LINKING CRIME THROUGH MODUS OPERANDI

ON LINKING SERIES OF BURGLARY INTO SINGLE OFFENDERS THROUGH CRIME SCENE INFORMATION

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ABSTRACT

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The current paper is aimed at providing an overview of the current state of research regarding the potential of linking series of crimes to single offenders through repeated modus operandi behaviors. A systematic literature review was conducted to document findings from previous evaluation research as to the predictive accuracy of crime linkage specific to residential burglary. The findings indicate that predictions of linked burglaries can be made with moderate to high predictive accuracy. In order to get an understanding of the extent to which residential burglary offenders repeat their crime scene behaviors, the findings are discussed in relation to the criminological theories Routine activities theory and the Rational Choice perspective. Future research is suggested.

Keywords: Linking crime, residential burglary, Modus operandi, ROC analysis, systematic literature review

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INTRODUCTION

In recent years, police agencies in many countries around the world have adopted strategies to collect and analyze information on crime scene behaviors in order to direct future police interventions. As an attempt to move into a more intelligence led policing approach, rather than a reactive, these analyses are carried out in order to effectively deploy limited police resources (Woodhams, 2007). These structured analyses has the ambition to link series of offences into single offenders by the offenders behavioral similarities, or modus operandi, at crime scenes. Linking series of crimes by behavioral information is not as reliable as physical evidence such as DNA or fingerprint matching. These analyses may however show indications that certain crimes are committed by the same perpetrator, and thus may assist criminal investigations (Woodhams, 2007).

Between the years 2012 and 2014 a research project was conducted by a collaboration between the Swedish Police agency, Blekinge Tekniska Högskola (BTH, Blekinge Technical College) and the state's forensic laboratory with three subprojects concerning; (1) structured data collection from crime scenes, (2) automatic methods for crime coordination and (3) automatic methods for shoeprint matching (Boldt et al, 2015). The sanctions of the first two subprojects led to the development of a new reporting system for crime scene information named SAB (strukturerad anmälningsrutin inbrott). This reporting system was used by the Police in the south regions of Sweden for a period of a few years after its invention but has now been taken out of use and it has not yet been implemented nationally by the Swedish Police.

The police's system for documenting crime scene information that was in use at the time of the mentioned project, as well as today, is called RAR (rationell anmälningsrutin, rational reporting routine). In using this system, individual police officers document their observations at crime scenes into RAR forms, using free-text writing. The limitations of this system as a working tool is described as ungainly and providing individual officers and investigators within the police force with unnecessary workloads (Boldt, 2018). This is because gathered crime scene information is documented in free text in RAR, which is described as rather unstructured and only makes analysis and linking possible manually (Boldt, 2018). Beyond this, crime scene information may go missing due to lack of categories and different types of evidence not being mandatory to document (Ibid.). Alongside this, the human factor, subjective stress levels and tiredness of individual police officers increases the risk of information being documented inconsistently (Boldt et al, 2015; Boldt et al, 2018). In other words, crime scene information has a very high risk of being documented inconsistently and important information may go missing, with regards to what figures or what type of information that are included in the RAR-reports.

To address the issues with the current methods for collecting crime scene information, the previously mentioned research project during the years 2012-2015 created a new reporting system. This system specialized in the crime type residential burglary and was called SAB (standardiserad anmälningsrutin bostadsinbrott, which translates to standardized reporting routine residential burglary) (Boldt et al, 2015). This system was theorized to increase the understanding of crime scene behaviors by collecting larger amounts of information fragments more systematically and in a consistent way across

multiple incidents of crime (Boldt et a, 2015). In practice, how it works is that Police officers arriving at crime scenes document their observations digitally into a standardized form. There are several sections for categorizing the crime scene information (Sectionsnamn) and various amounts of parameters for each section (parameters). A summary of the sections is shown in appendix A. These categories include specific behaviors of the burglar, such as what type of neighborhood have been chosen, entry methods, property stolen, preexisting crime preventive efforts of the household in question, etc. (Boldt et al, 2015). Moreover, the new system is theorized to allow for better opportunities to make crime linkage analyses through specific modus operandi behaviors documented in SAB-documents. In other words, by analysis of crime scene behaviors documented in this reporting system, serial offenders are hypothesized to be identified (Ibid.).

With this background, it is suggested that the more recently developed reporting system may provide better opportunities to perform crime linkage analyses (Boldt 2015; Boldt, 2018). However, it is not determined whether investing in this change of systems is the best way forward for the Swedish police. Some research has over the years been conducted that evaluates the effectiveness of crime linkage analyses through information on crime scene behaviors, or modus operandi. By providing an overview of some of this research this paper aims to discuss how effective crime linkage analyses through modus operandi are, and discuss whether it is worth investing in.

Purpose and research question
The purpose of this paper is to investigate the effectiveness of analyses on crime linkage through crime scene behaviours, i.e. modus operandi. This paper reviews empirical findings on crime linkage through modus operandi with a systematic literature review. This review seeks to answer the following question:

How accurate predictions can be achieved on linking crime through modus operandi?

A discussion on the utility of the new reporting system follows.

BACKGROUND

In 2018 about 1,8 per cent of all Swedish households were reported to have been burgled. In 2019 approximately 14 700 burglaries were reported to the police (BRÅ, 2020). Residential burglary in Sweden is a crime type associated with low clearance rates, in terms of connecting a person to the offense, prosecuting, and convicting individual offenders (ibid.). In 2019 approximately 4 per cent of residential burglaries were cleared up. The low frequency of clearances is theorized to be due to the difficulties of connecting a suspect or suspects to the offence (BRÅ, 2020).

It is also suggested that those incidents of burglary that include high value thefts are more likely to be reported to the police and that burglaries where less items have been stolen contribute to dark figures in the official statistics (BRÅ, 2020). Further, determining the specific time for the occurrence of residential burglaries is impossible due to the lack of interaction between the victim and offender, which is characteristic regarding this crime type (BRÅ, 2014). Hence,

determining temporal proximity will more likely reflect the moments when the crimes are noticed rather than when it has occurred (BRÅ, 2014). According to official statistics on residential burglary in Sweden during 2013, around 61 residential burglaries were reported every day during 2013 and the numbers were higher during holidays and longer weekends when residents typically travel away to leave their homes (Ibid.). Also, burglaries were more likely to occur during autumn and winter, in other words the darker periods of the year when visibility is limited (BRÅ, 2014).

In recent years there has been a growing interest in crime linkage through documented behaviors and crime scene information and existing research is concerned with many crime types such as rape, murder and different types of volume crime (Woodhams, 2007). Crime linkage through modus operandi intends to analyze specific offender behaviors to connect series of crime into single offenders (ibid.). The reporting system SAB is capable of collecting crime scene information regarding modus operandi from residential burglaries, and is theorized to improve burglar investigations by performing these types of analyses (Boldt, 2015). The reporting has yet to become implemented by the Swedish police nationally.

Poor and indistinguishable data collection of crime scene information is described as a major limitation in using computerized systems for linking crime, throughout multiple analytical systems being evaluated (Adderley & Musgrove, 2001) and figures not being reported in ways that can distinguish separate incidents of crime from one another is described as a predominant issue (Porter, 2016). The importance of quality in the data collected is stressed (Adderley & Musgrove, 2001; Boldt, 2018) as well as increasing the quantities in number of crime scene figures collected (Boldt 2018), in order to make analyses more effective. Furthermore, it is argued that at the same time as data needs to be collected in consistent manners, the figures from different crime scenes must be distinguishable from each other in order to identify specific figures for modus operandi that separates the single offenders (Porter, 2016). With this background, implementing a structured reporting system such as SAB may contribute to higher quality crime linkage analyses by offender behaviors, and in turn burglary investigations to become more effective.

The difference in effectiveness on using SAB compared to RAR has been evaluated by Boldt (2018) in regards to how time consuming the documentation is for the police officer performing it, and as to the difference in number of crime scene figures that are possible to detect between the two systems. The results show that documentation in RAR forms takes approximately 13 minutes, whereas the SAB took on approximately 8 minutes on average for the participants to complete. Furthermore, the RAR forms performs an average of 15,79 crime scene figures whereas the SAB performed an average of 46,71. In other words, SAB is both less time consuming and more effective on gathering larger numbers for crime scene data than RAR. (Boldt, 2018).

Previous research on crime linkage through modus operandi

Modus operandi is a rather wide and vague term and there are some uncertainties regarding what types of offender behavioral attributes should be included in the concept (Bennel & Canter, 2002). Typically, the term modus operandi refers to

specific offender behaviors at crime scenes, the offender's courses of action while performing the crime, as it is assumed that individual offenders to various extents commit their crimes in similar ways (Bennel & Canter, 2002). Crime scene behaviors such as how close crime incidents occur in time and space, how burglars have entered premises, factors for selecting targets and type of goods that have been stolen have been identified as relevant linking features whose predictive accuracy for crime linkage are necessary to evaluate (ibid.).

Woodhams (2007) states that crime linking through modus operandi is an adequate method for assisting police investigations, but that perfect predictions can not always to be expected. False positive as well as false negative predictions will inevitably be made, and therefore the purpose of crime linkage is to guide or complement investigations rather than provide evidence (Woodhams, 2007). The research on crime linkage through behavioral aspects extends across various crime types, originally sexual offences, and homicide but also volume crimes such as different types of theft, robbery, or burglary (Ibid.).

The best predictor for linking series of crimes to one offender is forensic evidence such as DNA or fingerprints (Tonkin et al, 2011; Woodhams et al, 2007). Crime linkage through behavioral factors have been of interest within police forces in different countries for several years and is sought to complement the available information of hard forensic evidence such as DNA or fingerprints, which may not present at burglar scenes. Forensic evidence is regarded as reliable information for linking series of crimes as well as evidence leading to convictions, but it has also been described as time consuming and expensive, alongside the fact that it can be difficult to get access to on many crime scenes (Woodhams, 2007).

Bennel and Canter (2002) have developed a useful model serving to evaluate the accuracy of predictions linkage between series of crime into single offenders. They describe the potential of diagnosing linked crime as comparable with meteorologists predicting the weather and argue that it is important to distinguish between which specific types of crime scene behaviors, or modus operandi, that are the most likely to be repeated across multiple offences (Bennel & Canter, 2002). Furthermore, they argue that the most repeated crime scene behaviors for burglaries are entry behaviors, target selection choices, stolen goods and internal behaviors (such as if the offender seems to have any specific behavior whilst inside the premises). Beyond these crime scene behaviors, they include spatial proximity into their analysis, in accordance with criminological literature stating that offenders rarely travel far distances (Bennel & Canter, 2002). This methodology has been adopted by more evaluation studies, including those included as material in this paper. An additional behavioral aspect that has shown to be useful for linking crime is temporal proximity, in other words how close the offences are in time. For instance, findings declare that linked burglaries are separated by 1,08 kilometers and 22 days on average (Tonkin et al, 2011).

The evaluation design invented by Bennel and Canter (2002) consists of regression analyses followed by receiver operating characteristics (ROC) analysis and is aimed at determining the predictive accuracy of the attempts of linking series of crime through modus operandi (Bennel & Canter, 2002). Effect sizes derived from ROC analyses are presented as area under the ROC curve values (AUC values). The measures for analysis are described more in dept in the methodology section. It is difficult to find any evidence as to offender signatures

regarding property crimes and it may be wishful thinking to assume that burglars tend to operate in the exact same way for every offense, but some behavioral domains may still be important to assess in order to find patterns in offending at least to a moderate degree (Bennel & Canter, 2002). For instance, Woodhams (2007) points out that some consistency is to be expected especially regarding primary behaviors when goal-directed offenders are faced with situations that allow them to choose their actions freely (Woodhams, 2007). The identified behavioral domains most useful to evaluate are, spatial proximity, temporal proximity, entry methods, target selection and property stolen (Bennel & Canter, 202) and these are further described below. It is also argued that linking offences by using multiple types of behavior domains will likely increase the possibility of positive predictions (Woodhams, 2007).

The design for evaluating linked crimes through modus operandi using ROC analysis according to the certain linking features were first used by Bennel and Canter (2002). It was first used to assess linked commercial burglaries and it has since then been adopted in several evaluation studies assessing different types of crimes. The articles used as material in the current paper uses this methodology in similar ways, assessing residential burglary using some of these linking features to varying degrees. The measures *spatial proximity* is a measure of inter crime distance, i.e. the distance between burglaries measured in kilometers (Bennel & Canter, 2002). *Temporal proximity* refers to the time periods in which the crimes are committed and are measured in days. *Entry methods* documents whether the offender entered the premises through the front door, *target selection* refers to the type of residence that have been broken into (i.e. a house or apartment for example), and *stolen goods* documents what has been stolen, for example if the offender has stolen jewelry (Bennel and Canter, 2002).

Theoretical approach

Criminology is a discipline which include many theories that seeks to answer questions as to why people commit crime, using various approaches. However, in practice and outside of academia aspects regarding the origins of criminal behavior are often overlooked in favor of discussions regarding what interventions and societal actions that can be effective to reduce crime levels (Wikström, 2006) and increase clearance rates. Following this argument, there is often a lack of consensus as to what should be done to address with crime as a societal issue, and why (Wikström, 2006). In the context of this paper, burglars are theorized to repeat some of their modus operandi in accordance with two theoretical perspectives, the routine activities theory and rational choice perspective. The findings of the literature review are related to these theoretical perspectives to get an understanding of why and to what extent burglars repeat their crime scene behaviors.

Routine activities Theory
The routine activities theory is a criminological theory which seeks to explain criminal events as a part of everyday life in society, rather than seeking explanations for crime among individual's propensities to commit crimes (Cohen and Felson, 1979). It argues that criminal events are made possible through the presence of three elements which are (1) motivated offenders, (2) suitable targets and (3) absence of capable guardians. If one of these elements is not present the likelihood of crimes to occur is heavily reduced, according to this perspective

(Cohen & Felson, 1979). Furthermore, if the levels of suitable targets and motivated offenders remain stable, increasing the presence of capable guardians is theorized to have positive crime preventive effects (ibid.). This perspective does not address why people engage in crime on an individual level or seek different offenders' propensities to break the law. Rather it discusses the opportunity structure for crime to be able to occur.

The Rational Choice Perspective
The rational choice perspective within criminology relies on a few assumptions regarding decision making, such as that offenders seek personal gain from their actions and that they make active decisions to commit crime. Within this perspective from a criminological point of view it is argued that offenders make decisions by contemplating risks against rewards with their actions and it takes situational aspects of the offence into account in order to explain the different types of decision making (Cornish & Clarke, 2014). For instance, with regards to residential burglary, decisions are influenced by a number of different factors increasing the risk of being caught such as that the burgled home is likely to be unguarded, isolated or easily accessible (Cornish & Clarke, 2014, p. 4).

The extents to how rational criminal decisions are have been debated. In their discussion of bounded rationality, Clarke and Cornish (1985) argue that rationality must be viewed in broad terms, and that what may seem irrational to non-offenders could be rational in other terms for the offender. It is also suggested that thinking patterns which seeks to achieve goals such as sensation seeking, excitement or more practical goals such as economic gain through antisocial means can be guided by a rationality which is described as cognitive shortcuts. In their discussion of bounded rationality it is suggested that this type of decision making has many rational attributes in its thinking patterns, but that they fail to include important factors, and may appear as irrational from a law abiding perspective (Clarke & Cornish, 1985).

Residential Burglary
Clarke and Cornish (1986) further argue that the decision making process influencing burglary offences consists of several levels of experiences and historical factors which are background factors, previous experience and learning, generalized needs, solutions evaluated, perceived solutions, reaction to chance events and readiness followed by the decision. More specific to the decision within the criminal event it is theorized that burglars upon having made a decision to burgle select their targets based on factors such as accessibility, absence of police and other forms of security, and in places which are familiar to the offender. Moreover, burglars are hypothesized to choose detached houses where they can break in without being disturbed (Clarke & Cornish, 1986). These assumptions are in line with the previously mentioned findings on burglaries in a Swedish context, which suggests that burglaries are more commonly occurred in the darker months of the year when visibility is limited, and also during periods when people leave their houses unoccupied (BRÅ, 2014).

Another issue with their theoretical model concerning rational choice and burglary is that it is crime specific and thus dependent on the assumption that offenders specialize in certain crime types rather than committing multiple types of offences throughout their criminal careers (Cornish & Clarke, 2014; Clarke & Cornish, 1986). This assumption is inconsistent with much empirical findings on criminal

careers (Cornish and Clarke, 2014). However, Kempf's empirical findings suggest a moderate degree of offender specialization, especially with older offenders than juvenile and also regarding property crimes (Kempf, 2014). These findings are relevant for the current paper as it seeks to get an understanding of repeated offender behaviors across incidents of crime and because residential burglary being considered a property crime is the crime type of interest for this paper. It is, in other words, difficult to determine whether certain offender do specialize in certain crime types which is likely to be due that the way in which crimes occur is dependent on the opportunity structure in which it takes place. A possible explanation to lack of specialization may that the rational choices are guided by for instance the lack of capable guardianship given a specific criminogenic situation.

Burglary behaviors discussed by Coupe (2017) regarding target selection suggest that offenders often choose to operate in environments familiar to them, and that they are unlikely to travel far distances to unfamiliar areas to find suitable targets. Moreover, suitable targets for burglary tend to consist of premises that are unoccupied and detached, thus less visible. As for entry methods, Coupe (2017) argues that it is more common to enter through the rear of houses which generally is under less supervision from neighbors and others, hence making decisions to decrease the presence of capable guardians. It is more difficult to generalize as to patterns of stolen goods for residential burglary. Coupe (2017) argues that portable items such as jewelry, cash, passport, laptops or mobile phones constitute suitable targets due to its values as well as their practical benefits, but at the same time it is not uncommon for larger items such as TV's to be stolen . Clarke and Cornish (1985) further suggest that the most vulnerable targets for burglaries are explained largely by opportunity factors for low risks and high rewards for the burglar. These factors include the risk of the house in question being occupied if the access to the building is restricted or not or the visibility of the house allowing for entering without being seen. They also suggest that houses that stand in the middle of terraces are more vulnerable to burglary than houses that are connected by yards (Clarke & Cornish, 1985), thus becoming less suitable for selection.

METHODOLOGY

A systematic literature review was conducted using four different search databases available and accessible through Malmö University's website. The searches were performed in a consistent manner to increase the likelihood of similar results being found in terms of data collection if the study were to be replicated. In other words, for the purpose of the paper's validity. The searches were carried out on February 3rd, 2020 using the databases *ProQuest, Scopus, Social Science Index/ Web of Science* and *Academic Search Elite*. The search string used for the same search string for all databases; *linking crim* AND modus operandi AND burglar*,* limited to peer reviewed and full text. This provided a total of 87 articles, in which *ProQuest* gave 63 articles, *Scopus* gave 4 articles, *Social Science Index/ Web of Science* gave 20 articles and finally *Academic Search Elite* gave 4 articles as results. All 87 articles were reviewed by reading, first the abstracts and some of the articles as a whole and many of them could quickly be excluded. Many of the articles that were found through these searches discussed linking crime through modus operandi in regard to other crime types, such as sexual crimes or other types of theft or discussed burglary more as an

illustrative example than the primary concern for the article in question. Articles with purposes aimed at fear of crime or risk for victimization and articles that assesses geographical mapping and categorizing of crime incidents were excluded. In total, 27 articles were included as potential material after reviewing them and after further readings of these 27 articles, some patterns in the methodology for evaluating crime linkage regarding residential burglary became apparent. Finally, seven evaluation studies were included as material according to the criteria described below.

Inclusion criteria

The inclusion criteria for articles in this literature review are: (1) The articles assess linking crime through modus operandi, (2) the crime type in question for the articles is residential burglary, (3) different attributes for modus operandi are evaluated, such as temporal proximity, spatial proximity, entry methods, target selection choices and (4) effect sizes and statistical power for predictions regarding different attributes for modus operandi are analyzed using ROC analysis. These criteria were chosen to make the material consistent in terms of the crime types evaluated as well as how the results are presented. The articles were found using search string described in the previous section and selected by their methodology and crime type evaluated.

Predictive accuracy

ROC analysis is commonly used to assess how accurate predictions can be made and was originally invented for the use of radar technology to distinguish meaningful electronic signals from noise (Bennel & Jones, 2005; Swets et al, 2000; Fox & Farrington, 2018). To date it is commonly used in crime linkage research, as well as within psychology, engineering, and other clinical disciplines to evaluate predictive accuracy (Ibid.).

Receiver Operating Characteristics (ROC) analysis is a commonly used measure to determine predictive accuracy between two variables, and in the crime linkage evaluation literature it is often used to empirically validate different regression models (Bennel & Jones 2005). The purpose of ROC analysis is to identify which factors that are correlated, and to distinguish between for possible outcomes; to identify positive-, negative-, false positive- and false negative- correlations. ROC analyses produce a measure called area under the ROC curve (AUC) which gives an opportunity to determine whether predictions are dependent on more than chance (Levander, 2019). The AUC is measured ranged from 0 to 1, whereas the closer the value is to 1, the more likely it is that two variables are related. Two central concepts of ROC analysis are sensitivity, meaning the number of correctly identified positive predictions, and specificity meaning number of correctly identified negative correlations, or false alarms. The sensitivity is presented by the Y-axis and the specificity by the X-axis in the illustration below. The point on the ROC curve where sensitivity and specificity intersect, or the point where the best balance between true positives and true negatives is found can be used as a decision threshold and a cut-off point (Swets et al, 2000). Any value above the cut-off point is a positive decision (Bennel, 2002). The AUC value represents the cut-off point in the illustration below. Using ROC analysis allows for setting different decision thresholds simultaneously, which is regarded as a strength (Bennel & Jones, 2005).
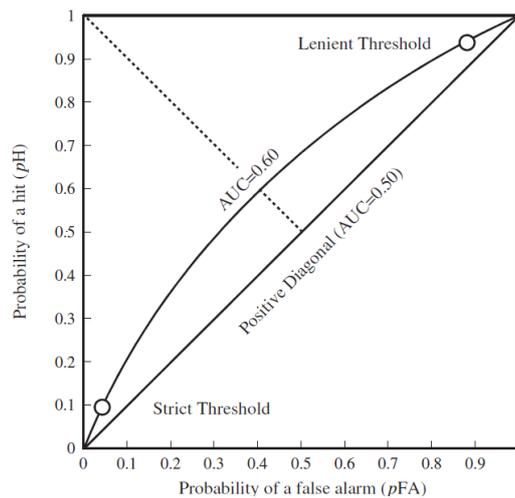
(Bennel and Jones, 2005)

To present findings on effect sizes in a consistent manner, area under the curve (AUC) values for different attributes of modus operandi as well as combined behavioral attributes will constitute the material in this paper. What AUC values that are considered as demonstrating effective predictive accuracy varies across different studies. In general AUC values over 0.9 are considered as highly accurate, values ranging between 0.7 through 0.89 are considered moderately accurate and AUC values below 0.7 are considered to demonstrate low predictive accuracy (Fox & Farrington, 2018). The AUC values are presented categorically in accordance with the design developed by Bennel and Canter (2002) and the criteria for inclusion of research is presented in the following section. For the purpose of presenting findings in a consistent and appropriate manner, the articles included as material for the paper at hand display effect sizes on predictive validity by referring to AUC values.

Limitations

Only articles using receiver operating characteristics analysis were included in the material for this paper which may limit the sample. Following this fact, the number of researchers concerned with the issues this thesis seeks to discuss becomes limited, as well as the geographical contexts where the residential burglaries serving as material in this paper.

Due to the relatively limited number of evaluation projects concerned with crime linkage specific to residential burglary, some inconsistencies regarding the aims and research questions in the articles included as material are displayed. Hence, the findings from the included material will in part be presented and discussed separately.

Ethical considerations

Detailed crime scene information from crime scenes of residential burglaries can be regarded as sensitive information and should therefore be treated with caution, and personal details of crime victims should preferably stay within the police forces information systems. Regarding linking crime by modus operandi to identify offenders it is expected that many false positive as well as false negative predictions will be made. This in turn may lead certain individuals being perceived as guilty of more offences than one, and it may also cause repeated

offenders to escape from detection. It should therefore be pointed out that the use of crime linkage analysis is to be regarded as a supplement or aid to burglar investigations rather than as a mean to determine concrete evidence of guilt for multiple offences or not.

All the material included in this paper is available through the search databases provided to students within Malmö University and no personal information neither from victims of crime nor offenders are displayed within the frames of this thesis. As all the material in this paper consist of publicly available and published literature no ethical considerations have been necessary to make within the frames of this thesis.

FINDINGS

In total, seven studies were included from the literature review (Bennel & Jones, 2005; Tonkin, Santilla & Bull, 2012; Markson et al, 2012; Tonkin et al, 2012; Tonkin et al, 2019; Melnyk et al, 2011; Fox & Farrington, 2018). These articles consisted of articles that evaluates predictions of linked residential burglaries by assessing burglary incidents known to be linked, either through the crimes being solved or matched by DNA. All the included articles assessed predictive validity through ROC analysis. The findings are presented in terms of area under the ROC curve (AUC) values. A summary of the included articles is found in table 1. Their AUC values for different attributes of modus operandi are presented in table 2. Moreover, the findings are presented separately in the following section categorized by the linking features spatial proximity, temporal proximity, entry methods, target selection and stolen goods, according to the design by Bennel and Canter (2002).

Table 1. Summary of articles included as material.

Title	Author	Year	Sample	Material	Context
Between roc and a Hard place: A Method for linking Serial burglaries by modus operandi	Craig Bennel Natalie J. Jones	2005	57 serial burglars and 637 burglaries	Official police records	United Kingdom, metropolitan police
The linking of burglary crimes using offender behaviour: Testing research cross-nationally and exploring methodology	Matthew Tonkin Pekka Santilla Ray Bull	2012	117 serial burglars and 234 burglaries	Records from a dataset extracted from a previous project	Finland, The greater Helsinki region
Linking Serial Residential Burglary: Comparing the Utility of Modus Operandi Behaviours, Geographical Proximity, and Temporal Proximity	Lucy Markson Jessica Woodhams John W. Bond	2010	80 serial offenders and 160 burglaries between 2006 -2008	Official police records	United Kingdom, Northamptonshire Police
Behavioural case linkage with solved and unsolved crimes	Matthew Tonkin Jessica Woodhams Ray Bull John W. Bond	2012	132 offenders and 264 solved and unsolved crimes	Identified linked burglaries via DNA evidence	United Kingdom, Northamptonshire Police databases
Linking property crime using offender crime scene behavior: A comparison of methods.	Matthew Tonkin Jan Lemeire Pekka Santilla Jan M. Winter	2019	160 residential burglaries and 80 burglars between 1990 – 2001	Records from a dataset extracted from a previous project	Finland, the greater Helsinki region
Another look at across-crime similarity coefficients for use in behavioural linkage analysis: an attempt to replicate Woodhams grant and Price (2007)	Tamara Melnyk Craig Bennel Donna J. Gauthier Donald Gauthier	2011	210 residential burglaries and 42 male serial burglars	Records collected by Bennel 2002.	United Kingdom, police records
What have we learned from offender profiling? A systematic literature review and Meta-Analysis of 40 Years of Research	Bryanna Fox David P Farrington	2018	426 academic publications published between 1976 and 2016	Available publications on crime linkage in general	Global

The included evaluations assessed the linking features somewhat differently, but all the features were included to differing extents. For instance, the project by Melnyk and colleges (2011) compared two different similarity coefficients, Jaccard's coefficient against taxonomic similarity index, to determine similarity between two crimes across two crime types, which are homicide and residential burglary. ROC analysis was performed to distinguish the difference in predictive accuracy between these two similarity measures (Melnyk, et al 2011). The findings from the ROC analysis suggest that both similarity measures could differentiate between linked and unlinked residential burglaries at significantly higher levels than chance (Jaccard's coefficient: AUC = 0.62) (Taxonomic similarity index, AUC = 0.59), and did not significantly outperform each other. The linking accuracy for residential burglary is described as low within the context of this project and the hypothesized explanations for this is that crime scene behaviors are more consistent within homicide than burglaries.

The project by Tonkin, Woodhams, Bull and Bond (2012) examined predictive accuracy of linking crime regarding spatial and temporal proximity across the two crime types residential- and commercial burglary. The sample for this study consists of offenders identified through police database searches linked via DNA evidence. These results do not provide clarity on predictions specific to residential burglars' tendencies to repeat their modus operandi. However, this project provides evidence on the good levels' of predictive accuracy on repeated crime scene behaviors for versatile offenders. Interestingly, this project unlike much of the previous literature, included unsolved crimes in its analysis. This may provide

a more practical approach and a more realistic evidence base for the analysis according to Tonkin and colleagues (2012).

Spatial proximity
Across the five articles included in this paper, spatial proximity as a crime linking factor overall showed high levels of predictive validity, in those articles that measured it; 0.94. 0.91 and 0.85 (Bennel & Jones, 2005) across three police districts, 0.84 (Tonkin, Santilla & Bull, 2012), 0.90 (Markson, Woodhams & Bond, 2012), 0.85 (Tonkin, Lemeire, Santilla & Winter, 2019), 0.82 (Farrington & Fox, 2018). The findings of high similarity of across offending patterns concerning spatial proximity as a linking feature may be explained by the argument of Coupe (2017) in that burglars tend to identify their suitable targets within environments familiar to them.

Temporal Proximity
The three articles that measured it showed relatively high levels of predictive accuracy for temporal proximity; 0.82 (Tonkin, Santilla & Bull, 2012), 0.86 (Markson, Woodhams & Bond, 2012), 0.82 (Tonkin, Lemeire, Santilla & Winter, 2019). In other words, estimating repeated burglary by assessing how closely they have occurred in crime gives a relatively high probability of the crime being committed by the same offender. This may be a result of most residential burglaries being committed during the darker periods of the year (Coupe, 2017).

Entry methods
In total, four of the included articles measured entry methods. The levels of predictive validity for this linking feature were moderate according to their AUC values; 0.57, 0.62 and 0.59 (Bennel & Jones, 2005) across three districts, 0.66 (Tonkin, Santilla & Bull, 2012), 0.54 (Markson, Woodhams & Bond, 2012), 0.72 (Tonkin, Lemeire, Santilla & Winter, 2019). Whether burglars enter the premises for instance through the front door, the rear or through a window may be more determent on the opportunity structure of the house being broke into. In other words, the entry method may be more depending on the risk of being caught than offender specialization in certain types of doors or windows. Some variation in the findings were found in this linking feature, which may be explained by the fact that the data was collected from different countries. The findings from the studies conducted in Finland shows slightly higher AUC values than the other studies, which may be due to different factors of the context in which the data has been collected.

Target selection
In total, five of the included articles evaluated target selection as a linking feative. The AUC values for target selection presented in the included articles are as follows; 0.53, 0.57, 0.64 (Bennel & Jones, 2005), 0.66 (Tonkin, Santilla & Bull, 2012), 0.54 (Markson, Woodhams & Bond, 2012), 0.67 (Tonkin, Lemeire, Santilla & Winter, 2019) and 0.66 (Fox & Farrington). These findings represent a moderate chance for linking serial offenders to multiple incidents of crime by this linking feature and that offenders tend to use different ways of choosing houses to break into. Similarly to the previously discussed linking feature, it is reasonable to assume that the type of house being selected is likely to be determined by the lack of guardianship.

Stolen Goods

Stolen goods were assessed in four of the included articles. The following area under the roc curve values are presented in the included articles for stolen goods; 0.56, 0.57 and 0.63 (Bennel & Jones, 2005), 0.58 (Tonkin, Santilla & Bull, 2012), 0.58 (Markson, Woodhams & Bond, 2012) and 0.65 (Tonkin, Lemeire, Santilla & Winter, 2019). The considerably lower values for predictive validity concerning repeated stolen goods for residential burglary may be an indication of burglar's tendencies not to specialize in this behavioral domain. Moreover, the values rather suggest that the items stolen are more likely to be dependent of what type of valuable items are available to the offenders given the situation of the crime.

Table 2. Findings on predictive validity (AUC-values).

Project	Spatial proximity	Temporal proximity	Entry behaviors	Target selection	Stolen goods	All combined
Bennel & Jones, 2005[1]	0.94	-	0.57	0.53	0.56	-
	0.91		0.62	0.57	0.59	
	0.85		0.59	0.64	0.63	
Tonkin, Santilla & Bull, 2012	0.84	0.82	0.66	0.73	0.58	0.73
Markson, Woodhams & Bond, 2012	0.90	0.86	0.54	0.54	0.58	0.61
Tonkin, Lemeire, Santilla & Winter, 2019	0.85	0.82	0.72	0.67	0.65	0.90
Melnyk, Bennel, Gauthier & Gauthier, 2011[2]	-	-	-	-	-	0.62
						0.59
Fox & Farrington, 2018[3]	0.82	-	-	0.66	-	0.71

[1] The results from this project is presented across three separate police districts.
[2] Predictive validity for this project was estimated by combining multiple attributes for modus operandi using two separate statistical measures and are presented according two those.

DISCUSSION

The question that the current paper intends to provide clarity on is regarding how accurate predictions that are possible to prognose are on linking crime through modus operandi. The reason for this research question is to assess and discuss the utility of this new reporting system in terms of its capability to make investigations more effective and link offenders to series of offences. The findings in the evaluation projects used in this paper suggests that the best predictors for repeated residential burglars to be identified are spatial- and temporal proximity. The more specific behaviors performed at the crime scenes, entry behavior, target

selection and items stolen are showing considerably more variation in terms of the extent to which burglars repeat them.

The results from this systematic literature review indicate that predictions on repeated modus operandi can be effectively performed, although when performed in practice, mistakes will inevitably occur (Woodhams, 2007). Regardless of the accuracy of different statistical measures, analyses can never outperform the data which is put into it (Boldt, 2018; Adderley & Musgrove, 2001) which is something worth considering for decisionmakers within the Swedish police force in relation to implementing a new reporting system for collecting crime scene information, such as SAB. SAB was invented with the intention of replacing documenting through the more manual reporting system RAR, which as mentioned has displayed limitations in terms of time effectiveness and the quality of information collected by making data collection more systematic.

Possible explanations for these findings can be found by reviewing offender behaviors through the routine activities approach (Cohen & Felson, 1979) and rational choice perspective (Clarke & Cornish, 1985; Cornish & Clarke, 2014). Burglar decision making may not be rational to law-abiding citizens but can rather be a of bounded rationality that includes rational aspects and is driven by self-interest. The action alternatives are chosen depending on the situational aspects of the crime and be results of contemplation of risk and rewards by the different choices being made, according to the rational choice perspective (Clarke & Cornish, 1986). Furthermore, these contemplated decisions can be regarded as reliant on which action alternatives constitute the most suitable targets as well as the least presence of capable guardians (Cohen & Felson, 1979). As suggested by Coupe (2017) it is common for burglar decision making regarding entry methods, target selection and stolen goods to be influenced by the alternatives that provides most rewards and least risks. For instance, entering premises through the rear of the house in the case that it presents the least visibility from the outside (Coupe, 2017), thus the lower presence of capable guardians. Similarly, regarding target selection, the decisions may be driven by a rationale that depends on the opportunities that the situation provides in terms of for example houses being unoccupied, giving them status as the most suitable targets (ibid.). Also, regarding stolen goods, it is theorized that the most suitable target i.e. the items available and convenient to steal is the most likely to be stolen, preferably then portable objects such as cash, jewelry or passports as suggested by Coupe (2017).

On the other hand, the findings presented by the articles included in this paper shows consistently high levels of predictive validity on linked residential burglary spatial- and temporal proximity. In other words, burglars tend to commit their crimes closely to each other in time and space, according to the empirical findings presented in this paper. The levels for spatial proximity could be regarded as consequences of burglar's tendencies to operate in settings which are familiar to them and unwillingness to travel far for their crimes, as suggested by Coupe (2017). These assumptions may in turn be explained by a bounded rational contemplation by the offender to seek the opportunities which presents the greatest rewards and least risk as suggested by (Clarke & Cornish, 1986) to identify suitable targets (Cohen & Felson, 1979). The high levels for temporal proximity could be explained by the seasonal residential burglary patterns that indicates that more crimes such as these are committed in the months of the year outside the summer, when it is generally less light. Darker months of the year

could be less risky to operate in due to its decreased visibility from outside, thus lowered presence of capable guardians (Coupe, 2017; Cohen & Felson, 1979).

As mentioned by Bennel and Canter (2002) offender signatures may be unlikely within the current crime types and the modus operandi is more likely to be chosen according to the most suitable opportunities, even though some behavioral aspects may be of interest to evaluate. To sum up, it is difficult to determine behavioral patterns on the crime scene regarding the linking features entry behavior, target selection and stolen goods simply because these actions decisions are made in the point of action of the crime and are guided by the opportunities in which they are perceived.

This paper used a systematic literature search to collect material. All the material included in this systematic literature review was available through Malmö university and chosen according to specific inclusion criteria. The use of this methodology increases the likelihood of the same material being collected and results being reported if the study were to be replicated. Furthermore, the use of this methodology and its inclusion criteria enabled consistency in the research projects presented as material, in that all the articles included used an appropriate methodology to evaluate predictive validity on linked crimes narrowed down specifically into residential burglary. Although this methodology provided a clear overview of the capabilities of crime linkage, the sample of included research articles is rather small. Many articles on the ability of crime linkage found through the literature searches were excluded either because they didn't use ROC analysis as measure or because they were not specific to the crime type of interest for this paper. The criteria for inclusion in this paper was rather narrow. Including articles beyond these criteria allows for more articles, using different effect sizes and perhaps displaying results from more contexts. Expanding the inclusion criteria may therefor also lead to other results being displayed.

A potential source bias for the included articles is that most existing research analyses consists of solved crimes (Tonkin et al, 2012), in that the burglars responsible for solved offenses may be less skilled and important aspects of repeated offender behaviors may be lost. Another source of bias in the included material is the lack of variety of contexts, United Kingdom and Finland, in which the burglaries have occurred. The mentioned limited variance reduces the ability to make a global assessment on repeated crime scene behaviors. However, the research question of this paper was to document how accurate predictions that can be made on linking crime through modus operandi, according to the current state of research, which the findings represents.

Future research should adopt the evaluation design invented by Bennel and Canter (2002) and present estimates on predictive accuracy on linked crime in a Swedish as well as international context using both solved and unsolved crimes in its analysis. The current state of research is limited both in terms of geographical context and in terms of consistency in evaluation designs. The discipline could also be further developed by assessing other crime types, such as other types of volume crime and more serious crimes such as murder, sexual offenses, violent crimes etc. Importantly, interventions implemented within the public sector should be adequately evaluated to assess its results, as well as it should adopt a theoretical approach regarding its implementation. By doing so, questions as to what works as well as how it works, regarding interventions to reduce crime and

increase clearance rates are enabled to properly be answered (Wikström, 2006). Beyond this crime linkage as an academic discipline could be further immersed through qualitative research designs. Free-text documentations of crime scenes from such systems like RAR could serve as a valuable source for information for discovering and widening knowledge on repeated modus operandi behaviors through qualitative content analysis. Performing research in these manners could increase the understanding of criminal behaviors across various crime types and in a Swedish as well as within international contexts.

CONCLUSION

Crime scene behaviors regarding residential burglary may often be dependent on the opportunities presented to the offender at the time for the offense. Making predictions of repeated linked crimes by the modus operandi of the offender moderately useful, as shown in the findings of the articles presented in this paper. Hence, implementing a new reporting system for this purpose may improve investigations to some extent, but some of the predictions will inevitably be incorrect.

Throughout the literature on crime linkage the importance of quality in the data for making predictions is frequently pointed out and it is stated that no matter how effective methods are for analysis available, they will be limited by poor data collection (Adderley & Musgrove, 2001; Boldt et al, 2015; Boldt, 2018; Porter, 2016). SAB as a system for data collection for the police force is capable of properly structuring crime scene figures more effectively both in terms of time consumption for the police officers using it and in terms of the number of crime scene figures possible to detect (Boldt, 2018). Beyond this, organizing crime scene information in manners suggested using SAB can have other benefits both for the police force as well as society in large. For example, it would create possibilities to structure stolen goods more structurally, thus enhancing the chance of personal belongings being returned to their rightful owner. Furthermore, gathered crime scene information in structured databases would help to improve evaluations and research by providing more organized datasets, which in a more long-term perspective would be useful in order to create an understanding on criminal behaviors and their developments. With these aspects in mind, decision makers within the Swedish police should consider implementing a new reporting system for structured data collection and automatic analysis, such as SAB, as a working tool to be used nationally by the Swedish Police.

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APPENDIX

A.

Sektionsnamn	Beskrivning	Parametrar
Brottsplats	Datum och tidsangivelser, ifall det är fullbordat eller försök	12
Typ av bostadsområde	Tätort eller landsbygd, samt tomtens beskaffenhet	7
Typ av bostad	Villa, gård, par/radhus eller lägenhet. Standard samt antal plan etc	12
Larm	Ifall det finns larm och om det var aktiverat, utlöst eller saboterat	5
Brottspreventiva åtgärder	Brottspreventiva åtgärder som vidtagits, t.ex. tömt posten	10
Målsägande	Hemma eller borta under brottet, märkliga iakttagelser som gjorts	16
Ingång objekt	Gärningsmannens tillvägagångssätt för att ta sig in	26
Genomsök	Vilken typ av genomsök som gjorts i bostaden	3
Gods	Godskategorier som tillgripits, t.ex. läkemedel, guld/smycken etc	19
Spår	Typer av spår som säkrats på platsen, t.ex. skoavtryck, DNA etc	18
Övrigt	Om det finns vittnesuppgifter, gods märkt med Märk-DNA etc	5
Totalt		133

Tabell 1: Summering av innehåll i formuläret för Standardiserad Anmälningsrutin Bostadsinbrott.

This is a summary of how figures are categorized, described and the number parameters or different types of crime scene behaviors under each section in the SAB documenting form (Boldt et al, 2015).