, nor the identification of an offence as hate related show any difference in prevalence between cleared and uncleared cases.

The only significant effect relating to type of weapon was for opportunistic weapons which was found in higher percentages in uncleared cases. No other weapon types were significantly more prevalent in either cleared or uncleared cases. Appendix 3 contains lists of individual weapons in these categories. Use of a weapon to cause injury or damage was significantly more prevalent in uncleared cases whilst all other usages of weapons were non-significant.

Figure 6 shows the results of chi-squared tests for prevalence of variables relating to offence location, reporting of offences, offence timings, special interest markers, forensic evidence and paperwork items in cleared and uncleared cases.

Figure 6: Results of Chi-Squared Tests – New Factors



For offence location, offences which occurred in private indoor, private outdoor or public indoor locations, along with offences occurring in dwellings, were significantly more prevalent in cleared cases, whilst offences that took place in public outdoor locations or on

premises licensed for alcohol consumption, alcohol sale or gambling were found in significantly higher percentages in uncleared cases. Appendix 4 contains lists of the location descriptions in each of these categories.

Reporting method seems important with use of slower reporting methods, such as police front offices or contact centres, being linked more with uncleared cases. Offences reported to police patrols were associated more with cleared cases. Speed of reporting appears important as offences reported within five minutes of occurrence were much more likely to be found in cleared cases than uncleared cases. This was also found for offences with duration of 15 minutes or under. A wide range of time-periods was initially examined and 15 minutes was the most significant duration, whilst under 5 minutes was the most significant time for reporting.

The presence of daylight at the start of the offence was established by working out the sunrise and sunset times for every offence date using USNO (2014) Sun or Moon Rise/Set Table with coordinates 52˚29'N, 1˚54'W. The days between first and last committed were calculated and cases where this exceeded one were counted as not definitely daylight as offence time is unknown. The remainder were compared to the USNO (2014) table using the offence start time as the comparison. Offences committed in daylight were significantly more prevalent in cleared cases.

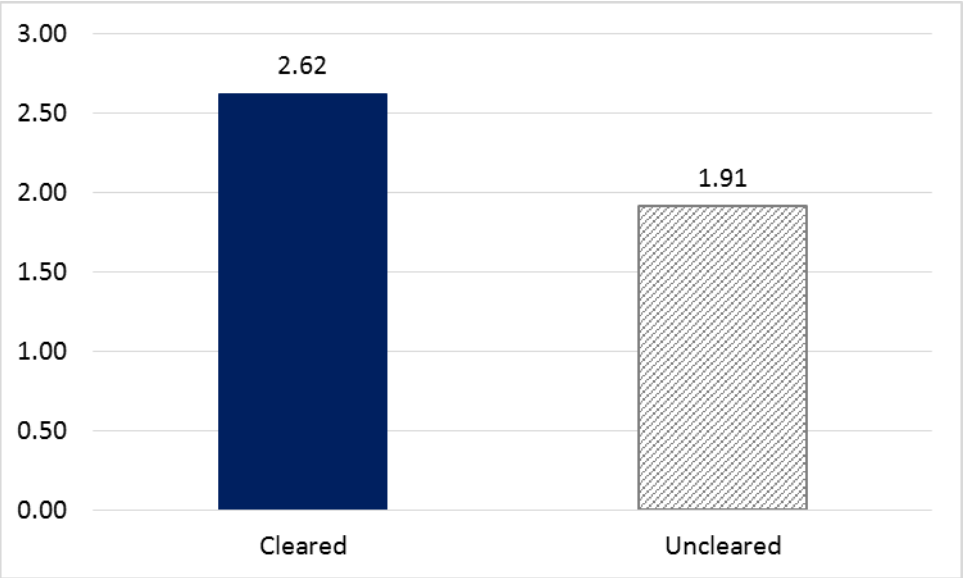
The presence of Drugs Involved or Alcohol Involved markers was found in a significantly larger percentage of cleared cases. These markers are put on during recording based on the determination of the recording officer.

The decision to send a forensic scene investigator (FSI) to examine a crime-scene is much more prevalent in cleared crimes than uncleared crimes. This is also the case when evidential items were recovered by an FSI. These items could be DNA, fingerprints, bullet fragments, photographs or many other items, unfortunately it was not possible to examine each type of evidence independently.

Documents collated during investigations are stored electronically by scanning them onto Crimescan. These scanned documents are then placed into folders by CST officers. The MG11 folder contains statements, PROP contains property record forms, SOCO contains forensic examination reports, DRAW contains photographs and drawings, SUSP contains suspect identity forms and MISC contains miscellaneous papers. The number of items in each folder for each case were examined and having at least one in the PROP, SOCO, MISC or SUSP folders was associated more with cleared cases. There was no significant effect for the DRAW folder. For statements; having no statements scanned was indicative of cleared cases, having one statement scanned was more prevalent in uncleared cases, whilst having two or more statements was more prevalent in cleared cases.

Figure 7 presents the mean number of documents scanned into the statements folder on Crimescan for cleared and uncleared cases.

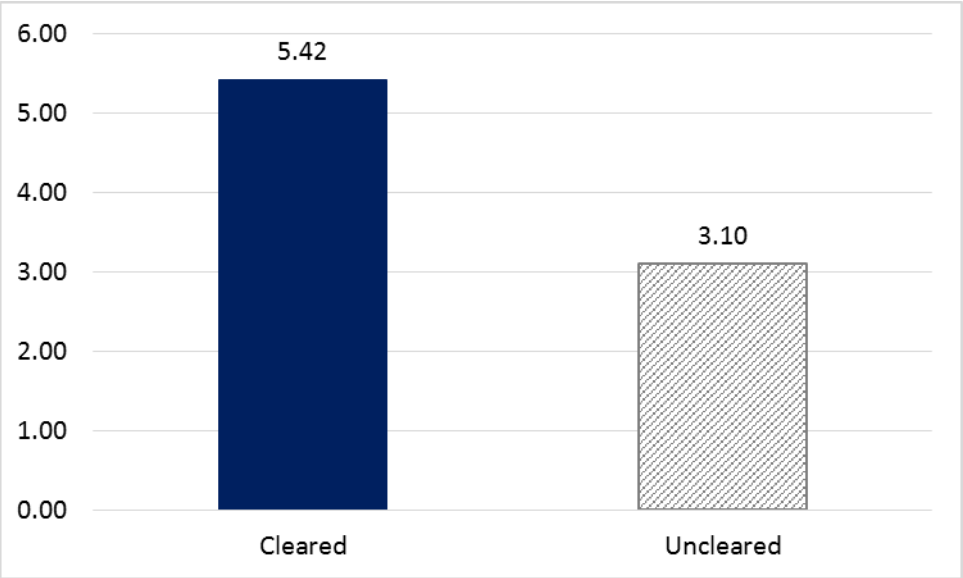
Figure 7: Mean Number of Statements



The assumption of homogeneity of variances was violated, as assessed by Levene's test ($p<.001$). Therefore an unequal variances t-test (Welch, 1947) was used. The mean number of statements was significantly higher for cleared cases, $t(10782.661)=13.590$, $p<0.001$.

Figure 8 presents the mean number of total documents scanned onto all folders on Crimescan for cleared and uncleared cases.

Figure 8: Mean Total Scanned Documents



The assumption of homogeneity of variances was violated, as assessed by Levene's test ($p<.001$). Therefore results are presented for an unequal variances t-test (Welch, 1947). The mean number of total documents was significantly higher for cleared cases, $t(10906.080)=27.251$, $p<0.001$.

A number of factors have been identified as being significant indicators of solvability through testing of individual factors. Results from a novel application of aoristic analysis are presented next.

Temporal Risk of Violent Crime

Figure 9 presents the findings of an aoristic analysis of temporal crime risk for violent offences. Values are calculated by taking the start and end time of each offence and working out the hours that the offence could have occurred in. For a crime window between 01:00hrs and 05:00hrs, the crime could have occurred at any point during that

window. Therefore each hour is allocated 0.25 as a score as there is an equal risk of the crime having occurred at that time. The totals estimate temporal risk of offences occurring during each hour of the week with higher scores indicating more offences may have occurred at that time.

Figure 9: Aoristic Analysis

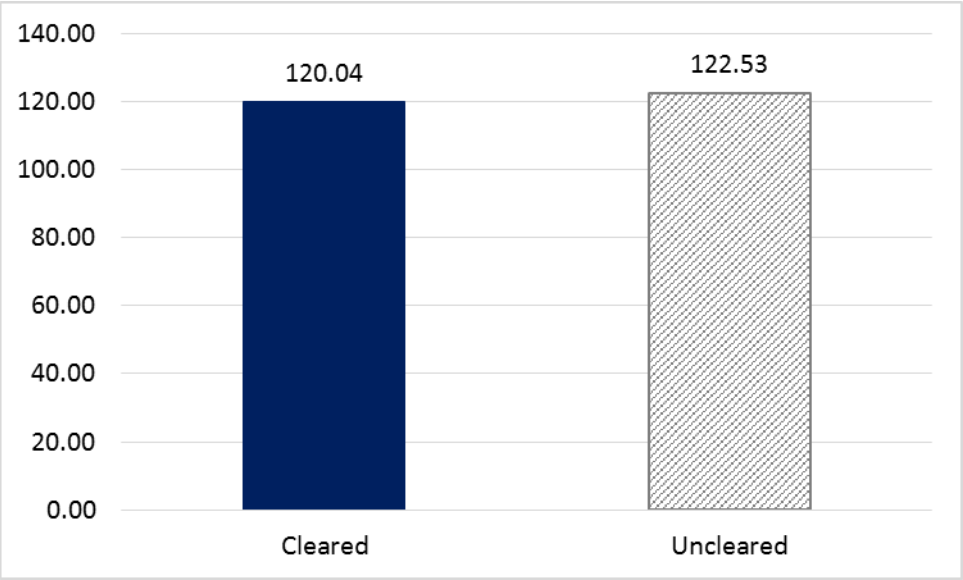
	MON	TUE	WED	THU	FRI	SAT	SUN	Total
0000-0100	75.07	57.01	41.87	57.15	75.77	197.49	274.59	778.96
0100-0200	45.72	44.49	24.52	39.61	66.25	191.11	267.26	678.96
0200-0300	57.18	54.44	41.76	25.85	84.25	204.44	244.77	712.69
0300-0400	36.68	34.34	27.49	32.02	56.38	167.42	187.24	541.57
0400-0500	15.87	20.66	17.16	13.52	34.47	80.45	101.95	284.08
0500-0600	8.00	10.66	9.88	14.52	12.47	40.33	46.95	142.81
0600-0700	6.71	15.16	9.16	10.39	13.16	23.20	21.15	98.93
0700-0800	19.76	19.18	18.99	29.19	16.57	21.70	23.04	148.44
0800-0900	40.76	56.86	53.72	46.57	50.01	30.67	26.29	304.89
0900-1000	41.45	44.35	48.01	44.03	45.77	43.66	31.13	298.40
1000-1100	54.86	59.21	53.74	54.53	37.29	49.99	40.96	350.59
1100-1200	55.61	51.23	64.25	76.74	68.29	56.99	65.09	438.21
1200-1300	67.07	70.65	79.24	85.15	77.25	69.69	65.02	514.08
1300-1400	82.57	91.69	83.00	82.99	97.40	81.73	81.19	600.57
1400-1500	80.94	86.46	100.26	91.80	98.69	108.54	94.22	660.91
1500-1600	174.43	201.64	190.79	178.91	210.51	126.74	92.55	1175.58
1600-1700	136.43	135.40	124.62	135.22	128.28	134.09	122.65	916.68
1700-1800	127.24	136.28	143.96	149.75	143.55	110.47	118.86	930.11
1800-1900	131.71	125.22	115.88	159.25	127.89	130.57	124.62	915.13
1900-2000	128.40	131.97	122.08	118.92	149.64	117.28	121.95	890.24
2000-2100	120.26	104.05	118.52	101.37	137.48	151.72	118.61	852.01
2100-2200	116.62	98.76	97.16	114.43	136.44	135.35	84.39	783.14
2200-2300	95.62	71.96	67.33	86.68	139.54	159.41	116.42	736.95
2300-0000	69.12	64.02	64.34	84.90	156.55	205.75	86.39	731.06
Total	1788.06	1785.71	1717.74	1833.50	2163.91	2638.79	2557.28	14485

Omitted records:	68
Mean Score	86.22
Standard Deviation	55.21

Highest risk - > Mean + 2SD	
Moderately high risk - > Mean + 1SD	
Moderate risk	
Moderately low risk - < Mean - 1SD	
Lowest risk - < Mean - 2SD	

Figure 10 shows the mean total aoristic risk score for cleared and uncleared cases.

Figure 10: Mean Aoristic Risk Level



The assumption of homogeneity of variances is met and mean aoristic risk score was lower for cleared cases, $t(14551)=-2.565$, $p<0.001$.

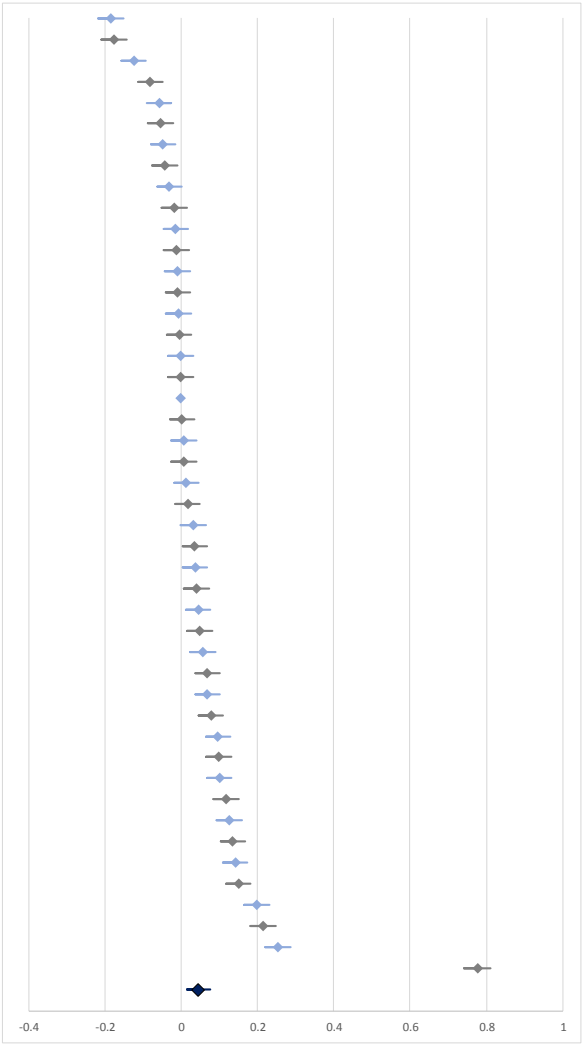
This result adds weight to the argument that increased officer workload is linked to lower clearance of crime. To assess the impact of the factors which have been identified in these first two sections, results of an effect size analysis are presented next.

Effect Size Analysis

The importance of different factors in terms of their identification of solvable offences may be examined by the statistical strength of their relationship with cleared and uncleared crimes. Stronger solvability factors are those which are present in a high percentage of cleared cases and are not as prevalent in uncleared crimes. The statistical effect size of all variables which have been examined by this research are presented both in tabular format and in a forest plot alongside the table in Figure 11.

Figure 11: Effect Size of Individual Solvability Factors

Indicator	Est. Std. Diff. in Means	Lower 95% C.I. Limit	Upper 95% C.I. Limit	χ^2	P-Value
One MG11	-0.1845	-0.2171	-0.1519	122.817	0.000
Public Outdoor	-0.1763	-0.2089	-0.1437	112.207	0.000
Cctv Flag	-0.1239	-0.1565	-0.0914	55.661	0.000
Reported in Front Office	-0.0803	-0.1128	-0.0478	23.406	0.000
Vrm Details	-0.0575	-0.025	-0.09	12.036	0.001
Reported to Help Desk / Contact Centre	-0.0544	-0.0869	-0.0219	10.763	0.001
Opportunistic Weapon Used	-0.047	-0.0795	-0.0145	8.027	0.005
Property Flagged	-0.0434	-0.0759	-0.0109	6.845	0.009
Licensed Premises?	-0.0306	-0.0631	0.0019	3.416	0.065
Other Weapon Used	-0.0173	-0.0498	0.0152	1.087	0.297
Blunt Instrument Used	-0.0143	-0.0468	0.0182	0.747	0.387
Lethal Firearm Used	-0.0123	-0.0447	0.0202	0.546	0.460
At least one DRAW	-0.0091	-0.0416	0.0234	0.304	0.581
Additional Factors	-0.0085	-0.041	0.024	0.261	0.610
Community Tension	-0.007	-0.0395	0.0255	0.178	0.673
Financial Impact	-0.0049	-0.0374	0.0276	0.086	0.770
Profile High	-0.0017	-0.0342	0.0308	0.01	0.919
Vehicle Used as Weapon	-0.001	-0.0335	0.0314	0.004	0.947
Non-Lethal or Imitation Firearm Used	0	0	0	0	1.000
Critical	0.0023	-0.0301	0.0348	0.02	0.888
Mandatory	0.0071	-0.0254	0.0396	0.185	0.667
Media Interest	0.0074	-0.0251	0.0399	0.201	0.654
Knife, Blade or Sharply Pointed Object Used	0.0139	-0.0186	0.0464	0.702	0.402
Witness Outstanding	0.0168	-0.0157	0.0493	1.032	0.310
Weapon Not Recorded	0.0315	-0.001	0.064	3.6	0.058
DRUGS INVOLVED (DI MARKER)	0.0361	0.0036	0.0686	4.728	0.030
At least one SUSP Form	0.0366	0.0041	0.0691	4.882	0.027
ALCOHOL INVOLVED (AI MARKER)	0.0398	0.0073	0.0723	5.77	0.016
Private Outdoor	0.0447	0.0122	0.0773	7.282	0.007
Forensic Evidence	0.0485	0.016	0.081	8.558	0.003
Series	0.0575	0.025	0.09	12.026	0.001
Public Indoor	0.0688	0.0363	0.1013	17.188	0.000
At least one SOCO	0.0692	0.0367	0.1018	17.423	0.000
Reported to Patrol	0.0779	0.0453	0.1104	22.023	0.000
Two or more MG11s	0.0967	0.0642	0.1292	33.954	0.000
At least one PROP	0.0981	0.0655	0.1306	34.898	0.000
Duration 15 minutes or under	0.1	0.0675	0.1326	36.313	0.000
Offence Committed in Daylight	0.1176	0.0851	0.1502	50.173	0.000
Dwelling?	0.1263	0.0937	0.1588	57.797	0.000
Private Indoor	0.1354	0.1028	0.168	66.4	0.000
FSI Dispatched?	0.1417	0.1091	0.1743	72.691	0.000
Something recovered by FSI	0.1503	0.1178	0.1829	81.778	0.000
Reported within 5 minutes	0.1983	0.1657	0.231	141.692	0.000
At least one MISC document	0.2153	0.1826	0.2479	166.644	0.000
Offender linked to victim	0.2539	0.2212	0.2867	230.858	0.000
Suspect Information	0.7765	0.7416	0.8113	1906.209	0.000
Grand TOTAL	0.0455261	0.0150696	0.075987		



The five most important factors can be identified as suspect information, link between offender and victim, at least one MISC document of Crimescan, reported within 5 minutes, and whether forensic evidence was seized. However, as can be seen from the forest plot, there are a large number of factors that play a small but significant part as determinants of violent crime clearance. However, to identify areas which can be developed by policing agencies, prevalence of factors is examined next.

Variable Prevalence

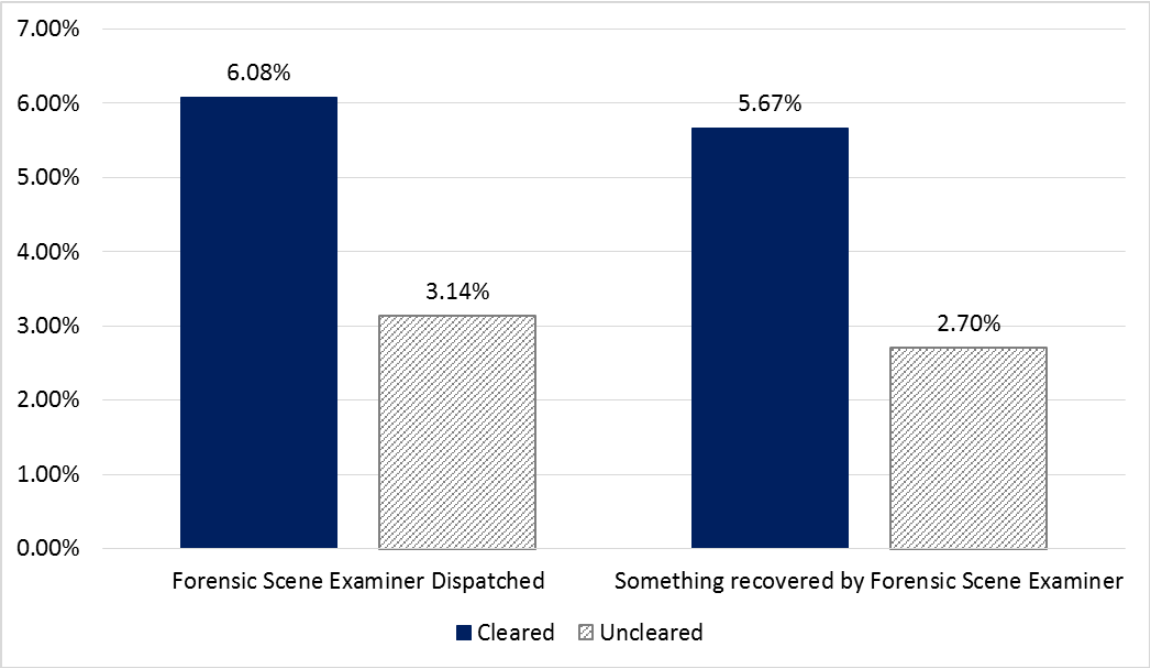
The prevalence of all relevant factors, and some that were not deemed relevant but which are part of a group with items that have been identified, was calculated and this is used to provide evidence of areas of evidence which are highly predictive of violent crime solvability but which are not used in large quantities as this would allow for increased use with potential for increased clearances. The relevant factors are presented in Table 4. The prevalence of other factors is presented in Appendix 5.

Table 4: Forensic Variable Prevalence

Variable	Prevalence in Sample	% in sample with variable
FSI Dispatched?	644	4.43%
Something recovered by FSI (Includes FP, DNA, Photos etc.)	582	4.00%

Forensic Scene Investigators are only dispatched to 4.43% of cases. Something is recovered by them in 90% of the cases that they are dispatched to. Despite this low percentage of incidents being attended, forensic evidence is still a predictive factor of solvability, as shown in figures 6 and 12.

Figure 12: Forensic Variables in Cleared and Uncleared Cases

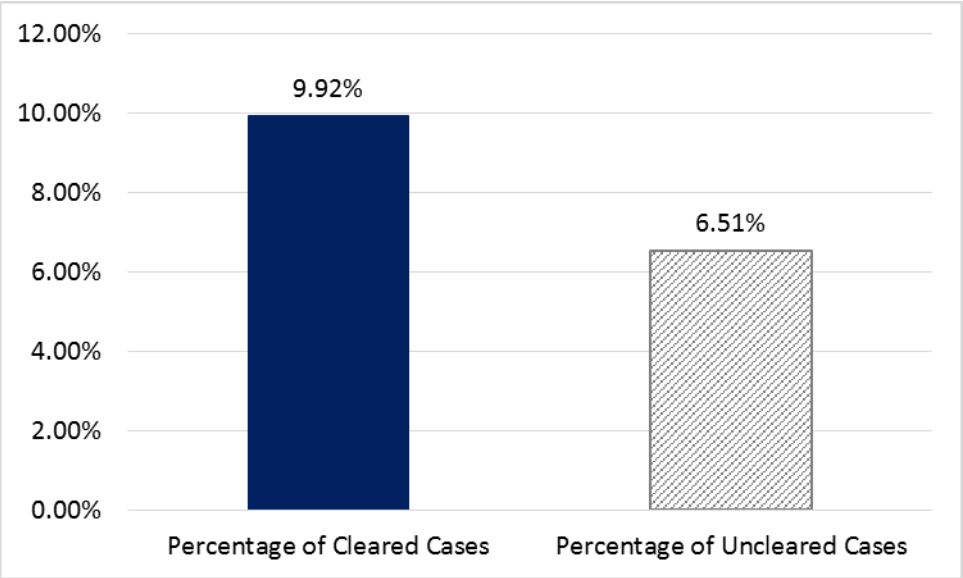


This demonstrates the impact of low-prevalence factors, so the next section addresses the important issue of assessing the inter-variable effect of high-powered suspect information.

Cases without Suspect Information

Suspect information has been demonstrated to be the largest predictor of solvability in these analyses. Therefore it is important to examine cases where this is not present to understand how factors compare in the absence of the most powerful factor. Therefore factors were examined using only cases with no identified suspect information. The results of the relevant factors, where the relationship is different without suspect information are presented below, starting with VRM information which is graphically represented in Figure 13.

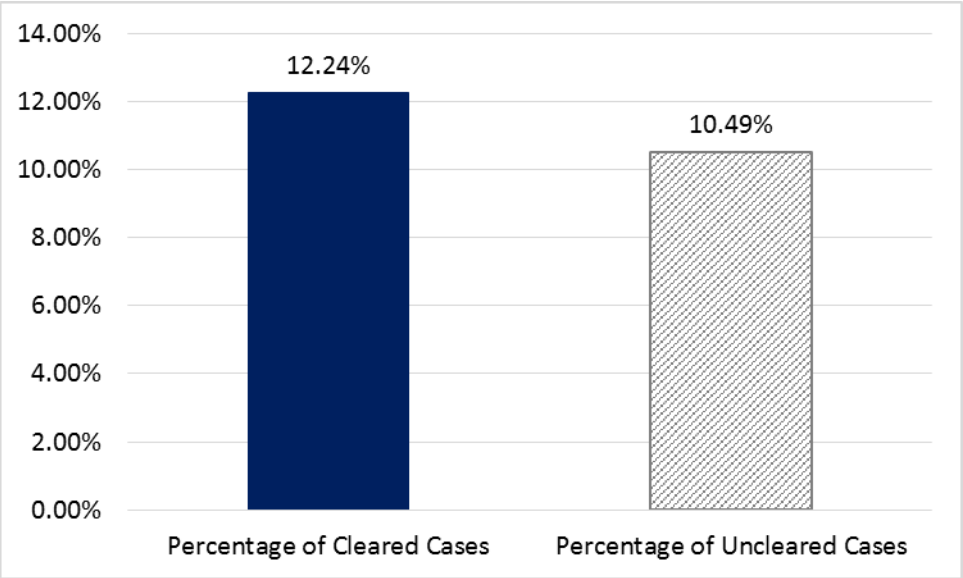
Figure 13: VRM Information – No Suspect Information



For cases without suspect information, VRM information is available in significantly more cleared cases than in uncleared cases, $\chi^2(1)=13.989$, $p<0.001$, a finding which is opposite to that shown earlier.

Figure 14 shows the availability of additional information in cleared and uncleared cases with no suspect information.

Figure 14: Additional Information – No Suspect Information



Additional information is not significantly different between cleared and uncleared cases, $\chi^2(1)=2.462$, $p=0.117$. However, the relationship is in the opposite direction to that seen when all cases are examined. Due to the fact that factors are clearly affected by the presence of other factors, a model which takes into account impact of factors together is vital. Therefore results for a logistic regression are presented next.

Logistic Regression

As is advisable to remove variables which are strongly correlated with one another ($r \geq 0.9$) (Pallant, 2001), all variables were compared against all others using Pearson Correlation tests. There were two pairs of variables for which multicollinearity would be problematic. Private indoor location and offence occurring in a dwelling were strongly positively correlated, $r(14553)=0.968$, $p<0.001$. FSI dispatched and Something recovered by FSI were also strongly positively correlated, $r(14553)=0.949$, $p<0.001$.

As private indoor location encompasses more locations than dwelling does, dwelling was removed. Due to the fact that FSI dispatched can be manually altered by policy or situational decisions, this was removed from the following analyses.

All variables relating to the number of factors present, such as count of WMP factors, were removed as they would have been problematic due to singularity as they are made up of other included variables. Presence of forms in the SOCO folder on Crimescan was removed as this should hold forms which are scanned following forensic recoveries. Therefore this will be measuring some of what is already recorded by other forensic variables. Presence of miscellaneous papers was also removed due to not knowing what forms are included in this folder or at which stage of the investigation they are uploaded.

A logistic regression was performed to establish the effects of the variables in Table 5 on the likelihood that cases would be solved. A decision was made to include whether the offence occurred in licensed premises as this neared significance and is easily measurable so can be used readily in a predictive model. A decision was also made to include whether additional factors were present, as this shows an interesting relationship with suspect information, and the measure of outstanding witnesses which contains information about witnesses who have not given statements that is unavailable to the remainder of the model.

Table 5: Logistic Regression Variables

Variable	Description
PrivateIn	Offence Location Private Indoor
PrivateOut	Offence Location Private Outdoor
PublicIn	Offence Location Public Indoor
RepPatrol	Offence Reported to Patrol
ForensicsRec	Forensic Items Recovered
WMPSusInfo	WMP Suspect Information
WMPWitOut	WMP Witness Outstanding
WMPForensic	WMP Forensic
WMPSeries	WMP Series
WMPVRM	WMP VRM Information
WMPCCTV	WMP CCTV Flag
WMPAddFact	WMP Additional Factors
TwoMG11	Two or more statements
OnePROP	One or more Property Forms
OffLink	Offender linked to Victim
Dur15Min	Duration under 15 minutes
DIMarker	Drugs Involved Marker
AIMarker	Alcohol Involved Marker
Rep0to5m	Reported in under 5 minutes
Daylight	Offence occurred in Daylight
PublicOut	Offence Location Public Outdoor
Licensed	Offence on Licensed Premises
RepFO	Reported in Front Office
RepHDCC	Reported to Help Desk/ Contact Centre
OppWeap	Opportunistic Weapon Used
JustOneMG11	Just one statement

The logistic regression model was statistically significant, $\chi^2(26)=2539.100$, $p<0.001$. The model explained 21.5% (Nagelkerke R^2) of the variance in clearance and correctly classified 66.9% of cases. Sensitivity (true positives) was 69.0%, specificity (true negatives) was 65.3%, positive predictive value was 60.7% and negative predictive value was 73.1%. Of the 26 predictor variables, 17 were statistically significant. All factors are detailed in Table 6. Cases with suspect information present had over five times higher odds of being solved than cases without. Cases with forensic items recovered had 2.52 times higher odds of being solved than those without.

Table 6 – Logistic Regression Results

Variable	B	S.E.	Wald	df	p	Odds Ratio	95% C.I.for EXP(B)	
							Lower	Upper
PrivateIn	0.219	0.264	0.689	1	0.406	1.245	0.742	2.087
PrivateOut	0.482	0.296	2.651	1	0.103	1.620	0.906	2.894
PublicIn	0.614	0.266	5.347	1	0.021	1.848	1.098	3.110
RepPatrol	0.136	0.051	6.983	1	0.008	1.145	1.036	1.266
ForensicsRec	0.923	0.101	83.512	1	0.000	2.516	2.064	3.067
WMPSusInfo	1.655	0.043	1471.640	1	0.000	5.231	4.807	5.692
WMPWitOut	-0.005	0.044	0.013	1	0.908	0.995	0.913	1.084
WMPForensic	-0.124	0.105	1.398	1	0.237	0.883	0.719	1.085
WMPSeries	0.179	0.068	7.036	1	0.008	1.196	1.048	1.366
WMPVRM	0.055	0.091	0.365	1	0.546	1.057	0.883	1.264
WMPCCTV	-0.118	0.044	7.276	1	0.007	0.889	0.815	0.968
WMPAddFact	0.139	0.065	4.631	1	0.031	1.149	1.012	1.304
TwoMG11	-0.141	0.044	10.376	1	0.001	0.869	0.797	0.946
OnePROP	0.255	0.054	21.997	1	0.000	1.290	1.160	1.435
OffLink	0.338	0.056	36.368	1	0.000	1.403	1.257	1.566
Dur15Min	0.225	0.041	30.018	1	0.000	1.253	1.156	1.358
DIMarker	0.232	0.191	1.471	1	0.225	1.261	0.867	1.833
AIMarker	0.140	0.050	7.679	1	0.006	1.150	1.042	1.270
Rep0to5m	0.325	0.038	73.868	1	0.000	1.384	1.285	1.490
Daylight	0.196	0.039	24.864	1	0.000	1.217	1.127	1.315
PublicOut	0.261	0.262	0.996	1	0.318	1.298	0.777	2.169
Licensed	-0.235	0.082	8.285	1	0.004	0.791	0.674	0.928
RepFO	-0.164	0.099	2.739	1	0.098	0.848	0.698	1.031
RepHDCC	-0.073	0.047	2.445	1	0.118	0.929	0.847	1.019
OppWeap	-0.409	0.139	8.707	1	0.003	0.664	0.506	0.872
JustOneMG11	-0.562	0.058	93.104	1	0.000	0.570	0.509	0.639
Constant	-2.060	0.269	58.603	1	0.000	0.127		

Cases that had any of the following factors; occurred in public indoor locations, were reported to patrol, were part of a series, had additional factors available, had at least one property sheet scanned, victim was linked to offender, had offence duration shorter than 15 minutes, had an alcohol involved marker, were reported within 5 minutes of the end of the offence, or occurred in daylight were significantly associated with higher odds of clearance than cases without. Cases with CCTV, statements scanned onto Crimescan, which

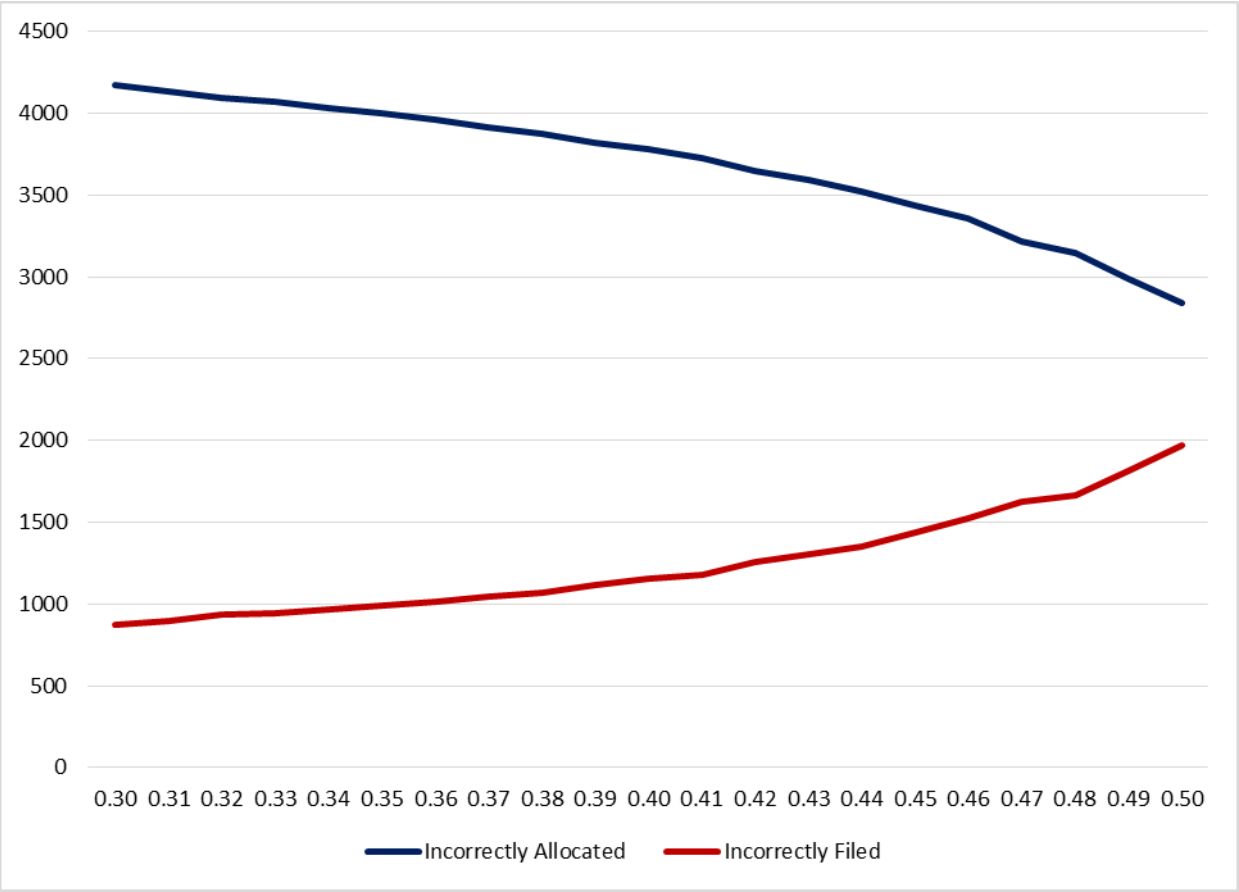
occurred on licensed premises, involved an opportunistic weapon, or had only one statement scanned were associated with lower odds of being solved than those without.

The basic result from the logistic regression uses a cut-off point of 0.5. This provides the greatest accuracy of overall prediction. However, it balances the errors between incorrect allocations and incorrect filing. This means that a lot of victims of solvable crimes would potentially be let down through filing of their reports at source. Eck (1979) stated that the balance between resource usage and detection levels can be altered by moving the cut-point in a weighted model. To give political weight to any model, the number of solvable crimes that are filed needs to be minimised, whilst balancing against the number of incorrectly allocated crimes as fewer of these may mean that more crimes can be solved overall. Therefore, the error rate was calculated for different cut-off points and these were examined using Table 7 and Figure 15.

Table 7: Comparison of screen-out values

Screen Out Criteria - Logistic Regression P Value	Correctly Allocated	Incorrectly Allocated	Incorrectly Filed	Correctly Filed	% Correctly Allocated	% Correctly Filed	% Overall Correct
Lower than 0.10	6345	8006	18	184	99.72%	2.25%	44.86%
Lower than 0.20	5958	5590	405	2600	93.64%	31.75%	58.81%
Lower than 0.30	5488	4170	875	4020	86.25%	49.08%	65.33%
Lower than 0.31	5466	4136	897	4054	85.90%	49.50%	65.42%
Lower than 0.32	5428	4097	935	4093	85.31%	49.98%	65.42%
Lower than 0.33	5419	4072	944	4118	85.16%	50.28%	65.53%
Lower than 0.34	5398	4030	965	4160	84.83%	50.79%	65.68%
Lower than 0.35	5374	4004	989	4186	84.46%	51.11%	65.69%
Lower than 0.36	5351	3961	1012	4229	84.10%	51.64%	65.83%
Lower than 0.37	5318	3911	1045	4279	83.58%	52.25%	65.95%
Lower than 0.38	5294	3874	1069	4316	83.20%	52.70%	66.03%
Lower than 0.39	5250	3823	1113	4367	82.51%	53.32%	66.08%
Lower than 0.40	5210	3779	1153	4411	81.88%	53.86%	66.11%
Lower than 0.41	5185	3729	1178	4461	81.49%	54.47%	66.28%
Lower than 0.42	5109	3644	1254	4546	80.29%	55.51%	66.34%
Lower than 0.43	5060	3591	1303	4599	79.52%	56.15%	66.37%
Lower than 0.44	5009	3522	1354	4668	78.72%	57.00%	66.49%
Lower than 0.45	4926	3436	1437	4754	77.42%	58.05%	66.52%
Lower than 0.46	4841	3356	1522	4834	76.08%	59.02%	66.48%
Lower than 0.47	4738	3213	1625	4977	74.46%	60.77%	66.76%
Lower than 0.48	4698	3149	1665	5041	73.83%	61.55%	66.92%
Lower than 0.49	4552	2989	1811	5201	71.54%	63.50%	67.02%
Lower than 0.50	4392	2841	1971	5349	69.02%	65.31%	66.93%
Lower than 0.60	2381	1282	3982	6908	37.42%	84.35%	63.83%
Lower than 0.70	586	258	5777	7932	9.21%	96.85%	58.53%
Lower than 0.80	101	25	6262	8165	1.59%	99.69%	56.80%
Lower than 0.90	3	0	6360	8190	0.05%	100.00%	56.30%

Figure 15: Number of errors for different cut-off points



Using Figure 15 and Table 7, P = 0.39 was determined as being the most appropriate to minimise the number of incorrectly filed reports (victims who are let down) whilst still reducing wastage of resources through incorrect allocation. This was turned into a predictive model which is demonstrated next.

Predictive Modelling

The prediction formula was created using the base of $\boldsymbol{logit(p)=b_0+b_1X_1+b_2X_2+b_3X_3+\ldots+b_kX_k}$. (Medcalc Software, 2014a) and the resultant formula can be seen in Figure 16 below. Where any of the variables are present in the dataset they are coded as one and where not present, as zero.

Figure 16: Predictive Formula

Predictive Model Logit(p) *= -2.06012231166749 + (Private Indoor x 0.21896234166784) + (Private Outdoor x 0.482221853049798) + (Public Indoor x 0.614168153975186) + (Reported to Patrol x 0.135507823875585) + (Something Recovered by FSI x 0.922678539797806) + (Suspect Information x 1.65451761371856) - (Witness Outstanding x 0.00509247368812278) - (Forensic Evidence x 0.124114369542983) + (Series x 0.179382232899131) + (VRM Details x 0.0552156712817925) - (CCTV Flag x 0.118196466193996) + (Additional Factors x 0.13909164461101) - (Two or More MG11s x 0.140966342491925) + (At least one PROP x 0.254753361095196) + (Duration 15 minutes or under x 0.225334514108994) + (Drugs Involved Marker x 0.23158147033591) + (Alcohol Involved Marker x 0.139861549604373) + (Reported within 5 minutes x 0.324619578460559) + (Offender Link to Victim x 0.338284590056064) + (Daylight Offence x 0.196372030404582) + (Public Outdoor x 0.261198299233381) - (Licensed Premises x 0.234972861437699) - (Reported in Front Office x 0.164408083792076) - (Reported to Help Desk or Contact Centre x 0.0734407903273885) - (Opportunistic Weapon Used in Offence x 0.409479586358932) - (One MG11 Exactly x 0.561505039063743)*

The model outlined in figure 16 above was compared to the logit(p) value for p=0.39 using the logit transformation table in Appendix 6 (Medcalc Software, 2014b). Logit(p) for p=0.39 is -0.4473. Therefore all cases with logit(p) greater than -0.4473 are screened in. This calculation makes up the main part of the model.

However, it is imperative that any model suggested for use in policing satisfies societal values, the values of the Police and Crime Commissioner, and of members of the organisation (Denis et al., 2007) and that it takes into account seriousness of offending (Eck, 1983), as well as offence types that could cause serious damage to the reputation of forces if not investigated. Therefore a number of screen-in factors are combined with this formula to create the final model. These screen-in criteria are items that, if present,

automatically cause allocation, regardless of the solvability calculation. These factors are presented in Table 8.

Table 8: Automatic Screen-In

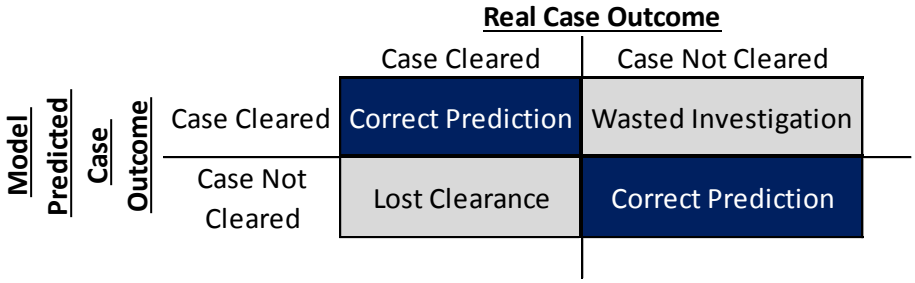
Screen-In Category	Description of Specific Screen-In Factor	Rationale
Incident Type	Hate Crime	These are offence types that may cause severe reputational damage if investigation does not occur
	Media Interest	
	Community Tension	
	Critical Incident	
	High Profile Offence	
Case is Resolved	Case is already resolved and has been cleared	Case is already solved
Allocated by Logit Model	Case is allocated based on its score on the solvability equation	Case is deemed by the equation to be solvable
Offence Severity	GBH without Intent (or Attempt)	These are offences where serious injury has been caused, or intended
	GBH with Intent (or Attempt)	
	Attempt Murder	
Overwhelming Evidence	It has not been possible to create these yet but examples would be; CCTV which is clear, shows the offender and the offence taking place or Offence witnessed by a Police Officer	These are pieces of evidence where officers can identify that there is sufficient, even if in weak evidential types to permit a prosection

The design of the model was hypothetical at this point therefore it was applied to the second data set, and its accuracy is compared to the WMP model in the following section.

Screening Model Accuracy

The predictive accuracy of the WMP current allocation model and the weighted statistical model created through this research are presented below. Figure 17 demonstrates the graphical representation which was adapted from Eck (1979) and provides an estimation of where the error lies. It is extremely important to establish whether the model is producing false positives which result in wasted investigative effort, or false negatives which result in cases which are detectable not being allocated for investigation.

Figure 17: Model Accuracy (Adapted from Eck, 1979)



The overall accuracy of the model is then calculated using the following formula:

Accuracy (%) = (Correct Prediction + Correct Prediction) / Total Cases x 100

Figure 18: Model Accuracy – WMP Current Model

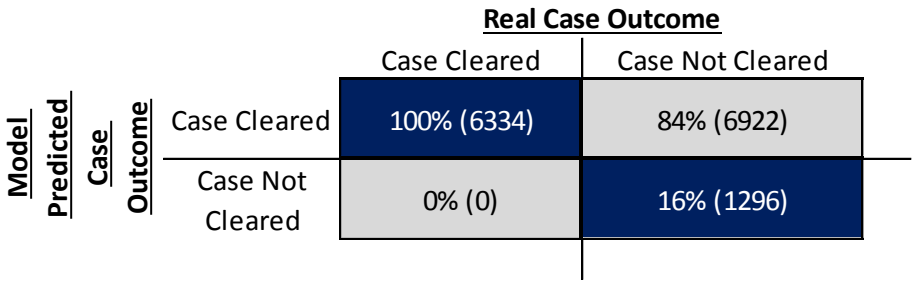


Figure 18 demonstrates the quantities and percentages of cases that are correctly and incorrectly predicted by the WMP current model. Due to there being 1296 which were not allocated, the actual error for cases incorrectly filed may not be zero as some of these cases may in fact be solvable.

For the WMP current model, 7630 out of 14552 cases are correctly predicted. Therefore the overall accuracy of the WMP current model is 52.43%.

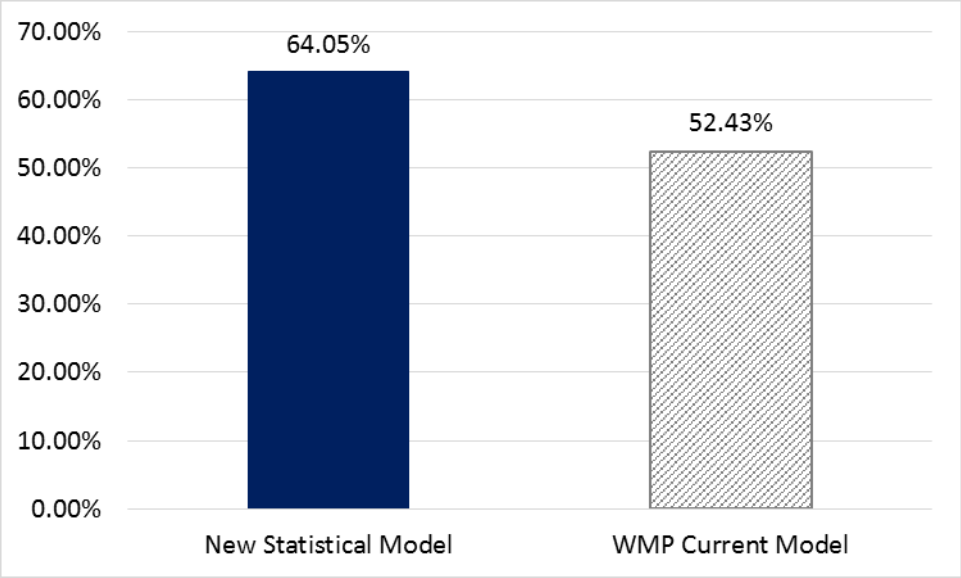
Figure 19: Model Accuracy – Weighted Statistical Model

Model Predicted Case Outcome	Real Case Outcome: Case Cleared	Real Case Outcome: Case Not Cleared
Case Cleared	93% (5864)	58% (4761)
Case Not Cleared	7% (470)	42% (3457)

Figure 19 demonstrates the quantities and percentages of cases that are correctly and incorrectly predicted by the weighted statistical model.

For the weighted statistical model, 9321 out of 14552 cases are correctly predicted. Therefore the overall accuracy of the weighted statistical model is 64.05%. This equates to an 11.62% increase in accuracy of prediction through use of the weighted statistical model over the WMP current model which is shown graphically in Figure 20. This equates to an additional 1736 cases being accurately predicted.

Figure 20: Difference in Model Accuracy



Through this process of identifying factors using novel, as well as standard, techniques and testing them with a logistic regression, the author has gone one step further than previous research to both design a new model and then test that new model on a second dataset, increasing the generalisability of the findings. The meaning and applicability of the findings are discussed next.

Discussion

This research set out to target factors that predict clearance of non-domestic violent offences. This has been done through analysis of a large-scale secondary dataset, comprising all non-domestic violent crimes reported between 1st March 2012 and 31st December 2013, with a total of 29105 cases. Some of the analysis has been done using methods which were also used in other research into solvability factors, such as examination of individual factors (Paine, 2012), effect size analysis (Robb et al., 2014) and logistic regression (Alderden and Lavery, 2007; Jarvis and Regoeczi, 2009), but these techniques were then extended using novel methods including aoristic analysis (Ratcliffe and McCullagh (1998), reverse engineering of logistic regression analysis (Hosmer et al., 2013) and cut-off point variation (Eck, 1979) to build a statistical predictive model which is capable of predicting case outcome from initial investigative factors, and is appropriate for use in policing.

Identification of Solvability Factors

The primary question asked by this thesis was; what factors indicate clearance (solvability) of non-domestic violent offences? Due to the difficulties that others have had in identifying solvability factors for violent crime (Greenberg et al., 1977), this study addressed this question with a large secondary dataset, and has had no difficulty in identifying factors which are indicative of solvability of violent offences. The most impactful factor in relation to prediction of clearance of violent offences is the presence of suspect information. This is consistent with Brandl & Frank (1994, p.156) who stated that “suspect information is the most powerful, if not the only, evidence consideration vis-à-vis the solvability of burglaries

and robberies," and corroborates findings of other authors (Tilley et al., 2007; Burrows et al., 2005). It is not surprising therefore that if there is a link between victim and offender, meaning the offender is not a stranger, this also indicates solvability. This was also found in other research examining homicide (Roberts, 2007), and assault (D'Alessio and Stolzenberg, 2003; Peterson et al., 2010).

The effect seen for non-stranger offenders may suggest a reason for the finding that offences which occur in dwellings and private indoor locations being strongly linked with solvability. The view that this is linked to knowledge of an offender (Eitle et al., 2005) is strongly supported by these findings as private indoor location was no longer a predictive factor when other factors were controlled for in the logistic regression. This was also the case for offences which occurred in private outdoor locations. Public outdoor locations indicated lack of solvability until controlled for by other factors when it lost significance, demonstrating the importance of creating multivariate models. The occurrence of violent crime at public indoor locations remains consistent with clearance, despite controlling for other factors. This may be due to the presence of witnesses in public locations. However, this may not be the case for licensed premises which are negatively linked to solvability.

Despite licensed premises being a negative indicator of solvability, the involvement of alcohol or drugs in commission of the offence is positively related to clearance. Gill and Spriggs (2005) suggest that alcohol-related crimes are less likely to be deterred by CCTV and therefore CCTV may assist with clearance. Whilst CCTV has been demonstrated to be a negative indicator of solvability and the potential reasons for that will be discussed later,

it is possible that this explanation also applies to the offender's awareness of other types of evidence. Alcohol may reduce inhibitions to commit offences in front of witnesses, or may also be linked to offenders being less forensically aware, or making decisions that are less well planned, leaving more evidence for investigators. However, incidents involving alcohol may also suffer from issues due to the negative effect that alcohol (Read et al., 1992; Yuille and Tollestrup, 1990) and drugs (Thompson, 1995) may have on memory and witness testimony. Memory of violent (Clifford and Scott, 1978; Loftus and Burns, 1982) or stressful situations (Yuille et al., 1994) are already associated with reductions in quality of memory. It would be of benefit to develop this research by assessing whether there were delays before statements were taken and whether it is better to obtain statements at the time of the incident or the following morning when the stress, and potentially alcohol, have been removed from the equation.

Cleared cases are associated with a greater number of documents being created as part of the investigation. Given that suspect information is so important and others have found that witness evidence is key (Baskin and Sommers, 2012), it is unsurprising that having two or more statements scanned onto Crimescan was indicative of clearance. This would demonstrate that there are two pieces of witness evidence in relation to the case. More paperwork may be, in simple terms, a result of having more evidence and this is backed up by the presence of other paperwork types such as property forms, indicating evidence has been seized, SOCO forms, which denote evidence from forensic investigators, suspect information forms, and miscellaneous paperwork being indicative of cleared offences. However, when there is just one statement the relationship reverses to indicate un-

solvability. This may demonstrate that it is not enough to have one person stating that an incident has happened, without corroborating evidence, the one statement may not provide sufficient evidence to clear a crime. The finding for no statements scanned appears strange as it suggests increased solvability from having no statements. However, this author believes that this may be due to paperwork not being scanned if cases are already solved. These findings demonstrate the importance of encouraging attending officers to make every attempt to obtain written witness testimony.

It was surprising that the presence of photographs and drawings was not linked with solvability as this author believed that photographs of injuries presents strong evidence. However, this is not backed up by these findings and, contrary to findings of D'Alessio and Stolzenberg (2003), victim injury is not associated with higher solvability. This may be a side-effect of the lower solvability of mid-severity violent crime, where offences resulting in minor injuries are associated with unsolved cases. This needs more detailed examination of whether injuries are evidenced by photographs or officer statements. If not then it is unsurprising that minor injuries would not be demonstrative of clearances as they may heal before secondary investigators can photograph them.

Use of weapons is regularly found to be a factor affecting solvability of homicide, with contact weapons (Roberts, 2007) and knives (Addington, 2006; Puckett and Lundman, 2003) in particular being linked to increased solvability, whilst firearms are linked to decreased solvability (Litwin, 2004; Ousey and Lee, 2010) in some studies. However, there was no connection found between knives, firearms or contact weapons as a whole. The

only finding in relation to weapons was that opportunistic weapons such as broken bottles were negative indicators of solvability. The finding in relation to firearms could potentially be due to the fact that use of firearms in offences is not as prevalent in the UK as in the USA and therefore, despite such a large sample size, there may be insufficient instances of firearm-related assault to provide sufficient statistical power to show an effect. The small negative effect for weapon use causing injury could be a side-effect of mid-level assaults being solved less.

Rapid reporting has been shown to be important for other crimes where it can assist in allowing officers to get to the scene and arrest offenders at the scene (Clawson and Chang, 1977; Coupe and Blake, 2005; Spelman and Brown, 1981). This also appears to be the case for violent crime where offences that are reported within five minutes of the offence finishing are associated with greater chances of being solved. This may be due to rapid apprehension of suspects, however this cannot be confirmed without an in-depth examination of cases. Length of the reported incident is also related to crimes being solved, with durations of 15 minutes and under being associated with increased solvability. This may aid officers in investigating the offence as it will make tasks such as checking alibis much easier to perform. The importance of timing is also demonstrated by the fact that offences reported to patrol officers are more likely to be solved, where offences reported by slower methods; to help desk or front office, are less solvable. This demonstrates the importance of encouraging members of the public to contact police by the most appropriate method as it may make the difference between a crime being solved or not. Offences committed in daylight have been demonstrated as being associated with

increased solvability by Alderden and Lavery (2007) and Coupe and Blake (2006). This is consistent with the findings of this research. However, the timings in the other studies were constant so at some times of year they may not have been accurate in terms of demonstrating hours of darkness. This was addressed through use of sun/moon-rise charts against which all offence times were compared. This appears to be a much more robust method for examining the effect of time of day. This finding also suggests that it may be worth assessing the impact of lighting quality on clearance rate as improved lighting may lead to additional witnesses due to improved visibility (Welsh and Farrington, 2007).

Another novel method which was used in this research was aoristic analysis. Aoristic analysis is most used for identifying temporal risk to allow accurate deployment of officers. However, in this case it was used to measure workload. Consistent with other studies (Coupe and Griffiths, 2000; Puckett and Lundman, 2003; Tilley and Burrows, 2005), times of highest demand and therefore highest response officer workload were associated with lowed solvability. This lends support for the idea that high officer workload may lead to lower clearance rates. However, whilst this was a novel way of addressing this problem and is certainly better than no assessment of this factor, it cannot achieve the levels of accuracy that could be achieved by working out exact staffing and incident numbers or by observing investigative resourcing.

Overall, the total number of WMP solvability factors is indicative of solvability. However, this included whether suspect information is present and whether the officer believes there to be forensic opportunities. The third WMP factor which is significantly associated

with increased solvability is the crime being part of a series. This is likely to be due to each individual crime having a finite amount of evidence, but when there are more linked crimes, there is more evidence as a result of the additional incidents. The negative impact of flagged property on clearance is not entirely understood. This may be an indicator of concomitant theft-related offences, which would be of interest. However, without examining these cases in depth it is not possible to know. The majority of factors included in the WMP model are not significantly related to solvability. Witnesses outstanding is surprising as, if these witnesses provide statements it would increase the evidence available. However, it is possible that a lot of the potential witnesses do not aid investigations and therefore these would essentially be red herrings. The classification of the incident as mandatory to investigate, critical, of media interest, high profile or its association with community tension or financial impact have no relation with solvability. However, many of these have also been included in the model designed by this author. This is due to the high reputational risk that is posed by non-investigation of crimes in these categories. The same applies for hate offences which are also not linked to clearance. It is not enough to strictly allocate according to solvability. If the political needs of the organisation are not satisfied then the allocation model will not be implemented (Denis et al., 2007).

There are three of the WMP factors which are not straightforward in their interaction with clearance. CCTV is understandably suggested as a solvability factor and has been demonstrated to be so by other researchers (Robb et al., 2014). However, in this research it shows a strong negative link with clearance. It is contraindicative to think that having

CCTV would make it less likely that a crime was solved so the variable was examined more closely. However, the variable is actually measuring whether the officer thinks there may be CCTV. This includes a wide range of outcomes; from CCTV that the officer has seen and clearly shows the offender committing the crime, to no CCTV being present but the officer thought there might be. Taking this into consideration, it is recommended that more accurate measures are made of the presence of CCTV in order that it can be more useful in prediction of solvability. In the right circumstances, where officers are directed to the offender by live CCTV operation it can clearly be of major benefit (Brown, 1995, p.24). The final three WMP factors, presence of forensic opportunities, VRM information and additional factors, assist with answering research questions two and three.

Factors for Development by UK policing agencies

The WMP forensic factor refers to whether, in the officer's opinion, there are forensic opportunities. This is found to be positively associated with solvability. However, once placed into the logistic regression, it ceases to be a significant factor. This is likely to be due to the presence of another forensic variable, whether items were recovered by forensic investigators. The recovery of forensic evidence remains significant both in individual measurements and in logistic regression. It is positively associated with clearance of non-domestic violent crime. This is consistent with other research where forensic evidence (Peterson et al., 2010; 2013) and medically documented forensic evidence of injury extent (McGregor et al., 2002) have been found to be linked to clearance. Further research is required to determine which types of forensic evidence have the greatest impact upon solvability. However, this was not possible during this body of research due to data access

constraints. Bond (2007; 2008; 2009) has found that, contrary to findings of Greenwood and colleagues (1975), investigative skill is important when the evidence tying the offender to the crime is a movable DNA source, as well as that multiple sources increase the effectiveness of the evidence. Therefore this is an important next step, especially as McEwen (2010) found that the presence of probative forensic evidence was not only linked to charging decisions, but also to longer sentences.

The under-utilisation of forensic evidence is demonstrated by the analysis of prevalence. The second research question asks; are there investigative factors that contribute towards violent crime solvability which can be developed by UK policing agencies? Allocation of forensic scene investigators to violent offences is such a factor. Under five percent of cases receive allocation of a forensic investigator, despite the fact that there is contact between the victim and the offender in the vast majority of violent offences. Therefore there will be transfer of trace material, with injuries there are likely to be photographic opportunities, and the victim may have fought back, causing DNA to be available. With the introduction of DNA-17 (CPS, 2014; Forensic Access, 2014) earlier this year in the UK, DNA evidence has become more sensitive, meaning that there is the ability to obtain a DNA profile where previously none was detected. This further increases the benefit to UK policing agencies of investing in this area. This is a major area for development which has been highlighted by other authors (Julian et al., 2011; Ludwig and Fraser, 2014). In 2002, Blakey stated on behalf of HMIC that there was a lack of awareness of what forensic science could achieve. There may be opportunity to improve detection of violent crime by altering attendance policies for forensic investigators, or by training officers to seek out and recover forensic evidence.

Controlling for Suspect Information

The final two WMP factors; presence of VRM information and additional factors, do not respond in the same consistent manner as other factors. Research question three asked: are there factors which affect clearance of violent crime differently dependent upon whether there is suspect information available? Suspect information is such a strong factor that it may cause the effects of other factors to be overlooked or lost. For presence of VRM information and additional factors this is noticeably the case. Cases with VRM present are negatively associated with clearance when the whole dataset is examined. However, once all cases with suspect information are removed, cases with VRM information become positively related to clearance, consistent with findings of Robb and Colleagues (2014) for metal theft. The effect for VRM information did not survive once combined with other variables in the logistic regression. However, it demonstrates that VRM information is a beneficial variable in the absence of suspect information and that other researchers may have potentially missed relevant variables due to them being concealed by other variables.

Presence of additional factors was non-significant but negative in the overall data-set. With suspect information removed its relationship with clearance changed to a non-significant positive relationship. Once placed in the logistic regression, controlling for other factors to a greater degree, cases with additional factors identified were significantly related to clearance in a positive direction. This is interesting for two reasons. Firstly, it adds weight to the previous finding that suspect information may conceal other factors and cases with and without suspect information may have different predictors, secondly it appears that there are likely to be other factors that this study has not identified. These will only be

identified by examining the cases with additional information in detail which was not possible during this research but is certainly of value for future research.

Prediction of Clearance

This research has examined the variables above using logistic regression, leaving out those which would create difficulties with the regression model (e.g. due to multicollinearity) and those which could not be used practically, as the overall goal was to create a usable model. The logistic regression had an overall accuracy of 66.9%. However, it would not have been politically acceptable to fail to investigate the amount which would have been filed at source, but which the previous model would have allocated, and would have been solved. It is essential that models are politically acceptable (Fixsen et al., 2005) as whilst they may increase efficiency dramatically, if damage is done to the reputation of the organisation, it discourages further evidence-based practice. To make it politically acceptable, a novel mechanism for adjusting the cut-off value was applied, to ensure that as few victims would be let down as possible. To further ensure that this model is applicable to policing without exposing the organisation to excessive reputational risk, any cases that incorporate media attention, community tension, hate crimes, or with injuries amounting to GBH were automatically allocated in. Especially in times of PCC oversight, it is necessary to ensure that the predictive model is fit for purpose, and ready for implementation, to avoid a natural distrust of academics (Giluk and Rynes-Weller, 2012). Once applied to the second half of the dataset, it is possible to answer question four: to what extent can case clearance be predicted by factors identified in this research? The overall accuracy of this model is 64.05% with the majority of the error being concentrated in investigations that were not

detected but have been allocated. Because it was not possible to identify whether cases were marked as resolved or not following the initial investigation, it is possible that some of the incorrectly filed cases would be allocated through being resolved originally. 64.05% may seem low in comparison to Eck's (1983) 85% accurate prediction of burglary outcomes. However, Paine (2012, p.34) provides evidence of burglary detection rates being approximately 11%. This means that a decision to file all cases without investigation would be 89% accurate. This study has identified over double the number of predictive factors for violent crime than Paine (2012) did in his large-scale analysis of burglary so, unlike burglary, there are very few cases of violence with no solvability factors. Violent crime appears more difficult to predict due to higher clearance rates, though the best method of assessing the accuracy of the model is to compare it to the current experiential model which allocates crimes based on a combination of officer-derived criteria.

Question five asks; how does the current WMP case screening mechanism compare to the factors identified in this research when predicting case solvability? Applying current WMP allocation model to the dataset used in this study, it was demonstrated that it was 52.43% accurate. As the model created in this study had a 64.05% accuracy rate, the statistical model created in this thesis has predicted case outcome 11.62% more accurately than the experiential model is able to. This is a dramatic increase in accuracy which would see West Midlands Police investigating thousands fewer crimes per year, the vast majority of which have insufficient evidence to be cleared. This lower level of allocation would facilitate either an increase in service level for the crimes that are allocated, due to decreased investigator workload and may increase overall clearance rates, or it could lead to financial

savings as fewer investigators would be required to offer the same service level to victims of allocated crime. This author would hope that resources remain the same so that a better level of service can be given to victims across the West Midlands. The limitations and strengths of this research are discussed next as it is important to ensure that implications of research are presented accurately, and with humility (Weiss, 1988), to ensure that they are not overstated, which could potentially damage trust in the academic process (Lum et al., 2012).

Limitations and Strengths of this Research

The data used in this research allows for an extremely large-scale, powerful analysis but it does not allow for identification of non-electronically recorded variables. It would be of benefit to take a sample of records in addition to the overall dataset to examine them in detail. This would facilitate assessment of data accuracy and identification of additional factors, as well as granting an understanding into the mechanisms by which factors link to solvability, rather than just an overview of the links that are present.

It was not possible to examine some of the potential factors identified in the literature review due to lack of electronically retained data in relation to those factors. Presence of concomitant offences is one such example where due to Home Office counting rules, only the most serious offence is recorded, others being referred to within the investigation log.

The scale of the dataset meant that it was not possible to include a number of potential solvability factors which are not electronically accessible; such as the use of proactive

tactics and covert assets to gather information, and the use of intelligence systems to gather evidence. Consistent with Robb and colleagues (2014), these data were gathered from systems which do not record some promising factors. In terms of suspect information it would be beneficial to have multiple measures, so that suspects who are named can be differentiated from vaguely described suspects. It is also not possible to determine quality of factors without conducting an in-depth examination of all records which would potentially take years to complete, by which time the data may be out of date.

This study does not have an assessment of cost-benefit, and therefore cannot evidence the financial and service benefits that it would provide. Roman's (2008) analysis of the cost-effectiveness of DNA is unfortunately one of the sole cost-benefit analyses in relation to solvability, and it is imperative that this situation is improved. It is important to note that due to this being a descriptive study, despite the nature of the predictive analyses, it is not possible to argue that any of these solvability factors causes crime to be cleared (Black, 2002; Stigler, 2005).

Due to the variety of populated areas contained within the West Midlands policing area, and the quantity of data included, the results obtained are likely to be externally valid to be applied elsewhere in the UK. However, replication would be advised prior to any implementation to ascertain whether the predictive models retain accuracy for different populations.

Whilst it is limited by the factors detailed above, this research has conducted the largest scale examination of solvability factors to date. Use of a huge dataset has enabled a large number of disparate solvability factors, and case-limiting factors (negative factors), to be identified for non-domestic violent crime, an area where others had struggled to identify solvability factors. Using these factors, this research has combined traditional techniques with novel examinations of information to produce a predictive model which is capable of increasing the accuracy of allocation for WMP by just 11.62%.

Whilst it is probable that this model can be adjusted and improved upon through inclusion of additional information, this provides a tool which could dramatically increase the efficiency of the WMP investigative function. This method can also be applied to other areas and crime types, facilitating a large-scale improvement in policing efficiency to be achieved. However, it is important that this is implemented in a manner by which the effects can be properly documented. Therefore it is suggested that it be implemented as part of a randomised controlled trial to ensure the gold-standard of research evidence is obtained (Sherman, 1998) which should then be examined using cost-benefit analysis (Welsh et al., 2001), once the full benefits are realised, as this will allow policymakers to make informed decisions about further implementation.

Conclusions and Implications

Violent offences cause both physical and psychological harm and policing agencies are duty bound to investigate unlawful violence in the most effective manner possible, whilst maximising efficiency when using the public money they are granted.

Previous research has demonstrated that there are investigative factors which are indicative of case clearance (Eck, 1983; Roberts, 2008), though some studies (Greenwood et al., 1975) have struggled to evidence solvability factors for violent crime. This study used traditional investigative methods such as individual factor analysis and logistic regression, combined with novel techniques such as aoristic analysis and cut-off point alteration, and identified both solvability and case-limiting factors using a randomised sample of 14553 non-domestic violent offences, taken from a full population, with the other half being used to test the findings.

Twenty-five positive solvability factors have been identified: suspect information, victim-offender link, forensic investigator dispatched, forensic evidence recovered, officer-identified forensic opportunities, offence duration under 15 minutes, reported within 5 minutes, daylight offence, two or more statements, private indoor location, dwelling, public indoor location, private outdoor location, part of a series, reported to patrol, alcohol involved, drugs involved, GBH with intent, attempt murder, lower aoristic risk, at least one property form scanned, at least one miscellaneous form scanned, at least one forensic form scanned, at least one suspect form scanned, and, controlling for other factors, presence of additional officer-identified factors.

Thirteen case-limiting factors have been identified; just one statement, public outdoor offence location, officer-identified potential for CCTV, reported in front office, reported to helpdesk or control centre, opportunistic weapon used, ABH, minor wounding, GBH without intent, flagged property, offence on licensed premises, weapon used to cause injury and officer-identified VRM information, though this changes to a positive factor if suspect information is controlled for. This research therefore showed that there are differences between solvability factors with and without suspect information.

Presence of forensic evidence is one of the stronger solvability factors, yet forensic investigators are only found to be dispatched to 4.43% of cases. 90.37% of the cases they attend yield evidence. This is an area where policing agencies may be able to improve their clearance of violent crime, especially with recent improvements in the sensitivity of DNA evidence (CPS, 2014).

Most of the factors that have been identified as solvability and case-limiting factors were examined using logistic regression analysis which was then reverse engineered to create a predictive formula. Various cut-off points, above which cases are screened in for investigation, were assessed to ensure that the model was screening in as many solved cases as possible as the political ramifications of the public feeling that police will not investigate reported crime could be severe (Gill et al., 1996). It is also important to take into account what is important to police leaders and practitioners as failure to do this will only result in no change at all (Denis et al., 2007; Lum et al., 2012). The model therefore includes a number of automatic allocation criteria to address political risk. This new

statistical allocation model was tested on the second randomly selected 14552 case dataset and it correctly predicts outcome of 64.05% of cases.

Kahneman (2011) argues that statistical models are more accurate than human decision makers, yet Sherman (2013) states that, as of 2012, it was still hard to find a police agency using a statistical model for investigative resource allocation. WMP uses an experiential model where presence of any one factor screens in cases. The WMP model was also applied to the second dataset and it correctly predicts outcomes in 52.43% of cases. Therefore this research has designed a predictive model and has directly compared it to an existing experiential model. The statistical model has a higher accuracy of prediction by just under twelve percent.

There are various implications that arise from this research. Firstly, researchers in the field of solvability need to be aware of the impact that solvability factors have on one another, especially the presence of suspect information. Failure to address inter-variable effects may impact negatively on external validity of any such study.

It would be of benefit to any future research if police services recorded additional information relating to suspects in terms of whether they are described or named, and what date and how the suspect became known. Additional information would assist further examination of CCTV and VRM variables as at present quality, and whether the offence or offender is shown, are not captured.

It would be of benefit to conduct in-depth analysis of smaller samples to assess the impact of currently unidentified additional factors, covert and proactive tactics, and parts of the secondary investigation which may identify actions which could be better performed in the primary investigation but are currently associated with secondary investigations. This could be assisted by police systems retaining a downloadable audit trail of changes to records.

Sherman (1998, p.2) stated “police practices should be based on scientific evidence about what works best.” It has been demonstrated that forensic evidence is a little used but powerful indicator of solvability. These findings are consistent with Peterson and colleagues (2010) who identified that there is a worrying underutilisation of forensic science. Therefore consideration should be given to altering policy in relation to attendance of forensic investigators. However, this should be conducted in a manner that allows the costs and benefits to be analysed as Roman and colleagues (2008) have done and the necessary testing protocols should be in place to prevent evidence from being collected but not submitted as was found by Strom and Hickman (2010).

It is necessary to assess the impact of implementation of a model such as this on clearance rates, legitimacy, victim satisfaction and cost. Implementation of this model would be best done using a randomised controlled trial (Lösel, 2007) as these should be used where possible. This would allow the impact to be measured and assessed during implementation and would allow for a cost-benefit analysis to be conducted (Dhiri and Brand, 1999).

Appendices

Appendix 1: Table of Potential Solvability Factors

Factor	Included Details	System
Named Suspect	Not possible due to overwriting of this field	N/A
Suspect Information	Included as Suspect Information	WMP Solvability
Stolen Property	Included as Property Flagged	WMP Solvability
Location Characteristics	Type of Location is coded	Crimes
Presence of Witnesses	Outstanding Witnesses	WMP Solvability
	Number of Statements Provided	Crimescan
Temporal Characteristics	Offence Duration	Crimes
	Time from Incident to Report	Crimes
	Time from Report to Recording	Crimes
Forensic Evidence	Was FSI dispatched?	Socrates
	Was anything recovered by FSI?	Socrates
Speed of Response	Not possible to include due to difficulties linking crime information to log information	N/A
On-Scene Capture	Not possible due to overwriting of this field	N/A
CCTV	CCTV Flag	WMP Solvability
Vehicle Information	VRM Information	WMP Solvability
Footprints	Not possible due to Socrates data extraction issues	N/A
Fingerprints	Not possible due to Socrates data extraction issues	N/A
DNA	Not possible due to Socrates data extraction issues	N/A
Trace Evidence	Not possible due to Socrates data extraction issues	N/A
Photographic Evidence	Not possible due to Socrates data extraction issues	N/A
Proactive Investigation	Not possible to to size of dataset - this would require interrogation of individual records	N/A
Offence Visibility	Daylight Offence	Crimes
Availability of Resources	Aoristic Analysis	Crimes

Factor	Included Details	System
Early Reporting	Time from Incident to Report	Crimes
Victim Gender	Victim Gender	Crimes
Victim Age	Victim Age	Crimes
Victim Ethnicity	Victim Ethnicity	Crimes
Multiple Victims	Not possible due to poor recording of linked crimes	N/A
Concomitant Offences	Not possible due to most serious crime being recorded	N/A
Victim Injury	Victim Injury	Crimes
Offender is Acquaintance or Family Member	Link between Victim and Offender	Crimes
Victim and Witness Accounts	Number of Statements Provided	Crimescan
Within Dwelling	Offence Within Dwelling	Crimes
Unemployment Rate	Not possible due to lack of accuracy of this information	N/A
Racial Segregation	Not possible due to lack of accuracy of this information	N/A
High Population	Not possible due to lack of accuracy of this information	N/A
Stranger Offender	Offender Link to Victim	Crimes
Use of Firearm	Use of Firearm	Crimes
Use of Knife	Use of Knife or other bladed or sharply pointed article	Crimes
Use of Contact Weapon	Use of Contact Weapon	Crimes
Drug- or gang-related	Not possible to to size of dataset - this would require interrogation of individual records	N/A
Weather conditions	Not possible as this information is not recorded	N/A
Skill of Detectives, Officers per case and officer workload	Not possible as this information is not recorded	N/A
Caps on Overtime	Not possible as this information is not recorded	N/A
Offender under the influence	Alcohol Involved Marker	Crimes
	Drug Involved Marker	Crimes
Interest from NY Times	Media Interest	WMP Solvability

Appendix 2: Variables Considered for Analysis

Research Case URN	SOCO on Docutrak
Crime Number	SUSIM on Docutrak
Group	SUSP on Docutrak
Cuc Code	W200 on Docutrak
Days to Clear Offence	Total Scanned Documents
Detected	At least one MG11
Detecting Dept	Two or more MG11s
Offence Grid Ref Easting	At least one PROP
Offence Grid Ref Northing	At least one SOCO
Offence	At least one DRAW
Offence Coded	Offender Link to Victim?
Offence Severity	Daylight Offence
Offence Severity Common Assault	Time between First and Last Committed
Offence Severity ABH	Time between Last Committed and Reported
Offence Severity Wounding	Time between Reported and Recorded
Offence Severity GBH without Intent	Duration 5 minutes or under
Offence Severity GBH with Intent	Duration 10 minutes or under
Offence Severity Attempt Murder	Duration 15 minutes or under
Offence Severity	Duration 20 minutes or under
Offence Severity Common Assault	Duration 30 minutes or under
Offence Severity ABH, Malicious Wounding and GBH without intent	Duration 60 minutes or under
Offence Severity GBH with Intent and Attempt Murder	Duration 120 minutes or under
Visible Injury	Reported within 5 minutes
Hate Incident	Reported within 10 minutes
Offender Unknown	Reported within 15 minutes
Primary Location Type Description	Reported within 20 minutes
Primary Location Description - Coded	Reported within 30 minutes
Location Type	Reported within 60 minutes
Private Indoor	Reported within 120 minutes
Private Outdoor	Reported within 12 hours
Public Indoor	Reported within 24 hours
Public Outdoor	Reported within 48 hours
Licensed Premises?	Reported within 72 hours
Dwelling?	Reported within 7 days
Report Code	Reported within 14 days
Report Method	Reported within 30 days
Reported in Front Office	Recorded within 5 minutes
Reported to Help Desk / Contact Centre	Recorded within 10 minutes
Reported to Patrol	Recorded within 15 minutes
Days between First and Last Committed	Recorded within 20 minutes

Days between Last Committed and Reported	Recorded within 30 minutes
Days between Reported and Recorded	Recorded within 60 minutes
Weapon Usedt Recorded	Recorded within 120 minutes
FSI Dispatched?	Recorded within 12 hours
Something recovered by FSI (Includes FP, DNA, Photos etc.)	Recorded within 24 hours
Days in custody process	Recorded within 48 hours
Days between report and arrest	Recorded within 72 hours
Suspect Information	Recorded within 7 days
Witness Outstanding	Recorded within 14 days
Resolved	Recorded within 30 days
Mandatory	DRUGS INVOLVED (DI MARKER)
Critical	ALCOHOL INVOLVED (AI MARKER)
Media Interest	ARREST MADE (AM MARKER)
Community Tension	Victim Age at Date First Committed
Financial Impact	Victim Sex
Profile High	Victim Age 0-12 Years
Forensic Evidence	Victim Age 13-59 Years
Series	Victim Age 60+
Property Flagged	Victim Age 13-17 Years
Vrm Details	Victim Age 18-59 Years
Cctv Flag	Victim Identity Code
Additional Factors	White Victim
Count of WMP Factors Present	Black Victim
Allocated for investigation by WMP Model?	Asian Victim
Weapons List Code	Other or Mixed Race Victim
Weapons List	Aoristic Risk Level
Weapon Type	Duration 5 minutes or under
Knife, Blade or Sharply Pointed Object Used in Offence	Duration 5-10 minutes
Lethal Firearm Used in Offence	Duration 10-15 minutes
Opportunistic Weapon Used in Offence	Duration 15-20 minutes
Non-Lethal or Imitation Firearm Used in Offence	Duration 20-30 minutes
Blunt Instrument Used in Offence	Duration 30-60 minutes
Vehicle Used as Weapon in Offence	Duration 60-120 minutes
Other Weapon Used in Offence	Duration over 120 minutes
Weapon Not Recorded	Reported within 5 minutes
Contact Weapon Used - Knife, Opportunistic and Blunt	Reported 5-10 minutes
Non-contact Weapon Used - Firearm, Imitation, Vehicle, Other	Reported 10-15 minutes
Lethal Firearm Used in Offence	Reported 15-20 minutes
Knife, Blade or Sharply Pointed Object Used in Offence	Reported 20-30 minutes
Other Contact Weapon Used in Offence	Reported 30-60 minutes
Other Weapon Used in Offence	Reported 60-120 minutes
Lethal Firearm Used in Offence	Reported 2-12 hours
Knife, Blade or Sharply Pointed Object Used in Offence	Reported 12-24 hours

Other Contact (Weapon Used or No Weapon) in Offence	Reported 24-48 hours
Weapons Use Code	Reported 48-72 hours
Weapons Use	Reported 3-7 days
Weapon Use Type	Reported 7-14 days
Weapon Used Injury/Damage	Reported 14-30 days
Weapon Used Threat or Other	Reported over 30 days
Weapon Carried or Believed but not used	Recorded within 5 minutes
Weapon Use not Recorded	Recorded 5-10 minutes
CORR on Docutrak	Recorded 10-15 minutes
CRMSC on Docutrak	Recorded 15- 20 minutes
DET on Docutrak	Recorded 20-30 minutes
DRAW on Docutrak	Recorded 30-60 minutes
FILE on Docutrak	Recorded 60-120 minutes
INVST on Docutrak	Recorded 2-12 hours
MG11 on Docutrak	Recorded 12-24 hours
MISC on Docutrak	Recorded 24-48 hours
MISP on Docutrak	Recorded 48-72 hours
PROP on Docutrak	Recorded 3-7 days
PRPIM on Docutrak	Recorded 7-14 days
ROB on Docutrak	Recorded 14-30 days
SOCIM on Docutrak	Recorded over 30 days

Appendix 3: Coding of Weapons

The tables found below show the individual weapon descriptions which are coded into each of Knife, Blade or Sharply Pointed Article (Table 9), Lethal Firearm (Table 10), Opportunistic Weapon (Table 11), Non-Lethal or Imitation Firearm (Table 12), Blunt Instrument (Table 13), Vehicle (Table 14) and Other (Table 15).

Table 9: Weapon Descriptions that are coded as Knife, Blade or Sharply Pointed Article

Weapon Descriptions that are coded as Knife, Blade or Sharply Pointed Article
AXE
CRAFT KNIFE
DAGGER
FLICK KNIFE
KITCHEN KNIFE
KNIFE - UNKNOWN
LOCK KNIFE
MACHETE
MEAT CLEAVER
PEN KNIFE
RAZOR/BLADE
SCISSORS
SCREWDRIVER
SHARP INSTRUMENT
SWORD

Table 10: Weapon Descriptions that are coded as Lethal Firearm

Weapon Descriptions that are coded as Lethal Firearm
FIREARM - OTHER
HANDGUN - OTHER
HANDGUN - UNKNOWN
SHOTGUN - LONG BARRELLED
SHOTGUN - SAWN OFF
SUPPOSED FIREARM - TYPE UNKNOWN

Table 11: Weapon Descriptions that are coded as Opportunistic Weapon

Weapon Descriptions that are coded as Opportunistic Weapon
BRICK - STONE
BROKEN BOTTLE OR BROKEN GLASS
CHAIR
UNBROKEN BOTTLE OR UNBROKEN GLASS

Table 12: Weapon Descriptions that are coded as Non-Lethal or Imitation Firearm

Weapon Descriptions that are coded as Non-Lethal or Imitation Firearm
BALL BEARING GUN
HANDGUN - AIR PISTOL
HANDGUN - IMITATION
RIFLE - AIR RIFLE
SOFT AIR WEAPON

Table 13: Weapon Descriptions that are coded as Blunt Instrument

Weapon Descriptions that are coded as Blunt Instrument
BASEBALL BAT
BLUNT INSTRUMENT
COSH - BATON - STICK
HAMMER
IRON BAR
KNUCKLE DUSTER
SNOOKER/POOL CUE

Table 14: Weapon Descriptions that are coded as Vehicle

Weapon Descriptions that are coded as Vehicle
VEHICLE

Table 15: Weapon Descriptions that are coded as Other

Weapon Descriptions that are coded as Other
CS GAS
PEPPER SPRAY
STUN GUN/CATTLE PROD
ACID - BOILING WATER - CIGARETTE-BURNING
DOG
DRUGS - NOXIOUS SUBSTANCE
OTHERS
ROPE - SCARF - STOCKING ETC
EXPLOSIVE DEVICE

Appendix 4: Coding of Location Descriptors

The tables found below show the individual location descriptions which are coded into each of Private Indoor (Table 16), Private Outdoor (Table 17), Public Indoor (Table 18), Public Outdoor (Table 19), Unknown (Table 20), Licensed Premises (Table 21) and Dwelling (Table 22).

Table 16: Location Descriptions that are coded as Private Indoor

Location Descriptions that are coded as Private Indoor	
BUNGALOW - DWELLING	ABATTOIR
CARAVAN MOBILE HOME	DAY CARE CENTRE
CARE HOME	FACTORY
CHILDRENS HOME	GARAGE DOMESTIC
DETACHED - DWELLING	GOVERNMENT BUILDING
FLAT - DWELLING	MILITARY ESTABLISHMENT
HALLS OF RESIDENCE - DWELLING	NURSING HOME
HOSTEL - DWELLING	OFFICE
MAISONETTE - DWELLING	PORCH
OLD PEOPLE HOME - DWELLING	PORTACABIN
SEMI DETACHED - DWELLING	PRISON
SHELTERED/WARDEN CONTROLLED - DWELLING	SHED
TERRACE - DWELLING	WAREHOUSE
TOWN HOUSE - DWELLING	

Table 17: Location Descriptions that are coded as Private Outdoor

Location Descriptions that are coded as Private Outdoor
BUILDING SITE
COMPOUND
CONVEYANCE
DRIVE/DRIVEWAY
GARDEN
REAR OF PREMISES

Table 18: Location Descriptions that are coded as Public Indoor

Location Descriptions that are coded as Public Indoor	
BETTING OFFICE	GYMNASIUMS
CASINO	HEALTH CENTRE
CLUB - SOCIAL	HOSPITAL
NIGHTCLUB	HOTEL
OFF LICENCE - LICENSED PREMISES	KIOSK
PUBLIC HOUSE - LICENSED PREMISES	LANDSIDE
RESTAURANT / CAFE	LAUNDERETTE
AIRPORT	LAVATORY / TOILET
AIRSIDE	LEISURE COMPLEX
BANK	LIBRARY
CHILDRENS NURSERY	MARKET
COMMUNAL AREA	MUSEUM
COMMUNITY CENTRE	PETROL STATION
COURT	PLACE OF WORSHIP
ENTERTAINMENT INDOOR	POLICE ESTABLISHMENT
ESTATE AGENT	POST OFFICE
EXHIBITION CENTRE	SHOP
FAST FOOD OUTLET	SHOPPING COMPLEX
FIRE STATION	SPORTS CLUB
FOOTBALL GROUND	SUPERMARKET
FOYER	SURGERY
FUNCTION ROOM	SWIMMING BATHS (POOL)
GARAGE COMMERCIAL	

Table 19: Location Descriptions that are coded as Public Outdoor

Location Descriptions that are coded as Public Outdoor	
ALLEY	INDUSTRIAL ESTATE
ALLEYWAY	OUTSIDE ADDRESS
ALLOTMENT	PARK
BRIDGE	PLAYING FIELD
BUS	PUBLIC FOOTPATH
BUS SHELTER	QUARRY
BUS STATION	ROAD
BUS STOP	SUBWAY
CAR PARK	TAXI
CARAVAN SITE	TELEPHONE KIOSK
CASH MACHINE	UNDERPASS
CEMETERY	WASTE GROUND
COACH / TRAILER PARK	WATERWAY / CANAL / TOWPATH
COUNTRYSIDE	WOODLAND
EDUCATIONAL	YARD
ENTERTAINMENT OUTDOOR	

Table 20: Location Descriptions that are coded as Unknown

Location Descriptions that are coded as Unknown
COUNCIL OWNED
OTHER

Table 21: Location Descriptions that are coded as Licensed Premises

Location Descriptions that are coded as Licensed Premises
BETTING OFFICE
CASINO
CLUB - SOCIAL
NIGHTCLUB
OFF LICENCE - LICENSED PREMISES
PUBLIC HOUSE - LICENSED PREMISES
RESTAURANT / CAFE

Table 22: Location Descriptions that are coded as Dwellings

Location Descriptions that are coded as Dwellings
BUNGALOW - DWELLING
CARAVAN MOBILE HOME
CARE HOME
CHILDRENS HOME
DETACHED - DWELLING
FLAT - DWELLING
HALLS OF RESIDENCE - DWELLING
HOSTEL - DWELLING
MAISONETTE - DWELLING
OLD PEOPLE HOME - DWELLING
SEMI DETACHED - DWELLING
SHELTERED/WARDEN CONTROLLED - DWELLING
TERRACE - DWELLING
TOWN HOUSE - DWELLING

Appendix 5: Prevalence of all Identified Solvability Factors

Variable	Prevalence in Sample	% in sample with variable
Offence Severity Common Assault	3896	26.77%
Offence Severity ABH	6726	46.22%
Offence Severity Wounding	2084	14.32%
Offence Severity GBH without Intent	766	5.26%
Offence Severity GBH with Intent	1057	7.26%
Offence Severity Attempt Murder	24	0.16%
Visible Injury Recoded with Unknown Removed	10486	72.05%
Hate Offence	589	4.05%
Private Indoor	2826	19.42%
Private Outdoor	240	1.65%
Public Indoor	3295	22.64%
Public Outdoor	8120	55.80%
Licensed Premises?	1503	10.33%
Dwelling?	2683	18.44%
Reported in Front Office	635	4.36%
Reported to Help Desk / Contact Centre	6475	44.49%
Reported to Patrol	4090	28.10%
FSI Dispatched?	644	4.43%
Something recovered by FSI (Includes FP, DNA, Photos etc.)	582	4.00%
Suspect Information	9309	63.97%
Witness Outstanding	3571	24.54%
Resolved	6611	45.43%
Mandatory	2472	16.99%
Critical	30	0.21%
Media Interest	26	0.18%
Community Tension	55	0.38%
Financial Impact	9	0.06%
Profile High	6	0.04%
Forensic Evidence	500	3.44%
Series	1145	7.87%
Property Flagged	83	0.57%
Vrm Details	680	4.67%
Cctv Flag	5043	34.65%
Additional Factors	1318	9.06%
Allocated for investigation by WMP Model? Not including Resolved	12786	87.86%

Variable	Prevalence in Sample	% in sample with variable
Knife, Blade or Sharply Pointed Object Used in Offence	486	3.34%
Lethal Firearm Used in Offence	26	0.18%
Opportunistic Weapon Used in Offence	291	2.00%
Non-Lethal or Imitation Firearm Used in Offence	68	0.47%
Blunt Instrument Used in Offence	468	3.22%
Vehicle Used as Weapon in Offence	52	0.36%
Other Weapon Used in Offence	376	2.58%
Weapon Not Recorded	12786	87.86%
Weapon Used Injury/Damage	1446	9.94%
Weapon Used Threat or Other	250	1.72%
Weapon Carried or Believed but not used	71	0.49%
Weapon Use not Recorded	12786	87.86%
One MG11	2236	15.36%
At least one MG11	9338	64.17%
Two or more MG11s	7102	48.80%
At least one PROP	2302	15.82%
At least one SOCO	326	2.24%
At least one DRAW	560	3.85%
At least one MISC	4622	31.76%
At least one SUSP	114	0.78%
Offender Link to Victim?	1818	12.49%
Duration 15 minutes or under	10387	71.37%
DRUGS INVOLVED (DI MARKER)	135	0.93%
ALCOHOL INVOLVED (AI MARKER)	2934	20.16%
Female Victim	4547	31.24%
Victim Age 0-12 Years	603	4.14%
Victim Age 13-17 Years	1961	13.47%
Reported within 5 minutes	6183	42.49%
Lowest Risk Aoristic Group	2896	19.90%
Low Risk Aoristic Group	2906	19.97%
Medium Risk Aoristic Group	2852	19.60%
High Risk Aoristic Group	2819	19.37%
Highest Risk Aoristic Group	3080	21.16%
Offender Link to Victim?	1818	12.49%
Daylight Offence	7071	48.59%

Appendix 6: Logit Transformation Table

p	logit(p)	p	logit(p)	p	logit(p)	p	logit(p)
0.01	-4.5951	**0.26**	-1.0460	**0.51**	0.0400	**0.76**	1.1527
0.02	-3.8918	**0.27**	-0.9946	**0.52**	0.0800	**0.77**	1.2083
0.03	-3.4761	**0.28**	-0.9445	**0.53**	0.1201	**0.78**	1.2657
0.04	-3.1781	**0.29**	-0.8954	**0.54**	0.1603	**0.79**	1.3249
0.05	-2.9444	**0.30**	-0.8473	**0.55**	0.2007	**0.80**	1.3863
0.06	-2.7515	**0.31**	-0.8001	**0.56**	0.2412	**0.81**	1.4500
0.07	-2.5867	**0.32**	-0.7538	**0.57**	0.2819	**0.82**	1.5163
0.08	-2.4423	**0.33**	-0.7082	**0.58**	0.3228	**0.83**	1.5856
0.09	-2.3136	**0.34**	-0.6633	**0.59**	0.3640	**0.84**	1.6582
0.10	-2.1972	**0.35**	-0.6190	**0.60**	0.4055	**0.85**	1.7346
0.11	-2.0907	**0.36**	-0.5754	**0.61**	0.4473	**0.86**	1.8153
0.12	-1.9924	**0.37**	-0.5322	**0.62**	0.4895	**0.87**	1.9010
0.13	-1.9010	**0.38**	-0.4895	**0.63**	0.5322	**0.88**	1.9924
0.14	-1.8153	**0.39**	-0.4473	**0.64**	0.5754	**0.89**	2.0907
0.15	-1.7346	**0.40**	-0.4055	**0.65**	0.6190	**0.90**	2.1972
0.16	-1.6582	**0.41**	-0.3640	**0.66**	0.6633	**0.91**	2.3136
0.17	-1.5856	**0.42**	-0.3228	**0.67**	0.7082	**0.92**	2.4423
0.18	-1.5163	**0.43**	-0.2819	**0.68**	0.7538	**0.93**	2.5867
0.19	-1.4500	**0.44**	-0.2412	**0.69**	0.8001	**0.94**	2.7515
0.20	-1.3863	**0.45**	-0.2007	**0.70**	0.8473	**0.95**	2.9444
0.21	-1.3249	**0.46**	-0.1603	**0.71**	0.8954	**0.96**	3.1781
0.22	-1.2657	**0.47**	-0.1201	**0.72**	0.9445	**0.97**	3.4761
0.23	-1.2083	**0.48**	-0.0800	**0.73**	0.9946	**0.98**	3.8918
0.24	-1.1527	**0.49**	-0.0400	**0.74**	1.0460	**0.99**	4.5951
0.25	-1.0986	**0.50**	0.0000	**0.75**	1.0986		

Medcalc Software (2014b)

Accessed from http://www.medcalc.org/manual/logit_transformation_table.php

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