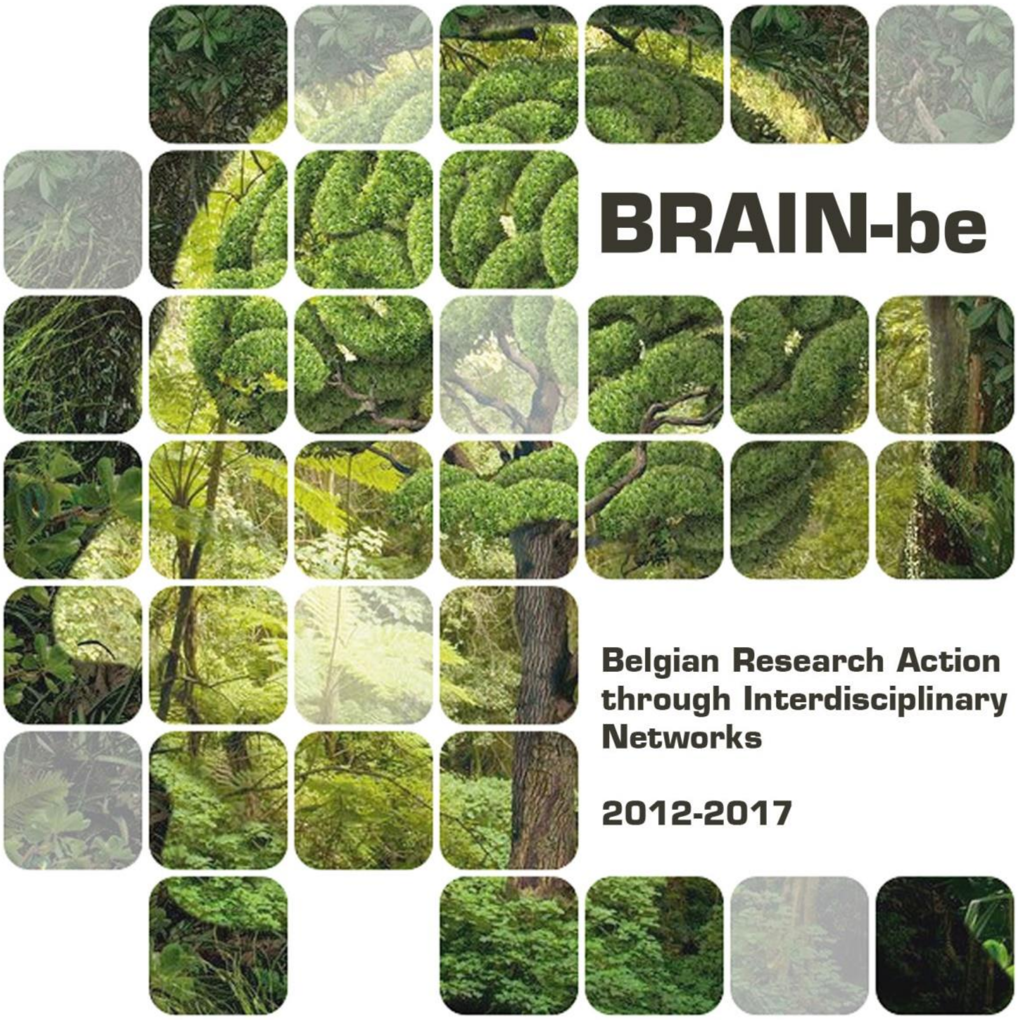

Be-Gen

Understanding the operational, strategic, and political implications of the National Genetic Database

CAROLINE STAPPERS (NICC) – SABINE DE MOOR (UGent) – INES GALLALA (VUB) – BERTRAND RENARD (NICC)

Axis 4: Federal public strategies

NETWORK PROJECT

[Be-Gen]

[Understanding the operational, strategic, and political implications of the National Genetic Database]

Contract - BR/132/A4

FINAL REPORT (January 2019)

PROMOTORS: BERTRAND RENARD (NICC) - Coordinator
TOM VANDER BEKEN (UGent)
PAUL DE HERT (VUB)

AUTHORS: CAROLINE STAPPERS (NICC)
SABINE DE MOOR (UGent)
INES GALLALA (VUB)
PAULINE PRAILE (NICC)
PIA STRUYF (UGent)

Published in 2019 by the Belgian Science Policy Office
Avenue Louise 231
Louizalaan 231
B-1050 Brussels
Belgium
Tel: +32 (0)2 238 34 11 - Fax: +32 (0)2 230 59 12
http://www.belspo.be
http://www.belspo.be/brain-be

Contact person: BOURGEOIS Emmanuèle
Tel: +32 (0)2 238 34 94

Renard, B., Vander Beken, T., De Hert P., Stappers, C., De Moor S., Gallala I., Praile, P. & Struyf, P. ***Understanding the operational, strategic, and political implications of the National Genetic Database.*** Final Report. Brussels: Belgian Science Policy Office 2019 – 128 p. (BRAIN-be - Belgian Research Action through Interdisciplinary Networks).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Context

Since the 1990's the Belgian Government has been exploiting DNA to help criminal investigations (e.g., by identifying the source of genetic material found on crime scenes).
However, no evaluation has ever been made either of its benefits for society, or of its impacts at large (i.e., positive and, potentially, negative effects). Since the first law on forensic DNA was written in 1999 our knowledge of DNA and everything surrounding it has grown exponentially and there is no reason to assume this will stagnate in the near future.
To understand the impact of such scientific evolutions in the forensic field, research like ours is paramount.

Objectives

In this research we studied the implications of Forensic DNA at three levels: operational (i.e., the level of judicial cases) (WP1), strategic (i.e., the level of criminal phenomena) (WP2) and political (i.e., the level of public policies) (WP3). These three different levels all come together in one specific aim: to connect the knowledge we have gained on the day-to-day business in the field (WP1), to explore new potential ways to use the structured information at hand (WP2) and to grasp the legal and political evolutions (WP3) in order to inform the legislator and policy makers and help them make conscious decisions in how to regulate and use DNA in criminal cases.

Conclusions

Our research was a new and multidisciplinary look on a subject (forensic DNA) in full evolution. This evaluation conducted on three distinct yet coordinated levels show that (1) on the operational front many actors are still unfamiliar with different aspects of DNA, the coordination between the different stages of the process is not optimal and that the practice is not identical depending on the geographical location of where the DNA is samples and analysed. On the strategic front (2) the research made it possible to emphasise the informational potential of DNA, its importance and the fact that, for now, it is underutilised. The added value of DNA linked to police data particularly shows that this leads to a better understanding of unknown offenders. The comparative study of the legal landscape and political discourse in the political aspect of the research (3) shows that the provisions adopted in Belgian legislation are characterised by extreme caution and restrictive solutions. The focus group discussions and analysis of the applied criminal policy confirm this conclusion.

In observing the technical and scientific evolutions as well as the social practices in the exploitation of forensic DNA, the triple approach on an operational, strategic and judicial-political level allow to bring forth concrete recommendations. These simultaneously take into account democratic values that support the different legal options, the perception of persons for whom the DNA is recorded, practical constraints for the judicial actors and the Justice Department, new social practices relating to DNA, as well as the added value for the efficacy of the tool and the exploitation of its informational potential for the Justice Department.
The research group, lastly, takes this opportunity to highlight serious obstacles relating to the access of data, both police and DNA data, for the sake of scientific research.

Keywords

Forensic DNA, crime analysis, DNA regulations, Prüm, criminal policy, public policies

1. INTRODUCTION

Since the 1990's the Belgian Government has been exploiting DNA to help criminal investigations (e.g., by identifying the source of genetic material found on crime scenes). In 1999 a law was voted to regulate its use – including its management by the National Institute for Criminalistics and Criminology (NICC) of the National Genetic Database (NGDB) which holds numerous DNA profiles sampled for the Justice Department. The NGDB can be used to relate judicial cases which *a priori* may not have anything to do with each other, by detecting whether they involve the same genetic profiles (i.e., *in fine*, the same individuals). Without a doubt, forensic DNA (i.e., genetic science in the service of justice) has revolutionised the pursuit of truth and helped numerous judicial investigations.

However, no evaluation has ever been made either of its benefits for society, or of its impacts at large (i.e. positive and, potentially, negative effects). Moreover, in 2011 a new DNA law[1] was voted to extend the range of applications of forensic DNA. Among other things, the conditions for recording profiles in the NGDB will be considerably extended, and Belgium started to compare its genetic profiles with the other member states of the European Union, under the so-called Prüm Council Decisions.[2]

This law of 2011 was the first to amend the principal law on forensic DNA in Belgium – twelve years after its establishment. Since then, however, the legislation has been in a rather constant state of flux. The most recently established Database Missing Persons and Elimination Database are products of this continuous evolution.

The legislator has felt the imperative need to evolve constantly in order to keep up with the evolutions in the scientific field. Since the first law on forensic DNA was written our knowledge of DNA and everything surrounding it has grown exponentially and there is no reason to assume this will stagnate in the near future.

To understand the impact of such scientific evolutions in the forensic field, research like ours is paramount. Through our research we can implement our new and improved understandings of DNA into the legislation. We can anticipate new technologies that will help authorities in their quest for the truth, and their implementation in this same legislation.

The Be-Gen project thus studies the implications of forensic DNA in view of improving our understanding of the technology and of its effective use. Besides the straightforward advantages of forensic DNA, little is known on its societal implications. In Belgium, we only have recent research devoted to understanding the practices surrounding the use of DNA in a criminal justice context. For instance, at the NICC, research has been conducted on the impact of DNA

[1] Act (Belgian Act) of 7 November on the changes to the Code of Criminal Procedure and the act of 22 March 1999 on the DNA identification procedure in criminal cases, BS 30 November 2011, 70.716. (hereafter'Act 7 November 2011').

[2] Prüm Treaty 27 May 2005.

on the judicial management methods (Renard, 2008), on the financial aspects of such expertise (Jeuniaux & Renard, 2012), and on the strategic possibilities offered by exploiting genetic profiles (Jeuniaux, Renard, & Vanvooren, 2012). However, after more than € 73 million spent on DNA expertise alone (Jeuniaux & Renard, 2012), and more than 10 years after the 1999 Act providing the judicial foundation of Forensic DNA was voted, the Federal Public Service Justice has yet to evaluate the impact resulting from performing such kinds of expertise – either in terms of benefits or costs at large.

In this research we studied the implications of Forensic DNA at three levels: the operational (i.e. judicial cases) (WP1), the strategic level (i.e., criminal phenomena) (WP2), and the political level (i.e., public policies) (WP3).

These three different levels all converge into one specific aim: to connect the knowledge we have gained on the day-to-day business on the field (WP1), to explore new potential ways to use the structured information at hand (WP2) and to grasp the legal and political evolutions (WP3) in order to inform the legislator and policy makers and help them make conscious decisions in how to regulate and use DNA in criminal cases.

2. STATE OF THE ART AND OBJECTIVES

2.1 FORENSIC DNA AT THE OPERATIONAL LEVEL (WP1)

2.1.1 The empirical contribution of DNA

How does it work in practice?

The first part of the operational level is centred around the individual judicial case. DNA is seen as a powerful tool to use during a criminal investigation (Bond, Phil, & Hammond, 2007; De Greef, 2008; Malsh, de Keijser, Luining, Weulen Kranenbarg, & Lenssen, 2016). DNA is therefore widely used during a criminal investigation to obtain information about the perpetrator since it is unique for each individual (with exception of identical twins) and is stable during lifetime (De Greef, 2008; Meulenbroek, 2009).

In practice different traces are collected at crime scenes in order to identify the perpetrator. The way in which these traces are collected and treated determines how they can contribute to the amount and quality of the information that can be used in a criminal investigation and during the trial (United Nation Office on Drugs and Crime [UNODC], 2009; van Koppen, 2011). Collecting traces is a decision that is on the one hand influenced by policy decisions that determine whether or not a crime scene should be investigated by the scientific police and on the other hand by guidelines about the type of traces available. Different studies have already shown that the way a crime scene is investigated can differ significantly (Adderley, Townsley, & Bond, 2007; Crispino, 2008; Tilley & Townsley, 2009).

The idea is to collect as many traces as possible and leave the decision to analyse the traces up to the magistrate (Bitzer, Ribaux, Albertini, & Delémont, 2016).

In a second phase it is up to the magistrate to decide whether or not the collected trace gets analysed and whether a DNA profile will be established from the traces. This is a crucial phase since a collected DNA trace that is not analysed cannot contribute to the criminal investigation.
The Belgian DNA-law prescribes a number of rules concerning the use of DNA in criminal cases. Those rules, however, are limited to the circumstances in which reference samples can be collected from a person or regulations concerning the DNA database. No guidelines are defined about how and when to use DNA traces that were collected at a crime scene. Therefore the magistrate is completely independent to take the decision to analyse a trace. When the decision is made to go for analysis of the trace, a DNA-laboratory has to establish a DNA profile from the DNA trace.

However not all traces result in a DNA profile because of the quality of the trace, the amount of DNA available or the technique that was used. The profiles are eventually sent to the DNA database where they can be compared with profiles collected in other cases and where they can be stored.

Selection occurs during these different stages: not all the available traces are collected, not all the collected traces are being analysed, not all the analysed traces result in a DNA profile and not all the profiles reach the database.
These selections, of course, have an impact on the usefulness of a DNA trace during the criminal investigation.

Research about the impact of DNA in criminal cases
Research about the impact of DNA in criminal cases are limited. Studies about the effectiveness and efficiency of DNA are mainly limited to indicators from a sociological, economical and policing perspective (Bitzer, Albertini, Lock, Ribaux, & Delémont, 2015). Literature is limited to measuring the effectiveness of DNA on the basis of the amount of matches in the DNA database and, at most, in the amount of identifications (Fraser & Williams, 2009; Mapes, Kloosterman, & de Poot, 2015; NFI, 2013). It is however important to understand the decision-making process of the actors involved in order to understand how DNA can contribute to a case.

No research has ever been conducted in Belgium to evaluate the effect of using the identification by DNA analysis in criminal investigations. For instance, we do not know how often DNA plays a significant role in the investigation, how often it has contributed to case resolution (relative to other types of evidence), etc.

In this study, the aim is to map the decision-making process concerning DNA traces and to study the role of DNA in a criminal investigation. The central research question therefore is: What is the role of DNA analysis in a criminal investigation?

Since there is a big drop out during the DNA analysis process, the main research question of WP1 is divided into 4 sub questions:

RQ 1: How does the selection process of DNA work in criminal cases?
RQ 2: What factors influence this selection process?
RQ 3: How does DNA analysis contribute to the criminal investigation?
RQ 4: How can this contribution be increased?

2.1.2 The relation between DNA and offenders

Since the DNA law of 1999, convicted persons can be registered in the DNA database. This database had not only a punitive objective (finding recidivism more quickly) but a preventive objective as well, namely to reduce the risk of recidivism. On the one hand, it should deter people from committing criminal offenses (generic prevention) and on the other hand it should prevent convicted persons whose DNA profile is stored in the database from re-offending (special prevention) (Taverne, Nijboer, Abdoel, & Farooq, 2012).

Research by Machado, Cunha, Miranda, & Santos (2011) investigated how detainees in Portugal opposed the storage of their DNA profile in the database and whether they would adjust their criminal behaviour accordingly. 31 semi-structured interviews were conducted with detainees whose profile could be included in the database. A theoretical sample was taken in order to have as great a diversity as possible with regard to the criminal record of the detainees and their socio-demographic profile. Prainsack & Kitzberger (2009) conducted a similar study in Austria in which 26 in-depth interviews were conducted with Austrian detainees. It did not explicitly investigate the influence of DNA research on the future behaviour of the detainees, but more attention was paid to the attitude of the detainees against the use of DNA research in criminal cases and the storage of their DNA profile.

The results of both studies are the same. DNA is seen as a powerful means to identify a person. In addition, they also experience it as a technique over which there is little control, because leaving behind DNA cannot be avoided, in contrast to, for example, leaving behind fingerprints (Prainsack & Kitzberger, 2009). Both Portuguese and Austrian detainees find DNA a good way to protect society and to catch the real criminals (Machado et al., 2011; Prainsack & Kitzberger, 2009). Although this is not absolutely questioned in the research by Prainsack & Kitzberger (2009), DNA is not perceived by either group as a useful tool for crime prevention or deterrence. On the one hand, according to the inmates, there are "*professional criminals*" who are aware of the risks and will take precautionary measures to leave no trace at the crime scene. On the other hand, there are fewer professional criminals who usually act impulsively and do not think about the chance of being caught or do not attract themselves (Machado et al., 2011; Prainsack & Kitzberger, 2009). Delinquents are apparently aware of the fact that leaving DNA behind cannot be completely avoided but say that they will not adjust the frequency of their criminal behaviour.

Belgian legislation attaches little importance to this relationship between DNA and convicts. The 1999 DNA law adopts some measures aimed at protecting the physical integrity of persons who are the subject of DNA sampling (through the guarantee of prior information) and the social reintegration of convicted persons (by erasure of their DNA profile from the database).[3] But it is striking that there is no political debate on this issue, even during the profound revision of the law in 2011. The government's position is even to consider that there is no stigma thanks to the anonymity of DNA.[4]

This component aims to feed one aspect of the political debate with the constitution of non-existent knowledge, and international literature shows that the collection of empirical material can be very rich. We therefore aim, through interviews with convicts whose DNA has been registered in the national DNA database 'convicted persons', to answer the following research question:

[3] Belgium Parliament, preparatory work of the Belgian law n°54-2087/006, p. 3 to 7

[4] "*In addition, it must be remembered that this long-term preservation cannot have a stigmatising effect for the person concerned in the context of his social reintegration because the consultation of the data bank by the competent magistrates does not provide them with any information on the persons concerned, except for positive comparison* ", Belgium Parliament, preparatory work of the Belgian law 54-2087/006, p 18.

RQ 5: What is the perception of convicted persons vis-à-vis the registration of their DNA?

This should make it possible to have specific knowledge of both the actual experience of the people sampled and the actual conditions of this collection, as well as the perception that these people have of the registration of their DNA.

2.1.3 The relation between DNA and crime scene workers

A third part of the operational level is a research that was initially not planned in this project but was added following the adoption of a new law on 17 May 2017. This law establishes a new DNA database: an 'Elimination Database' for people who attend crime scenes like policemen, medical staff, magistrates, etc. (hereafter 'Crime Scene Workers'). The details of this law will be discussed in the state of the art of WP3.

For the implementation of this law the drafting of a royal decree is necessary. In order to do so this research was conducted. There were two main research questions of this research:

RQ 6: What are the different options for the implementation of the elimination DNA database?
RQ 7: What is the perception of the people (crime scene workers) involved in the registration of their DNA in this database.

Identifying the options for implementation
In the draft of the law, two main objectives would be granted to the elimination DNA database: When a contamination is found, it should first be checked whether it has not been provoked by crime scene workers at one of the different stages of the investigation, so as to avoid continuing unnecessary investigations relating to the trace concerned on other persons, with all the expenses that entails. This would also eliminate the risk of these crime scene workers remaining unnecessarily associated with the investigation at a later stage of the investigation. The objectives are therefore targeted at different levels. The first is more about saving time and money for the justice system. The second is aimed directly at crime scene workers since it is in their interest not to be listed in the 'criminalistics' DNA database containing all the traces collected in investigations. However, the purpose of this new database is not clearly written in the law.

In other countries, such databases of genetic data are also set up. A comparison with the objectives of different countries is therefore essential in order to ensure the clarity of the objectives defined by the law, and of the relationship that other possible objectives could have with the database being developed in Belgium. Therefore the relevance of these objectives and their impact on crime scene workers is studied. Additional objectives to which the law does not directly refer to, are also discussed.

Different objectives are taken into consideration concerning the implementation of the law:

a) Categories of crime scene workers

The law gives a general definition of crime scene workers: *"the person who by virtue of his function and in that capacity is directly or indirectly associated with the search for traces, the analysis or the treatment of the traces discovered."* This research tried to define precisely the crime scene workers that may be targeted by this law and all the issues that arise from it in a concrete way for them, including in the implementation of such a device.

b) Refusal of withdrawal

The law does not provided constraint in case a crime scene worker refuses to give his DNA, which is different in the other DNA databases. Different options on how to deal with refusal are being looked at.

c) Cost

Starting a new DNA database is costly since a lot of profiles have to be drawn up. This study does not evaluate the cost itself but is attentive to reflect on this issue based on what is written in international literature and what the crime scene workers said during the interviews.

d) Registration and deletion

The law provides a deletion of the profile after 50 years. However this long retention raises some questions: What rules apply when an intervener leaves office? What is the minimum retention period of the profile in a specific file? Currently not envisaged by the law?

e) Use and control

A systematic comparison with profiles of the 'Missing Persons' and the 'Criminalistics' Database is provided by the law. Why is this and what will be the impact on crime scene workers? And what if this comparison results in a match: How will this be reported? Does it automatically need to be seen as a contamination or does it have to be looked into case by case? Does the match need to be kept in the database if it is a real contamination?

f) Procedure

In this research the key players for the procedure for the DNA analysis and exploitation of the crime scene workers profile are identified.

There are also some particular issues with implementing this law in practice that are also taken into consideration:

a) Contamination

International research shows the importance of a DNA database in the fight against contamination (Basset & Castella, 2018; ENFSI, 2016; Lapointe, Rogic, Bourgoin, Jolicoeur, & Séguin, 2015). However a number of countries show that these contaminations are present in, on average, 1% of the traces recorded but given the negative impact they may have on the judicial investigation, it is important to identify them.

b) International exchange

The law does not provide an international exchange of profiles of crime scene workers. Given the internationalization of crimes (particularly in the context of terrorism or cross-border crime) this raises the question of the relevance of this restriction.

c) Privacy

This research questions the coherence of the measures adopted for the sake of privacy in this legal framework with the possible option for the implementation of this database.

d) Increased control over crime scene workers

Sampling to detect possible contaminations is somehow a new form of control of 'crime scene workers'. To what extent does this control judge the quality of the crime scene workers' work because it entails contaminations that must be detected?

e) Fingerprints

How can it be explained that crime scene workers are not included in the Fingerprint database (AFIS) but only in the DNA database? This new database can be thought of in parallel with the planned system for fingerprints in order to detect the issues.

f) Consequences on the investigation and the trial

Many researches emphasise the benefits of a Elimination Database during an investigation since it avoids a waste of time on evidence that is in fact not relevant to the investigation. However, it is also interesting to wonder about the sometimes negative consequences that this could have at the level of a criminal trial. The work done by the crime scene workers could be questioned, with the risk of adverse effects on the results of the investigation.

Studying the perception of the people involved

The second goal of the research is to study the perception of the people targeted by this new law. Are they aware of the existence of this law and, if so, what do they know about it? For this purpose, the research will use other European research already conducted on other categories of citizens, who are not necessarily crime scene workers, and who, as such, are not concerned in the same way by the DNA databases. Indeed, a comparison of opinions and arguments according to the place occupied in society can be interesting. In the context of the Be-Gen research, this comparison can be made with respect to another category of citizens, since it is currently undergoing a component concerning the perception of DNA registration by sentenced persons.

This point is very interesting from the point of view of scientific research because it can help understand the issues that crime scene workers think about regarding the development of this DNA database, their own work and their position as citizens. Reference can also be made to the analysis of these perceptions to help present the royal decree to the crime scene workers in a constructive way.

2.2 FORENSIC DNA AT THE STRAGIC LEVEL (WP2)

2.2.1 Background

The vast majority of criminological research is based on recorded crime data from police or court records (e.g., Bernasco, 2006; Felson, 2003; Reiss, 1988; Weerman, 2001, 2003). It seems logical to use such data, since they provide a rich source of information about crimes, offenders, modus operandi, etc., and are continuously updated. Much of our knowledge about crimes, offenders and their behaviour is therefore based on the data stored in police databases. However, police-recorded crime data only include information on detected or reported crimes. As a result, they may underestimate the true magnitude of crime. Many crimes are not reported by victims or members of the public or are not detected or recorded by the police. In scientific literature, this unrecorded proportion of all crimes is described as the 'dark number' (Biderman & Reiss, 1967). In addition, only a small proportion of all registered crimes are cleared – about 20% in most Western countries (De Wree, Vermeulen, & Christiaens, 2006; Lammers & Bernasco, 2013), and not all co-offenders of a crime are identified. In fact, the police are not always aware of the existence of co-offenders. The identification of one offender or even several offenders does not imply that there were no other offenders involved in the crime, and it seems unlikely that every offender will spontaneously inform on all his co-offenders (Alarid, Burton Jr., & Hochstetler, 2009) or confess to their other offences (Kocsis & Irwin, 1998). Kocsis & Irwin (1998, p. 199) state that as *"some serial criminals have committed more offences than those for which they are charged, it would be inappropriate to assume that a person found guilty of only a single offence could not be a serial offender"*. As a result, undetected crimes by known offenders, and unknown offenders and their crimes, remain out of reach if recorded crimes are the sole data source when studying offending behaviour.

Researchers who use police-recorded crime data to study offenders' criminal behaviour often generalise their findings to 'offender behaviour', although clearly the data on which they base their study do not include all offenders (e.g., Townsley & Sidebottom, 2010). Researchers usually mention as a limitation the fact that only information about (offenders of) (solved) recorded crime was available (e.g., Vandeviver, Neutens, Van Daele, Geurts, & Vander Beken, 2015). Also, very few studies mention the possibility that there could be differences between the behaviour and characteristics of known and unknown offenders. Are known and unknown offenders alike? Do they display the same behaviour? If the answer to these questions is yes, there would be no need to study unknown offenders and their crimes, since including data about unknown offenders in research would only yield 'more of the same' results. The conclusions would be the same, regardless of whether known or unknown offenders were studied. The only exception to this would be estimates of the size of the offender population; these would require information about both known and unknown offenders. However, if the answer to the above questions is no, then both known and unknown offenders and their crimes must be included in the study in order to be able to make valid statements about the general offender population and their crimes. This also implies that current research gives a distorted image of offenders and their crimes, since it is (mainly) based on known offenders registered in police-recorded crime data.

Several authors have already expressed concern about the generalizability and applicability of research findings based on registered crime data, and the implications this has for both theory and policy (Lammers, 2013, p. 2). It is possible that the effectiveness of crime prevention initiatives and law enforcement deployment strategies could be compromised if they are based solely on analysing known offenders' offending behaviour. Arguably, prioritising law enforcement strategies that target known offenders lowers detection and clearance rates and renders unknown offenders invisible again. It is therefore important for the offending behaviour of unknown offenders to be understood as well, in order to develop new and inclusive prevention and law enforcement strategies (De Moor, Vandeviver, & Vander Beken, 2018b). Nonetheless, empirical research into unknown offenders is still limited, precisely because of the difficulty of studying these offenders.

How, then, can the unknown offenders responsible for a large number of crimes in police-recorded crime data be studied? Forensic DNA databases offer opportunities here. Generally, there are two types of DNA profiles in forensic DNA analysis: 'unknown' forensic profiles obtained from samples gathered at crime scenes (e.g., saliva or drops of blood), and 'known' reference profiles obtained from samples taken directly from a person (e.g., a buccal swab from an offender, suspect or victim) (Jeuniaux, Duboccage, Renard, Van Renterghem, & Vanvooren, 2016). These forensic profiles are very interesting when considering a study of unknown offenders. First, an unknown offender can be differentiated from another known or unknown offender using a DNA profile from the crime scene. Second, various crimes can be linked to the same offender by means of a DNA profile that is found at several crime scenes, even if this offender is (as yet) unknown. Third, similarly, different offenders can be linked to one crime, even though they are unknown, by means of their (different) DNA profiles found at the crime scene. This enables the serial and co-offending behaviour of unknown offenders to be studied. Fourth, DNA databases can supplement the police database with information about unknown offenders, and this for each individual crime.

Figure 1 illustrates these four advantages. The figure presents eight crimes that were committed between 2011 and 2015 by a total of five different offenders (A, B, C, D and E). It shows information about the eight crimes that is stored in both the police database and the DNA database. Offenders A, B and E are unknown offenders stored in the DNA database, offenders C and D are known offenders stored in the police database. The DNA profile of offender B, for example, was found at the crime scene of a theft in Ghent in 2011 (crime 2), a theft in Ghent in 2013 (crime 3) and finally at a theft in Liège in 2014 (crime 5). Moreover, for two of the three thefts, this unknown offender B was accompanied by one or more co-offenders known to the police. In other words, integrating a police database with a DNA database makes it possible to study the serial co-offending behaviour of the eight offenders, regardless of whether they are known or not. Using only police-recorded crime data would only give a partial image of the total offending behaviour.

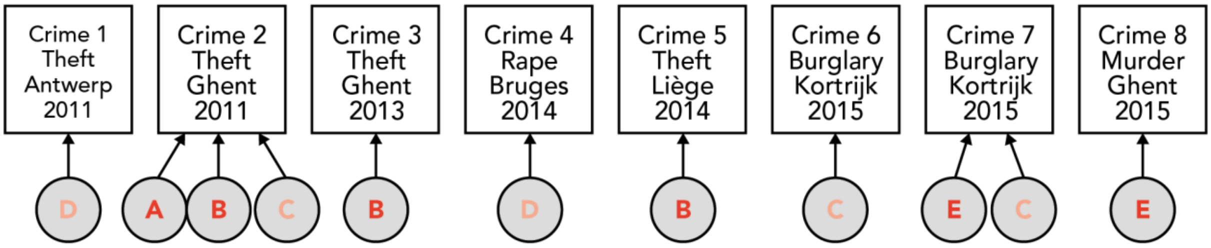

Figure 1: Fictitious example of eight recorded crimes

In theory, therefore, a DNA database is an ideal data source for studying the criminal behaviour of unknown offenders. But is that really the case? Can DNA databases be used as a meaningful source for criminological research, or are there disadvantages that would restrict or even prevent their use? In contrast to the extensive research on the use of DNA to solve specific crimes, very little criminological research has made use of DNA databases. In addition, and more importantly, the validity of the data source has been largely unexplored. This research therefore assesses the use of forensic DNA databases in the study of unknown offenders and their offending behaviour. The research is of both methodological and theoretical importance – methodological in the sense that a DNA database is evaluated as an alternative data source for criminological research; and theoretical in the sense that, by evaluating a DNA database, some substantive issues regarding unknown offenders are dealt with. This research is also of practical importance, as guidelines for crime prevention and control can be derived from the improved insight on unknown offenders.

2.2.2 Research questions

Forensic DNA databases offer the opportunity to extend forensic intelligence to unknown offenders of crimes registered in police databases. In the study by Wiles and Costello (Costello & Wiles, 2001; Wiles & Costello, 2000) forensic DNA data was used to supplement other (police) data. The researchers used both reference profiles of known offenders and forensic profiles of unknown offenders. They did not distinguish between the two types of profile. The researchers therefore made statements about the entire offender population, without being able to prove any difference between known and unknown offenders. Lammers (2013) explicitly made this distinction, and in her research on probability of arrest found a (limited) difference between known and unknown offenders. However, she only used DNA data to make statements about both known and unknown offenders. DNA data represent only a proportion of all offenders, whether known or unknown, because not every crime registered in the police database provides DNA profiles that are stored in DNA databases. Therefore, DNA databases only contain data on certain crimes, and thus do not include all offenders. Using only a DNA database to study offenders and their offending behaviour can therefore give a distorted picture.

In the (limited) research that has so far used a DNA database as data source, too little attention has been paid to the question of whether such databases are suitable for criminological research. The selectivity of the data source is usually mentioned, but not examined further. However, it is important to establish which unknown offenders and which crimes are actually stored in a DNA database, before starting research that examines the difference between the behaviour and characteristics of known and unknown offenders.

This brings us seamlessly to the goal of this research, which is to assess the usability of DNA databases as a data source for criminological research. The resulting central research question is:

How can DNA databases contribute to the study of unknown offenders and their criminal behaviour?

The research question is operationalised by evaluating the specific characteristic weakness and strength of DNA databases as a source of criminological research: the selectivity of the source versus the ability to study (links between) unknown offenders and their offending behaviour. This results in four research questions that are explained below.

Selectivity of the DNA data

Generally, all the crimes in a DNA database are also included in police-recorded crime data. The opposite, however, is not the case. As already mentioned, only a minority of all registered crimes are represented in a DNA database, as not every crime scene is swabbed for DNA, and not every crime type provides suitable DNA profiles. Crimes such as money laundering, for example, are generally not represented in DNA databases. Before a DNA profile can be stored in a DNA database, it must pass various selection processes. The answers to the first research question provide an overview of these selection processes:

RQ 8: Which actors and factors have an impact on the selectivity of DNA databases?

Because of its selectivity, a DNA database is only a 'sample' of all crimes stored in a police dataset. Before a DNA database can be used as a criminological data source, it is therefore important to question the representativeness of this sample. Criminologists frequently use police-recorded crime data and, although it is also selective, researchers generally regard it as a valid data source. Therefore, the second research question weighs the validity of DNA databases against the validity of police-recorded crime data:

RQ 9: Are DNA databases less valid than police-recorded crime databases for the study of unsolved crimes?

***Networks* of unknown offenders and their crimes**

Although DNA data represent fewer crimes than police-recorded crime data, DNA databases have specific advantages that can make a fundamental contribution to the study of crime and criminal behaviour: the ability to study unknown offenders and their (serial and co-)offending behaviour. Moreover, by integrating police-recorded crime data and DNA data, links between known and unknown offenders can be identified, which is not possible with any other data source. This also offers new research possibilities, as it is very unlikely that known and unknown offenders are two completely separate groups.

The question that arises from these opportunities is whether a different image of crime emerges if the study is based on both police-recorded crime data and DNA data compared to the crime image arising solely from police-recorded crime data. As these two types of database store information on both crimes and offenders, the image can be studied on both these levels, resulting in two different research questions:

RQ 10: To what extent does the crime picture change when unsolved crimes are included in a network analysis?

RQ 11: To what extent does the offender profile change when unknown offenders are included in a network analysis?

2.3 FORENSIC DNA AT THE POLITICAL LEVEL (WP3)

In a third and final part, we ponder the role of forensic DNA in public policies in terms of efficacy of legal systems and respect of the fundamental rights of individuals. We determine how the various scientific products developed at the operational and strategic levels can be used to inform public policies in order to adequately (i.e., legally, fairly and efficiently) address the problem of crime in its various dimensions (McCartney et al, 2011).

What is paramount in creating a comprehensive understanding of the legislation surrounding the use of DNA in a forensic setting, is an in-depth study of all legislation relating to this topic. This includes all legislative proposals, as well as all executing decisions and orders.

An exhaustive study on this subject was done at the beginning of the project and maintained throughout (Error! Reference source not found.), as many changes were applied over those 4 ears (e.g., the creation of a database Missing Persons). The *ratio legis*, reasoning of the legislator, was also studied. These documents were a treasure trove of information into the mind of the legislator and the context in which these laws were established. At the end of the study, in 2018, the legal landscape for forensic DNA testing in Belgium and the Belgian DNA databases had completely changed in comparison to the situation at the beginning of the project; the changes established by the law of 2011 had gone into force in 2014, new databases were created, the exchange in light of the Council Framework Decisions has expanded each year to include more countries and technology has not ceased developing new ways to apply DNA testing in a forensic setting.

Another exclusively theoretic, but necessary, part of our study concerned the theories of security policies. We identified the sources that would contribute to influencing the policy makers, as to ensure that our findings would be disseminated in the most efficient of ways and to the right individuals. To this objective we organised several dissemination events to which we invited all actors who could potentially benefit from our findings and published them in specific and very general journals.

Part of this study was also to identify the impact that security policies, more specifically policies regarding forensic DNA testing, could have on the fundamental rights of people. We identified several potential practical issues, such as function creep and the abundance of information contained in DNA, which in turn translated into abstract fundamental rights that could be harmed; the right to privacy, the presumption of innocence, the right to inviolability of the body,…

Research questions included: how is data recorded during criminal investigation and how long is it kept? Has there been a widening of the use of forensic DNA beyond its initial purpose? Is there a risk that the NGDB will invade one’s right to privacy?

We attempt to answer these questions to come to a conclusion on what is exactly an efficient and just security policy.

An integral part of the study is the comparative aspect; how is DNA regulated in foreign legal systems? We compared the Belgian system to the French, Dutch and English ones. Hence, we gained insight into the advantages and disadvantages of our own system and were able to identify potential weak spots or alternative solutions to problems that have occurred or will occur when implementing new legislation. We identified different aspects that were subject to comparison. In the first instance, the criminal investigation part. We studied the historical and societal context in which the legislation regulating forensic DNA first emerged. We then answered certain questions that arose from this study; what is the legislative framework today and which are the applications of forensic DNA that are accepted and applied?

Then we looked at the procedural details of each of these regulations to determine which actors are involved in the process of taking and analysing biological materials, whether the forensic DNA analysis was a responsibility of the police or justice department and how exactly the procedure unfolded.

Databases are an integral part of DNA analysis in criminal cases. Without them, comparison on a regular basis with known offenders would be impossible. Furthermore, they can be used outside of the realm of police application, for researchers like us for instance. We looked at several aspects of the databases; which databases are acknowledged in each country and what do they contain? Is there a limitative list of crimes that lead to an inclusion in such offender databases or a certain threshold that should be crossed? Finally, which are the time frames during which the DNA profile is kept by the authorities in each country?

Another important aspect of DNA analysis is the quality of the laboratory work and the scientific interpretation of the results. We studied the guarantees that were set up in each country to assure a certain level of scientific quality and assurance.

Finally, the impact of these regulations on the potentially infringed human rights was analysed. The principle of inviolability of the body is endangered by the need of police authorities to be able to force an individual to give a sample of their biological tissue (most commonly saliva or hair and, in extreme cases, blood) for the purpose of analysis in a certain criminal investigation. How did the respective legislators decide to tackle this hurdle? What is the opinion of the European Court of Human Rights (ECtHR) on this issue? The ECtHR does indeed have the authority in human rights matters, which was proved again by their ruling in the Marper case. We discuss this case and look at the impact of their ruling in matters of conservation periods of personal data on the national legislations.

The aim of this study was to answer one main important question:

RQ 12: What can we learn from the comparison of our system with that of other countries?

Finally, the main aim is to come to conclusions on the basis of the outcomes of WP1, WP2 and WP3 and to translate these into concrete recommendations for security policies.

In light hereof our preliminary results were presented to different Focus Groups, to which actors from each and every potentially involved professional group were invited and their opinion on these matters was probed. Once again, the results of these focus groups were, in turn, an outcome on their own and were taken into account for the formulation of specific recommendations for security policies. These regard indicators of efficiency of public policies, prioritization of means for the investigations, decision criteria to carry out investigations by magistrates, strategies to optimise communication, etc.

RQ 13: What is the criminal policy in Belgium and what possible problems present themselves when amending legislation?

All these recommendations attempt to answer the biggest research question of them all: how can we optimise the use of forensic DNA in Belgium?

3. METHODOLOGY

This research combined different methods. Both qualitative and quantitative methods were used as well as a comparative legal study. Some of the methods were applicable to all the work packages and are described below. The more specific methods for each work package are elaborated in the relevant result sections.

3.1 ACCES TO DATA

The success of the Be-Gen project relied heavily on access to a number of data, both judicial and police. The project was conceived on this basis, taking care to associate the natural partners of such a project, namely the judicial authorities, the federal police as well as the DIS service of the NICC which manages the national genetic databases (NGDB). From the beginning of the research steps were taken to get access to the data from those different partners.

3.1.1 Judicial data

Arranging for access to judicial files concerned exclusively the implementation of WP1 (operational evaluation) of the Be-Gen project.

On 28 July 2014, a request was sent to the College of Attorneys Generals to get access to court files. On 4 November 2014 we met with Attorney General Ignacio De La Serna at a meeting at the NICC to clarify the request. A summary of the request was sent to the College on 12 November 2014. We then attended the meeting of the College of Attorneys General to present our request orally and to agree on the terms of access. We received letters of authorization for access to court files on 18 December 2014.

On a practical level, access to judicial files and meetings with magistrates and court clerks generally went well. To access the court files in concrete terms, we sent our targeted access requests directly to the DNA reference magistrates who, on the basis of the access authorization received from the College of Attorneys Generals, informed us of the state of the court file or possibly made it available to be studied. Some files could be found at the clerk's office of the public prosecutor while others had to be accessed by the clerk's office of the court. Therefore it took a while to find out where all the files could be found and contact the right persons to get access. Some of the selected files could not be found so other files had to be selected.

3.1.2 DNA data from the National Genetic Database

Access to data from the NGDB involved adhering to the strict rules set out in the 1999 DNA law, which requires the manager (NICC DIS Service) to comply with strict data access control. On this basis, in order to comply with the law of 8 December 1992 on the protection of privacy, we began in September 2014 by approaching the Commission for the Protection of Privacy (CPVP). In November 2014, a formal request was made to the CPVP 'Federal Authorities' Sector Committee for the use of the NGDB data by the Be-Gen researchers. The CPVP promptly asked to complete our request. We sent, on 15 January 2015, a document defining our data security policy and a declaration of conformity. The acknowledgment of receipt on 20 January 2015 was followed by a response on 17 March 2015 informing us that such authorization was not necessary, as these data from the NGDB would be processed internally by the authority that requested them. On this basis, access to the NGDB data was initiated in accordance with the primary needs of the research. Specific access procedures were defined to ensure compliance with these rules and decisions for the needs of WP2 undertaken by Ghent University. The access modalities could be applied during 2015-2016 so that the researchers of both WP1 (operational evaluation) and WP2 (strategic evaluation) where able to obtain the expected data, according to the specificity of their WP. This took place at the end of March 2016 for the researcher of Ghent University and in August 2016 for the NICC researcher.

3.1.3 Police data

In its letter of authorization concerning the judicial data, dated 18 December 2014, the College of Attorneys General drew our attention to the fact that: "*for access to police databases, it is appropriate to apply for the authorization to the Supervisory Body of the National Police Database (NPD)*" (article 44/7 of the Police Function Act).
Our attempt to contact this Supervisory Body, now integrated into the CPVP failed since the members had not yet been appointed and therefore this body was not yet established within the CPVP. The CPVP therefore informally referred us to the Federal Police Directorate.

An authorization application was sent to the Federal Police to obtain data on two levels. On the one hand, concerning the WP1 (operational evaluation), in order to obtain the data relating to the activity of the Laboratories of the Technical and Scientific Police. On the other hand, concerning WP2 (strategic evaluation), to obtain data to evaluate the information potential of DNA data contained in the NGDB held by the NICC. In addition to the telephone calls, here are the main lines of the steps taken and the answers received:
On 23 September 2014 a request was sent to the CGO Service of the Federal Police.
On 23 October 2014 an acknowledgment of receipt was sent to us by e-mail, sending us back to the file manager within the Federal Police.

On 18 November 2014 a response from the Director of Police Information and ICT asked us for details on the type of information sought, while underlining the rules provided for in articles 44 and following of the law of 5 August 1992 on the function of the Police (LFP). In particular they referred to the articles on data communication and access to the NPD of the law of 18 March 2014 governing access to police data by third parties.

We proposed to hold a meeting to clarify our request which never actually occurred.
On 11 February 2015 we sent a letter specifying our request for each of the two analysis components concerned (operational and strategic).

On 10 March 2015 a reply by mail from the Director of Police Information and ICT informed us that access to the requested data was not possible because "*the communication of personal data and access to the NPD are regulated in articles 14/11/4 and following of the law on the police function*". In other words, apart from certain services entitled to access, any other service may be given information only in the context of scientific research, which is regulated by article 44/11/10 LFP. This article provides that the King must determine the bodies or persons, data and conditions of their communication to these bodies and persons. The letter states that "*to date, such a Royal Decree does not exist and therefore there is no legal framework to provide personal data managed by the police services to the researchers concerned*."

Despite this response, we immediately relaunched our efforts with the Commissioner General of the Administrative Police. By e-mail on 21 April 2015 we received confirmation of the decision of 10 March 2015, with the suggestion of making representations to the concerned ministers in order get the missing Royal Decree adopted, as well as to turn to the college of the Attorneys General to search for a workable solution. The relaunch of the College of Attorneys General led to an exchange between the Attorney General of Mons and the Commissioner General of the Federal Police, on the basis of the fact that authorization of access to court files granted by the College of Attorneys General already allowed us access to the required police data. After several contacts, we finally received on 27 October 2015 an e-mail from the Commissioner General of the Federal Police stating that "*this file is in order as to the principle of access to the data concerned*" and referring to Commissioner Liekens, director of informatics and police information, to define the practical modalities of access.

For WP1 (operational evaluation) a first extraction of the data of the technical and scientific police was provided on 28 January 2016. A month of exploration of these data showed that the quality of the extraction did not allow exploitation. New, more adequate, extractions were received on 25 March 2016. Concerning WP2 (strategic evaluation) concrete access to the police data was achieved on 10 March 2016.

3.2 OBSERVATIONS AND EXPLANATORY INTERVIEWS

At the start of the project the researchers had limited knowledge about forensic DNA in practice. To better understand scientific literature and the legislation, various observations and interviews were carried out. The main actors in the forensic DNA process were contacted to explain their role in the process. Five actors were selected to cover the whole process starting from the collection of traces and on to the registration of the DNA profiles in the NGDB (**Figure 2**). Unstructured interviews were conducted at the Central Directorate of the Technical and Scientific Police (DJT), the National DNA Cell, and the DIS service of the NICC (between October 2014 and January 2015). At the NICC DNA laboratory (October 2014), one of the accredited forensic DNA laboratories in Belgium, and at the Laboratory of the Technical and Scientific Police (LTWP) of the judicial district of Antwerp, Ghent, Brussels and Liège (February and March 2015) participant observations were carried out.

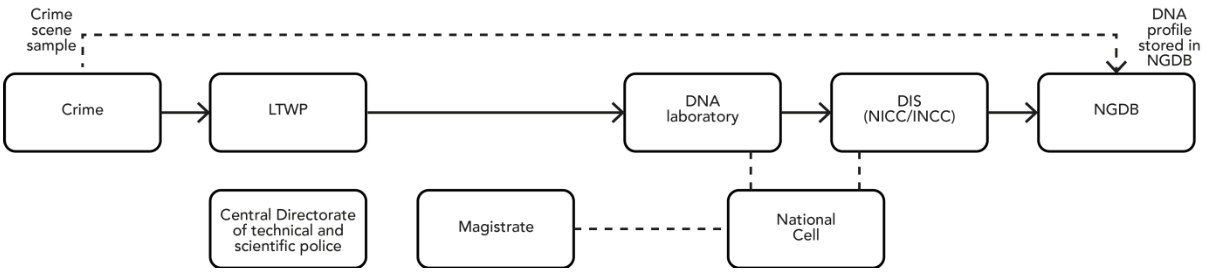

Figure 2: Actors involved in the forensic DNA process (De Moor, 2018)

3.3 NETWORK MANAGAMENT AND FOLLOW-UP COMMITTEE

The different tasks in the work packages implied collaboration among the researchers. They met regularly, exchanged information and evaluated each other. Both researchers and promotors met several times a year for seminars where they discussed methodological choices and the preliminary results. Three of the researchers were also engaged in doctoral activities at the University of Leuven (WP1), Ghent University (WP2) and the Vrije Universiteit Brussel (WP3).

A follow-up committee was composed of representatives of (1) the judicial actors, (2) the police, (3) the policy makers (in the Departments of Justice and Interior), and (4) scientists in criminology and political science (Error! Reference source not found.). One a year they received report of the annual activities and where asked to provide feedback during the annual follow-up committee meeting.

4. SCIENTIFIC RESULTS AND RECOMMENDATIONS

The fruits of our research are detailed in this section. These results all build up to the final and essential result: the recommendations that the research team has formulated based on all the foregoing results and conclusions of their research.

We start by introducing the normative and legal framework, the basis of forensic DNA in Belgium. We then discuss the theoretical and practical aspects of criminal and security policies regarding forensic DNA. The understanding of these two aspects (legislation and criminal/security policy) is paramount when developing policy recommendations. A comparative research then compares the Belgian integration of DNA analysis in criminal cases to that of our neighbouring countries. The relation between DNA and Crime Scene Workers is then examined, followed by an analysis of forensic DNA in criminal investigations and in scientific research.

4.1 NORMATIVE AND LEGAL FRAMEWORK

For this research, we started by carrying out an exhaustive study of Belgian legislation on forensic DNA. This means that the laws were carefully read and analysed, as well as the parliamentary works and the executing decrees and orders. We limit ourselves here to the summarised version of our findings of this analysis, but Error! Reference source not found. gives detailed and chronological overview of the history of forensic DNA in Belgium.

Forensic DNA was introduced in the Belgian legal landscape in 1999. In some respects and compared to other surrounding states this might be considered rather late. This , however, was not a disadvantage in comparison to other countries. The legislator was very careful in implementing provisions that might affect the public's fundamental rights (e.g., the right to privacy, integrity of the body and presumption of innocence). Its main characteristic was its prudence, and the Act was introduced in a very controlled way. The 1999 legislator attempted to protect the right to privacy by relying on the safeguard of sole use of what was then assumed to be non-coding DNA. He was also confronted for the first time with the need to introduce a possibility of force in case of sampling refusal, and as such introduced the possibility to use force under certain, restrictive circumstances. Since sampling and recording the DNA of convicted offenders for example is of paramount importance to assure a completely functioning and effective database, the legislator introduced the possibility of coercion in this case.

A major revision of the Act came in 2011, aimed at enhancing the original Act's efficiency and efficacy. After that several amendments followed in the aim to facilitate international exchange of profiles, establish a National Cell, create new databases and integrate the Marper judgement. Further amendments, specifically regarding the introduction of new technologies in the field, are to be expected in the near future.

4.2 SECURITY POLICIES IN BELGIUM REGARDING DNA

4.2.1 Policy makers

When identifying the persons who actually have an influence on policy, one might think that this would be limited solely to the politicians. However, this is far from the case. Policy is formed, moulded by a group of people in an interaction, a policy-creating dance. Actors in the field are consulted, magistrates communicate what has been said during their meetings on this topic, possible human rights infringements should be considered and as such the Belgian Privacy Commission should also be consulted, etc.

This was the reason for our decision to include representatives of as many of these groups as we could during our Focus Group Discussions, where we presented our preliminary findings, on the basis of which we formulated our recommendations.

4.2.2 Potential issues to be taken into account

4.2.2.1 *Safeguarding privacy*

When establishing the legislation on forensic DNA, the legislator paid special attention to a potential infringement on the concerned individual's right to privacy. DNA is full of personal information, and even the DNA profile – which in itself is nothing more than a numeric code – is considered a personal information by the Belgian Privacy Commission.

A lot can be calculated and learned about an individual based on his or her DNA: medical situation, appearance, cerebral lesions, etc. DNA is a personal construction manual, detailed and unique to each individual.

In order to safeguard the right to privacy, the legislator based himself on the scientific knowledge available at the time of the first DNA law in the nineties. A difference was made between "coding" DNA and "non-coding" DNA, also called "junk DNA". It was believed that this non-coding DNA did not contain any personal information such as medical conditions. The legislator thus believed it was best to form DNA profiles solely on the latter form of DNA in order to protect one's private life.

This concept was later rebuked. There is no such thing as junk DNA and even no such thing as non-coding DNA. In fact, all DNA codes information on the donor individual and sometimes we are even not yet aware of what it is exactly that it codes.

Consequently, it is of paramount importance for the legislator to find alternative ways to assure the protection of privacy. Since new technologies aim at going beyond a mere comparison of DNA profiles, it is recommended that the legislator find a standard other than the information contained in the DNA markers. Phenotyping, for example, requires certain markers to be studied in order to deduce and calculate the colour of the skin, the eyes and the hair. Scientists are currently working on finding out exactly how they can add additional information to these sketches made, based on the genetic information they dispose of: facial features, baldness, lifestyle, etc.

Of course the legislator is not obliged to introduce these new technologies into the law, but history has proven that in case of a legal vacuum, investigators will find alternative ways to apply these new technologies.

In Belgium, there were new findings in the investigation into the Brabant Killers (Bende van Nijvel/Tueurs du Brabant) in 2017 and investigators applied this novel technique of phenotyping by providing a foreign lab with the genetic material and asking them to analyse it. Aside from its questionable legality in court, this shows that the legislator should sit with the representatives of the Belgian Privacy Commission in order to develop new legislation all the while taking into account the right to privacy.

4.2.2.2 *Universal Database*

The presumption of innocence is one of the pillars of modern defence and criminal law. One has to be considered innocent as long as the contrary has not been proven.
This brings us to the repeated proposals of creating a universal database: a DNA database in which the DNA profile of every citizen would be stored. This proposal has been mentioned a few times by Belgian policy makers, and in times where terrorism is prevalent and authorities are trying everything to capture them, some could find such an idea tempting.
This, however, goes against the idea of the presumption of innocence. If one is considered innocent, there is no need to store his or her DNA in a database.

Furthermore, as mentioned before, DNA is considered a personal information. The mere storage of this information by the authorities is an infringement on the right to privacy. When dealing with profiles of trace evidence or of convicted offenders, a certain proportionality is required by the European Convention of Human Rights. Proportionality is one of the three requirements to allow an infringement on the right. Since it already fails this first test, it is certain that the European Court of Human Rights would never allow such a measure to be taken.

The importance of the jurisprudence of the European Court of Human rights cannot be underestimated. Following its decision in the Marper case regarding retention delays, the Belgian legislator not only saw the need to modernise its delays, but also provided persons acquitted the possibility to ask for the deletion of their DNA profile from the database.

There is also the matter of the principle of inviolability of the body. Sampling the DNA of new-borns who are not able to give consent or the use of force on adult concerned citizens who are unwilling to give their DNA, can hardly be considered ethical in a modern democracy.

But even on the practical side, the creation of an exhaustive universal database seems to be counterproductive. Mathematically, the chances of false positives increase at the same rate as the number of profiles that become stored in a DNA database[5].

4.2.2.3 *Function Creep*

Function creep are changes in, and especially additions to, the use of a technology. When personal data, collected and used for one purpose and to fulfil one function migrate to others that extend and intensify surveillance and invasion of privacy beyond what was originally intended, this is known as function creep (Dahl & Saetnan, 2009).
The legislator, in his prudence in implementing novel technologies, behaved admirably in this regard. The National Genetic Database (NGDB) was conceived with the intent of merely comparing DNA profiles and, since then, it has not been used for any other purpose.

Certain novel technologies would not involve the DNA database and so would not entail the risk of function creep. Phenotyping, for example, does not work on DNA profiles but on DNA markers that contain genetic information. The DNA profiles in the database are useless in the light of phenotyping.

Familial searches, on the other hand, tell an entirely different story. It is perfectly possible to carry out familial searches with the DNA profiles that are presently stored in the NGDB. This would mean that if the DNA of a perpetrator is found and then compared to the profiles in the database with the intent of carrying out an active familial search (partial likeness), investigators would be directed to his or her next of kin if they had already been recorded. This comes with a variety of risks. First, it could represent an infringement on the right to privacy, since there are subsidiary ways to find the perpetrator of a crime and its proportionality can be argued. Secondly, it could be a risk to discrimination since a person could be identified faster if their kin are in the database, which could especially be the case in poorer sections of the population. This would, in turn, give a wrong impression of which layers of the population are responsible for crime. All this leads to the conclusion that there would be a risk of function creep: the database would be consulted for goals that are outside the original intent.

There are also ways in which function creep could occur outside the scientific level. WP2 has shown that when the data from the NGDB are combined with data contained in other databases (e.g., police database), this leads to new deductions and additional information. However, the NGDB was not conceived with the idea of combining it with other databases and so such use of it would be outside the legislator's initial intent of to use the NGDB solely for identification through comparison.

---

[5] Porter, H. (2009, May 25). The rising odds of false DNA matches. *The Guardian*. Retrieved from www.theguardian.com.

4.2.3 Belgian Policy

The Belgian policy on the use of forensic DNA has throughout time always been one of prudence towards potential infringements of the right to privacy.
While in neighbouring countries such as the Netherlands and France phenotyping has been used to solve criminal cases, this has not been the case (yet) in Belgium. Mainly because the legislator does not approve of it and limits the technologies and applications of forensic DNA.

When reading through the parliamentary debates, it becomes clear that it is mainly the parties leaning to the right that want to expand the application field of forensic DNA. This can either mean expanding the list of crimes that lead to database inclusion, a further reaching genetic analysis or other possibilities. The political parties that lean to the left tend to be more concerned with potential infringements of fundamental rights, more specifically the right to privacy.

In the last decade, especially the last five years, the European continent has been under attack of terrorist and extremist cells. The perpetrators often have a European nationality, live in Europe and are part of a wide network that is spread throughout the continent. Belgium also suffered such attacks in 2016. A metro station and the Brussels airport became targets of ISIS, where they planted bombs and were able to kill and wound an impressive number of people.
As a consequence, there has been a political shift to the right that has spread throughout the European continent. The last Belgian local elections proved this as well, and in the federal elections the electorate will show whether they also are part of this wave.
Furthermore, with these attacks came calls for more far-reaching security measures and a more stringent security policy. The legislator amended several laws, granting an easier procedure for wiretapping, searches, etc. All the actions were quite limited and faced potential infringements of the right to privacy. Its facilitation should be seen as a portent for the evolution of the use of forensic DNA in Belgium.

During the focus group discussions many actors mentioned the novel technologies, more specifically phenotyping, as a paramount evolution in forensic DNA testing. They would be happy to see it established in a law so that they could also apply it in their investigations. As we have said before, it is unavoidable that these novel technologies will be used and so it is of extreme importance that they be embedded in laws. It is even more important that these laws be conceived with the utmost respect for the right to privacy and not fuelled by events. This would chip away at our fundamental rights.

This is where the Belgian Privacy Commission comes into play. They have an essential role to fulfil in the conception of these new laws and in assuring the safety of our acquired fundamental rights. It is a difficult rope to balance on: the disintegration of our rights and liberties on one side, and a far too rigid and unrealistic protection of these rights and liberties on the other..

Strangely enough there has been no mention of the implementation of new regulation concerning forensic DNA in any of the policy notes of the Minister of Justice, Koen Geens. In his policy note of 2011, he did pay a lot of attention to quality guarantees of the laboratories, including new educational seminars for those working on the levels of Crime Scene Investigation and Forensic Police Laboratories.

Furthermore, he vowed to continue the PACOS project, which aims to make evidence traceable in order to assure chain of custody.

The Minister of Security, Jan Jambon, however did express himself about his interest in creating a general fingerprint database for the entire population. He states that those who have nothing to hide, have nothing to fear. This is important since a fingerprint is another personal information, and thus the step to DNA is not far off. Furthermore, it shows a certain mindset and direction in which the authorities would like to evolve. We refer to our examination of the possibility of a universal database and the impact on the presumption of innocence, inviolability of the body and private life hereof.

In the field of forensic DNA the politicians have focused more on the creation of two new databases: a database Missing Persons and an Elimination database. The first one is now entering into force, while the latter is still under discussion and is facing many practical hurdles. We refer to an earlier chapter (2.1.3) in this report, dedicated to this matter.
The implementation of the Missing Persons database, even though it is not yet at the point where it should be, has already proven to be fructuous. The identification of the body of Mrs. Corrie Van der Valk[6] for example, or of the unidentified man in the Maas[7]. It is clear that the successful exploitation of the new databases has received a lot of media attention, stating for example that of the 42 case files opened last year, 35 had been closed but that in total 138 cases still remain unsolved.

4.2.4 Focus Group Discussion

4.2.4.1 *Methodology*

In short, a focus group discussion can be described as a group interview. The researcher asks a question that several persons, because of their professional occupation or experience, can answer. There is a moderator present during the discussion, possibly (one of) the researcher(s), who manages the conversation and ensures that everything goes smoothly. The content of the replies, comments, answers of the focus group interviewees is the core of the results of the focus group discussion.

[6] Decré, H. (2018, November 16). 17 Jaar lang spoorloos, nu gevonden in anoniem graf in klein dorpje in Wallonië. *Vlaamse Radio en Televisie*. Retrieved at www.vrt.be.
[7] X. (2018, March 12). Federale Politie heeft 138 dossiers rond niet-geïdentificeerde doden. *Het Laatste Nieuws*. Retrieved at www.hln.be

There are several reasons why one would conduct such a discussion. It can be a group interview in which there is a collective attempt to identify certain issues. The discussions can also be conducted in the intent to establish planning for a research. Researchers may also want to evaluate certain information that they have gathered and test it by presenting it to actors in the field. Lastly, and in most cases, focus group discussions are led with the aim of gathering as much information as possible about certain subjects or questions in a particular research. It is this latter function that was the case in the Be-Gen research.

There are three main characteristics of a focus group discussion (Morgan, 1998). Firstly, its aim is to collect qualitative data. Secondly, it aims to collect as much data as possible. Lastly, all of this information is generated in the form of an actual genuine discussion. One participant can share an opinion and the others can reply, creating an interactive discussion in which the participants do not feel like they are being interviewed, but are merely sharing ideas, opinions and beliefs. The researcher then behaves as a participant-observer, making it possible to collect the data.

The methodology of a classical focus group discussion is quite simple. There is a preliminary phase, in which all the practical aspects are handled: booking a room, sending the invitations, preparing possible materials, planning the timeline of the focus group, defining the subjects to be discussed, etc.

Then the actual focus group discussion takes place. Each person participating in the focus group has a well-defined task. There has to be a moderator, and there can also be someone taking notes. The subjects should be defined in advance and the moderator has to make sure that the discussion stays within the foreseen timeframe and on topic.
Finally, once the focus group discussion has taken place, this does not mean that the work is over. It is now time to start the process of analysing the information that has been shared, distilling the important data and staying in touch with the participants.

For the focus group discussion organised under the Be-Gen project however, the researchers developed an entirely new approach. They combined the classical focus group discussion with the lesser known group analysis.

Group analysis is another qualitative method of gathering data, developed at the University of Saint-Louis in Brussels (Van Campenhoudt, Franssen & Cantelli, 2009). The researchers who developed this method state that the main difference with a classical focus group discussion lies in the fact that the participants are involved in the entire process from the first to the very last moment. For more information on this, we refer to Error! Reference source not found. of this eport, which goes into further detail.

By combining these two approaches, we developed a hybrid qualitative method. We chose to do this because the classical focus group discussion has its merits; it is a renowned method that

has been applied many times in the research field and always yields results. The group analysis then offers the possibility of getting much more information from the participants than the classical discussion does, since it involves the participants to a greater extent.
This led us to the following structure:

Table 1: Structure of hybrid focus group analysis

Phase 1: Experiences	
Step 1	Sharing experiences
Step 2	Selection of experiences
Step 3	Questions
Phase 2: Interpretations	
Step 4	Round table reactions
Step 5	Reactions of experience sharer
Phase 3: Focus group discussion	
Step 6	Classical FGD
Phase 4: Analysis	
Step 7	Similarities and differences across the subjects
Step 8	Hypotheses of researchers and reactions/suggestions
Phase 5: Practical recommendations and evaluation	
Step 9	Practical recommendations
Step 10	Evaluation

4.2.4.2 *Results*

When we sent out the invitations for the focus group discussion the participants were asked to think about an experience they had in the field that had marked them, and to translate this to a concrete proposal or recommendation that would bring an improvement to the field of DNA analysis in criminal cases. Our intention was to limit this to one proposal per person, but we quickly saw that our participants were eager to share much more. To remain flexible, we allowed this, also because the main aim of a focus group discussion/analysis is to gather as much information as possible.

This led to quite a number of proposals, which can be classified in five distinct categories: raising awareness and cooperation (1), policing (2), laboratories (3), databases (4) and new technologies (5).
The participants wished for a larger range of trainings and educational sessions concerning forensic DNA open to a very broad public. People who work with forensic DNA on a professional basis, but also the larger public.

As the cooperation between the different services involved starts with good communications, many of the participants agreed that the establishment of an online interface would greatly benefit the communication between the services and the efficiency of their actual communication.

The suggestions related to the policing aspect ranged from introducing DNA as a biometrical tool to enabling the possibility of 'secret' DNA gathering (e.g., from the coffee cup of a suspect without their knowledge).

The laboratory workers shared that they would like a more harmonised policy throughout all of the laboratories. While they are all accredited and comply with quality standards, the management and policy in each laboratory is different, leading to discrepancies. They would also enjoy feedback from police, so that they can improve their workings and optimise their cooperation. Lastly they have witnessed a steady and continuous decrease of the funds made available to them, while the cost of the materials needed for analysis continues to rise.

The suggestions regarding the databases varied widely. In short, they concerned a greater input of information in the existing databases (through the expansion of the database inclusion crime list or the expansion of the individuals sampled and recorded) and an expansion of the number of databases (e.g., the establishment of a Suspect Database). Another point tackled the anonymous nature of the databases, stating that they are professionals and should be trusted with this information. Also, assigning the database management to the police instead of the judiciary branch was discussed, as well as the idea of combining different existing databases with the DNA database in order to come to new data that can be distilled from this merger.

Regarding the new technologies, the evolutions in the field of phenotyping were discussed at length. In order to move forward, the participants would like to see the differentiation between coding and non-coding DNA to disappear and would like to enable research on so-called coding markers. Other technologies were also mentioned: ARN DNA, mitochondrial DNA, Y analysis, Rapid DNA and New Generation Sequencing.

Aside from the suggestions that came forth from the participants themselves, the researchers defined certain subjects to be discuss during the classical focus group.

One of the first preliminary findings coming from WP1 was that the investigators would often collect trace evidence to be analysed, but they did not specifically collect the victim's DNA. This had the effect of forming a Trace database containing DNA of the victims of the crime . We do not know how many of these profiles exist. The reaction amongst the participants was lukewarm. Some stated that specifically collecting victims' data would be too costly and too much of a burden for the system. In any case it was not considered a priority.

When asked about federal harmonization in the handling and assessing of evidence, what came forth was that the communication between the laboratory workers and the police officers was of paramount importance here. When the two groups work together and communicate, they can assist each other in order to come to the most efficient selection, sampling and analysis of trace evidence.

The strategic aspect of this research (WP2) studied what data would spring from combining other databases with the DNA database. The participants were enthusiastic about this idea since it would be of great help to investigators. They also stated that this would be easier if the responsibility of the DNA database would become that of the police rather than of the judiciary system.

The new technologies facet was only discussed briefly during the focus group discussion, since many of the suggestions in the first phase referred to this. There was a large consensus that the new technologies in the field of forensic DNA should be implemented in the law and made available to the investigators.

One of the main research questions of WP3 is in what way the right to privacy of the individual is affected by the DNA analysis and potential new technologies and applications. When confronted with this question, the participants stated that they believe the current regime of privacy protection provisions is too farfetched. They believe that there should be a little less attention to the protection of the right to privacy in favour of security policies. One of the participants stated that once the DNA is analysed and translated into a numeric code, it is not much different from a license plate and as such the far reaching protective provisions are ridiculous.

4.2.4.3 ***Conclusion***

The main amendment that was realised in 2011 aimed at a modernization of the use of forensic DNA in criminal cases and an improvement and simplification of the procedure[8]. While the law of 2011 introduced many positive changes, many experience the extreme formalization as inefficient. In all these suggestions, we can conclude there is a double need.

First, a greater efficiency. Education, improved communication and cooperation would benefit this greatly. Secondly, a greater attention to the quality and reliability of forensic DNA analysis.

[8] *Parl. St*. Kamer, 1504/001, 26 mei 2011, 3.

4.2.5 Conclusion

DNA in our society today is no longer as controversial as it once was. The European Court of Human Rights has defined some clear guidelines in their Marper judgment that have set some limits to its use but have also consolidated DNA as a forensic tool in criminal cases. The Belgian legislator has taken the ECtHR judgment into account and the Commission for the Protection of the Right to Privacy is certainly working as a watchdog to assure that it is respected and followed.
The focus group discussions clearly emphasised the call to introduce new technologies in the legislation on behalf of the actors in the field, and the policy analysis showed that the introduction of new applications (such as a database missing persons) does yield results. The Marper judgment and the Commission do not hinder the possibility of introducing new technologies, given that they are accompanied by sufficient safeguards.

4.3 COMPARATIVE LEGAL AND POLICY FRAMEWORK REGARDING DNA

4.3.1 General

Evidently the legislation surrounding forensic DNA research in Belgium was not created in a vacuum and had been established in relation to a historical background, an evidentiary necessity and other countries' best practices.

By carrying out a comparative analysis with our neighbouring countries, our aim was to discover both the advantages and disadvantages of our own system. The intention was to not only carry out a descriptive legislative comparison, but to draw conclusions from this analysis and to evolve to an improvement of our own criminal policy concerning the application of forensic DNA analysis.

Forensic DNA analysis in Belgium was compared to practices in the Netherlands, France and England – in that order. The reasons why we have opted for these three countries are plural. Firstly, they are also part of the PIES project, which was finished in 2015 and formed one of the bases of the Be-Gen research. Secondly, another factor, obviously, was geographical proximity. Thirdly a comparison can only be carried out when dealing with comparable subjects – the legal systems need to be comparable so as to not compare apples to pears. Lastly, the access and processing of the information sources in terms of distances and languages were also important.

Since the primary goal of this comparison was to increase our understanding and potentially improve our own Belgian legislation regarding forensic DNA analyses, the subjects compared were limited to those that arose during the analysis of our own legislation (as done above).

Firstly, this report gives a general description of forensic DNA research in each specific country. We have applied the functional method of legal comparison, which implies a full understanding of the background in which the legal framework was established. We then analyse all of the different applications of forensic DNA that are authorised in each country.

Then follows a more in-depth analysis of the procedure of forensic DNA research and of the databases that exist in those countries. We then discuss the quality guaranteed that has been built in, followed by an analysis of the human rights that potentially may be infringed and how each of these countries has found solutions to assure that that would not happen.

4.3.2 Comparison of the legal frameworks

Firstly, a short description is given of the background and the history behind the forensic DNA research in each country and of the steps to establish a real legislation. The surface of every legal framework is then scratched, without getting lost in the details themselves. After this, the applications authorised are deduced in each country as well as what exactly is to be understood from it. This information, combined with some other elements, will grant a deeper insight into the use of forensic DNA in the selected countries.

4.3.2.1 ***The Netherlands***

In 1985, the same year that Sir Alec Jeffreys discovered the DNA fingerprinting method, various women went to the police after being attacked and raped in the Amsterdam World Trade Centre by an unknown individual. The police arrested a man who was identified following a line-up, a voice test and a blood sample analysis (the scientific grandfather of DNA analysis). The person was convicted for the rapes, but later filed an appeal and asked for a DNA test. The test showed that he was not the perpetrator the police were looking for and the man was cleared of all charges. This marks the first case in the history of the Netherlands where DNA evidence was allowed in court (Toom, 2011) - not to convict a person, but to prove his innocence.

The first steps towards genuine legislation are found in another rape case in the late 1980s. In the context of a rape case a dirty clown suit was found with traces of sperm that was suspected to be from the perpetrator. Although a blood analysis showed a positive identification, this was not considered as conclusive evidence to state with scientific certainty that he was the only possible donor of the sperm traces. The authorities wanted to carry out a DNA analysis and asked the suspect to participate. The person however denied that he was implied in any way and refused to cooperate and carry out the DNA testing. The Dutch authorities were then confronted with a serious shortcoming in the Dutch legislation; the absence of the possibility to forcefully obtain a DNA sample. Although the *rechter-commissaris* issued a warrant stating that the suspect was obliged to give a DNA sample, the suspect filed an appeal against this warrant. He stated that the DNA sampling was not provided for in any law and consequently, in order to guarantee the human rights from the ECtHR[9], an analysis could not be carried out without the explicit consent of the concerned party[10].

Being confronted with this shortcoming, the legislator realised that there was a need for a larger legal framework. This was established in September 1994 in the form of the very first Law on DNA research[11].

The legislation concerning forensic DNA research in the Netherlands is found in different legislative sources. The core legislation is divided over the following: 151a-da and 195a – g of the Dutch Code of Criminal Procedure, Act DNA analysis for Convicted Offenders[12], Decision on DNA analysis in Criminal Cases[13], Ministerial Decision DNA Analysis in Criminal Cases[14] and Instruction DNA kinship analysis[15]. Regarding the exchange of information of DNA profiles on a European and international level, one should look at Guideline concerning the exchange of information in light of reciprocal legal aid in criminal cases (552iSv.) and at Council Decisions 2008/615/JBZ and 2008/616/JBZ.

Article 138a of the Code of Criminal Procedure foresees the possibility of phenotyping. Phenotyping means that, through statistical calculations based on the DNA profile of an individual, researchers can deduce the most likely externally visible characteristics: hair, eye and skin colour. This application was introduced in 2003 and has been used since then.

The Dutch law also foresees a familial research. It is aimed at establishing familial bonds between different DNA profiles based on partial similarities. There is a need for a warrant from a judge, who in turn has the discretionary power to consider the proportionality and subsidiarity of the familial research: whether the measure of a familial research is proportional to the case in which it is requested and whether there is no subsidiary for the requested measure that could yield similar results.
Furthermore, there is a difference between an active and a passive DNA familial research. In a passive research, one does not specifically look for similarities between the DNA profiles. In a rape case for example, the profile of the perpetrator and of the victim can be analysed. I this the laboratory workers and the researchers may by chance notice certain similarities between both profiles, providing them with the information that the perpetrator is a family member of the victim. In an active familial research, the scientists will specifically look for a familial bond between certain profiles. This can happen based on an entire database, where one profile is compared to all collected profiles and similarities are studied to come to conclusions on familial

[9] Right to bodily integrity, right to a fair trial and right to respect for one's private life.
[10] Amsterdam Court 1990.
[11] (Dutch) Act 1 September 1994 DNA-analysis.
[12] (Dutch) Act 16 September 2004 concerning the DNA-analysis on Convicted Offenders (Act DNA-Analysis Convicted Offenders).
[13] (Dutch) Decision 27 August 2001 concerning detailed regulation on the use of DNA-analysis in Criminal Cases (Decision DNA-analysis in Criminal Cases).
[14] (Dutch) Regulation 17 October 2001 concerning DNA-analysis in Criminal Cases.
[15] (Dutch) Guideline 9 February 2012 concerning DNA kinship analysis.

relations between these profiles. The active familial research can also be used to identify an unknown victim. It is possible that the remains of a human body are found and the authorities suspect that the person has perished as a consequence of a crime for which the law foresees a minimum of 4 years imprisonment.

4.3.2.2 ***France***

The first DNA law dates from 17 June 1998[16] and foresaw the establishment of a national DNA database in which originally only traces found on crime scenes of sexual crimes and the DNA profiles of convicted offenders were included. One of the reasons for limiting the field of inclusion to crimes of a sexual nature only is probably due to the case that led to the establishment of such database: the case of Guy Georges. In Paris, in 1991, the body of a unknown woman was found. She had been raped and then brutally murdered. In 1995 they arrested a certain Guy Georges for aggressing a young woman and he was consequently sentenced to 30 months in prison. A DNA sample was taken from this man, but no comparison was made between his sample and the trace samples collected on crime scenes. A couple of years went by and in 1998 the *juge d'instruction* (investigating judge) asked all laboratories to compare the DNA profile of the crime scene samples with the profiles that they have analysed each in their respective laboratories. The *juge d'instruction* made a breakthrough in the case: the trace profiles matched the identified profile of a man named Guy Georges.
The proposed law was drafted a few months after that. It was clear that a centralised national DNA database was part of a logical evolution in time and essential in the fight against crime. Because of the sexual nature of the cases in which it would primarily be of importance, the legislator opted to first limit the field of application to these types of crimes. That application field was later expanded,[17] leading to a maximised exploitation of the DNA database[18].

The legislation regarding forensic DNA analysis in France is spread over different codes: articles 16-10 to 16-13 of the French Civil Code, articles 55-1, 76-2 and 706-54 to 706-56-1 of the Criminal Procedure Code (*Code de Procédure Pénale*, hereafter 'CPP'), articles R53-9 to R53-21 of the Regulation of the Criminal Procedure Code (*Partie Réglementaire of the Code de Procédure Pénale* hereafter 'PRCPP') and articles 226-25 to 226-30 of the French Criminal Code (*Code Pénal* hereafter 'CP').

In order to fully comprehend the legislative framework, one must read all of these articles together as one whole.

It is remarkable that there is no definition of what is considered in France as a DNA analysis. The law only mentions identification of a person through their genetic fingerprints. The

[16] (French) Act 17 June 1998 concerning the fight against crimes of a sexual nature (Loi relative à la répression des infractions de nature sexuelle).
[17] (French) Act 15 November 2001.
[18] (French) Act 18 March 2003 on homeland security (Loi sur la sécurité intérieure).

legislation also tends to focus more on the database itself (the FNAEG) than on the different modes of analysis and research.

The aim of DNA research, and of the FNAEG, is summarised as the identification and the prosecution of perpetrators of certain crimes[19].
Article 16-11 of the Criminal Code handles comparative analysis, which is only allowed when it is applied within a criminal investigation, when it has a medical or scientific aim, when it can help identify unknown remains or when it is used in a military setting (e.g., to identify fallen soldiers). The comparative analysis, according to the law, can only be made on ″non-coding″ DNA segments. The only exception is the marker for gender, which can be deduced[20].

Article 16-10 of the Civil Code mentions the research on externally visible characteristics. This can only be done when there is a scientific or medical purpose for it. The concerned individual should then give his or her explicit consent. It appears as if there is no room for this phenotyping in a criminal investigation … or is there?
Recent jurisprudence tells an entirely different story, one that can possibly also be of consequence for Belgium. In a decision dating from December 2014, the French *Cour de Cassation* agreed and gave its fiat for the analysis of genetic markers that code externally visible characteristics in a rape case.
In a matter of months, in Lyon in 2012, five different female students were raped by a man, armed with a box cutter knife and hiding behind a ski mask. The victims could not describe this man and the police disposed of very few leads in their investigation. They only had the DNA of the man, which was found on the victims. After establishing the DNA profile and comparing it to all profiles included in the FNAEG, there is still no positive match. The French investigating judge, confronted with a difficult case that raised a lot of media attention but where little to no leads could be found, then decided to establish a genetic 'sketch' of the perpetrator. He contacted a scientist in Bordeaux, who specialised in such research.

The Minister of Justice had sent a message to all General Prosecutors in 2011, stating that it condoned the application of DNA research to determine externally visible characteristics. Its opinion was that such analysis should not be applied in criminal investigations. Consequently, it filed a complaint against the scientist from Bordeaux for carrying out illegal research on DNA. The investigating judge who relied on the scientist presented the case to the *chambre d'instruction* to assure the legality of his request. After a long procedural battle, the French *Cour de Cassation* finally confirmed in 2014 the legality of the expertise that aims to deduce morphological characteristics of suspects from trace DNA samples.
France adopted an amendment in November 2018 that allows familial searches and, more importantly, no longer refers to coding or non-coding DNA[21].

[19] (French) Art. 706-54, par. 1 CPP.
[20] (French) Art. 706-54, par. 5 CPP.
[21] (UK) Act on the 2019-2022 Programme and Justice Reform (nr. 1349) and article 50 Amendment nr. CL846.

4.3.2.3 *England*

It is quite evident that England has a long and important history regarding forensic DNA research, since the 'genetic fingerprinting' method was developed there in 1985 by Sir Alec Jeffreys. Since then, England has claimed the oldest, proportionally largest and most inclusive DNA database in the world[22].
The first case in which forensic DNA research was used to identify the perpetrator of a crime, was the one concerning Colin Pitchfork; probably the most famous case in the history of forensic DNA testing.

In 1983 on a country road the lifeless body of a fifteen year old girl was found. She had been raped and brutally murdered. The investigators found traces of sperm on her body. Classic blood type testing showed investigators that only 10% of the population could be considered the donor of that genetic material. All the leads investigators found led to dead ends and there was no breakthrough in the case.

In 1986, not too far from where the first girl was found, another fifteen year old girl was raped and murdered. The modus operandi was completely the same, and investigators suspected they were dealing with the same perpetrator. Here too, sperm traces were found and collected. Investigators thought they had identified a suspect: an employee of a nearby psychiatric institution. Although the blood type testing showed no comparison with this young man, he presented such an accurate and convincing admission of guilt that authorities thought they had caught the perpetrator. The young man's father, however, could not believe that his son was capable of committing such heinous acts. He remembered something he had read in an article: through Sir Alec Jeffrey's new science, researchers could take a DNA sample of his son and compare it to the DNA found at the crime scenes. They could then decide it was either a positive match or not. It was Jeffreys himself who conducted the comparison and informed the investigators of the fact that neither the first nor the second sperm traces belonged to the young man. He could however assure them that both sperm traces belonged to the same person.

Investigators then decided to start a massive screening of the male population in the area, a so-called dragnet. In 1987 they requested a DNA sample from every local male individual between the ages of 16 and 34. In total they collected more than 1000 samples that needed to be analysed, in a time where such analysis took weeks instead of days.

A few months later a local woman overheard a conversation in a local pub between a group of men, where one of the men admitted that he took the DNA test for his colleague: Colin Pitchfork. The woman forwarded this information to the police, who abruptly arrested the man, who did not deny being involved in the two gruesome murders. He was sentenced to life in

[22] Wallace, H. (2006). The UK National DNA Database: balancing crime detection human rights and privacy. *EMBO Reports*, *vol. 7*, p. 26.

prison in 1988. The Pitchfork case is the first case in which DNA analysis was used, not only to identify the perpetrator but also to exonerate an innocent person[23].

Five years after that, in 1993, the Royal Commission on Criminal Justice formulated a recommendation to establish a national DNA database. England was thus the first country to establish such a database.

The main reason for formulating this recommendation in 1993 was the plummeting trust of the people in the judicial system after a few serious mismanagements of cases, such as the Birmingham Six. Six young men were pressured psychologically to the point of all confessing to a crime they did not commit[24]. Establishing a national DNA database would enhance the trust the public had in the judicial system since it concerns an objective scientific method of forensic identification.

Consequently, the Criminal Justice and Public Order Act (CJPOA) was established in 1994. It foresaw a national DNA database that included the profiles of all those convicted for crimes of a sexual nature and home invasions. It also changed the regulation concerning the sampling of DNA material without consent of the concerned party, which is still the lion's share of all regulation surrounding forensic DNA testing.

DNA sampling was originally only possible for serious crimes, but this quickly changed and became 'any recordable offence'. Most crimes, including begging and drunken disorder, are classified as such. Originally only the profiles of those who were convicted would be included, but this changed in 2001 due to the Criminal Evidence (Amendment) Act. It stated that all profiles that were established would be kept for an unlimited amount of time, regardless of whether this person was convicted or not and also if the profile was established in the context of a dragnet research.

The Criminal Justice Act of 2003 infringed on the human rights even more and stated that the possibility of forced sampling could be applied to anyone who was arrested for whatever reason and that the profiles established consequently to this sampling, would also be kept indefinitely in the NDNAD. This meant the largest inclusion perimeters of the world and would mean forced sampling and indefinite inclusion for small infractions, such as throwing a snowball at a patrol car.

The Serious Organised Crime and Police Act of 2005 expanded the use of the NDNAD to identifying human remains or body parts in the case of dramatic accidents or situations.

[23] Evans, C. (2007). *The Casebook of Forensic Detection: how Science solved 100 of the World's Most Baffling Crimes*. New York, Berkley Books.

[24] At some time during the interrogation the police officers had dogs barking outside of the young men's cells so that they were unable to sleep, leading up to psychological pressure.

S. and Marper v. UK[25] led to the establishment of the Counter-Terrorism Act of 2010. The details of this case are discussed later in this report, but it essentially dealt with the indefinite recording of personal information (e.g., fingerprints and DNA data), which was found by the ECtHR to be an infringement of human rights. As such, the Act halted the indefinite recording, and instead introduced delays after which the personal information had to be deleted from the database and any other files.

All enumerated laws are laws that changed the Police and Criminal Evidence Act (1984 –PACE) which to this day is still applicable regarding biological sampling.

PACE is a very large act; the articles that are important for DNA research are articles 63, 63A and 64(ZA-ZI, ZK-ZN).

PACE focuses more on the procedure of forensic DNA analyses than it does on the applications themselves. It is important to remember that England is one of the countries where there is precedent which, in this case, shows the limitations that the application of forensic DNA has in the UK.
Those limitations, in the legal documents, seem to be almost absent. Classical comparative analysis is quite obviously allowed, where one profile is compared to another to decide whether it is a positive match or not.

We have also already discussed the possibility to apply dragnets in the UK, where the DNA of a certain population group in a certain area is requested on a voluntary basis. This is, however, not always feasible and it demands a great amount of work and resources to carry out.

The UK also applies familial searches in their forensic DNA arsenal[26], where based on blood relatives who might be in the database, the investigators try to discover the identity of the unknown DNA donor. This can be done through Y-searches, where scientists mainly focus on the genetic material been passed down by the father. The other option is to do this research on mitochondrial DNA and focus on the DNA passed on by the mother.

Phenotyping is also an option in the UK; determining the most likely externally visible characteristics such as eye, skin and hair colour. It has come so far that commercial tests are available on the open market, although their efficacy is highly doubtful considering the amount of calculation and lab work required to come to scientifically sound conclusions. Even then, we will most likely never attain a percentage of correctness that is close to 100%, which is the case for regular comparative DNA testing.

[25] ECtHR 4 December 2008, *S. & Marper.vs.United Kingdom*, Appl. nrs. 30562/04 and 30566/04.
[26] Forensic Genetics Policy Initiative (2010). *DNA* Databases and Human Rights. Retrieved from http://dnapolicyinitiative.org.

Table 2: Comparison of Legal Frameworks

	Genesis	Legislation	Application
Belgium	Legal necessity in 1999	Code of Criminal Procedure + Law of 1999 + Royal Decree	Classical comparative research
The Netherlands	WTC- & clown suit murders → no possibility to force sampling	Code of Criminal Procedure + different laws + Ministerial Decrees	- comparative analysis - phenotyping - familial searches
France	Guy Georges murders & practical necessity	CC + CPP + CP + Decrees	Comparative analysis (phenotyping???)
England	Black Path murders + lack of trust by public (Birmingham Six)	PACE & Code D	- comparative analysis - dragnets - phenotyping - familial searches

4.3.3 Comparison of the procedural provisions

Firstly, we checked if the procedure is foreseen by law and, if so, where we could find it. We then studied whether forensic DNA analysis was a prerogative of the police or of the judiciary system. Then we looked at who is responsible to carry out this procedure: who samples the DNA? Who compares it or does other scientific manipulations? Is the concerned party informed of the result? And is there a possibility for a counter-analysis to check the work of the laboratory workers?

4.3.3.1 *The Netherlands*

The Netherlands distinguishes between a procedure by the *officier van justitie* (public prosecutor) and the *rechter-commissaris* (prosecuting judge). These are the key figures involved in the forensic DNA analysis and testing. Since they are closely involved, we can conclude that forensic DNA testing is a power that belongs to the judiciary authorities.

What is regulated in much more detail than in the Belgian system, is the possibility of aliases and confusion surrounding the true identity of a person. First the fingerprints of the individual must be checked before carrying out a DNA analysis. Added to this is the fact that a person can be held for six hours in case that is necessary establish his or her identity. This time frame can, under certain circumstances, be prolonged by another six hours.

In the regulation of DNA testing on convicted offenders, the possibility of forced sampling is foreseen in cases where the concerned party does not want to give his or her explicit written consent. In article 151a-da of the Code of Criminal Procedure (CCP) and article 195a-g CCP the different procedures, depending of which functional application is used, are described in fairly

minute detail. For more details the legislator refers to the ministerial decrees, just as the Belgian legislator does when referring to the Royal Decrees.
Article 151a CCP describes the procedure for the comparative application of forensic DNA research; a profile is compared to another profile to come to either a positive match or not. Apart from that, article 151a is very procedural: the *officier van justitie* (public prosecutor) can order a comparative analysis, but this can also occur on request by a suspect. The *officier van justitie* then appoints an expert who is linked to an accredited laboratory, and this person in turn reports the results of the analysis to the public prosecutor. The concerned party is informed – as quickly as possible – of this result. If he wishes to do so, he can request a counter-expertise. Article 195a CPP provides the same system for the *rechter-commissaris* (investigating judge).
Phenotyping analysis is provided for in article 151d CPP. Only the officer of justice can order such an analysis of the genetic material of an unknown suspect or of an unidentified victim. The externally visible characteristics that cannot be determined from the genetic material are not enumerated exhaustively. It does state that the traits that can be deduced are the gender and skin colour, and that the other traits are decided upon at an ad hoc basis. Phenotyping can only take place in case it concerns a crime for which there is a minimum penalty of 4 years or more of imprisonment. The same holds for the investigating judge in article 195f CPP.

The last application of the forensic DNA analysis, familial searches, are provided for in articles 151da and 195g CPP. The first one concerns the public prosecutor, the second one the investigating judge. It states that this legal provision is an exception to article 21 of the Dutch law on the protection of personal information[27]. The public prosecutor or investigating judge are the ones who have to order a familial search. However, it is a legal requirement that the case concerns a crime punishable by a minimum of 8 years of imprisonment.

4.3.3.2 ***France***

The French system is a hybrid system: the law mentions that the database is under supervision of the magistrate at the public prosecutor's office[28], yet at the same time DNA sampling is ordered by the police and the management of the database is also left to the police. So while there are elements that are a judiciary prerogative, it is undeniable that the police also have powers in this regard. The forensic DNA analysis can be ordered by the *officier de police judiciaire* (judicial police officer - JPO) or by the *Procureur de la République* (Prosecutor of the Republic - RP).
The JPO can collect the genetic material himself, but he can also order it and have it done under his supervision[29].
Prior to the sampling of genetic material the JPO ensures that the concerned individual is not already included in the FNAEG. Nevertheless, studies show that it is quite normal for the same person to be included in the FNAEG several times. It is a police officer who will take a sample of the biological material. In case, for one reason or the other, sampling biological material of the

[27] (Dutch) Act 6 July 2000 concerning the protection of personal data (Act Personal Data Protection).
[28] (French) Art. R53-9 CPP.
[29] (French) Art. 706-56 CPP.

concerned person appears to be impossible, it is foreseen by law that the investigators can take genetic material from an object that is supposed to be from the concerned individual in order to carry out the DNA identification analysis[30].

The JPO then orders a person, authorised under the law, to carry out the comparative analysis. Although in article 16-15 of the Civil Code the legislator mentions the fact that this person should be acknowledged as a judicial expert on a set list, this article contradicts that and states that this is not a requirement in order to carry out a comparative DNA analysis. The RP and the investigating judge can also order such analysis.

The person whose DNA profile has been established, with the exception of convicted offenders, then have to give their written consent so that their profile can be compared to those included in the FNAEG. If the concerned party does not provide this consent, a comparison can only be made with the DNA profiles of non-identified human remains.

It is remarkable that the French procedure is formulated a lot less strictly than those in Belgium and the Netherlands. This is probably due to the fact that the analysis is a hybrid prerogative, but one where the police play a far greater role than the judiciary system.
The law does not mention any notification of the result to the concerned individual, nor the possibility of a counter expertise.

4.3.3.3 **England**

It is clear from the procedures of forensic analysis and the management of the NDNAD that forensic DNA is a prerogative of the police. Even though this is not explicitly mentioned in the Police and Criminal Evidence Act (PACE), the title of the act is self-explanatory in regard to who is responsible for carrying out these analyses.

The procedure is stipulated for a large part in the acts, but not completely. Just as in France some of the elements appear to be missing. This is due to the fact that the police act upon internal guidelines, that are not part of the published acts and the documents for the larger public. More specifically, code D (Home Office, 2010) which is a part of the six Codes for police officers, indicates how police officers must handle the identification of an unknown individual.

The legislator, to a certain extent, has described the procedure. A lot of emphasis is put on the consent of the concerned individual[31], which should be given before carrying out any step of the DNA analysis. In many cases, this consent cannot be retracted[32]. However, the law foresees many exceptions to the requirement of a preliminary written consent.

[30] (French) Art., 706-56, I, par. 4 CPP.
[31] (UK) Art. 63 PACE.
[32] (UK) Art. 63 A PACE.

According to the law, any kind of police officer can sample genetic material[33]. Prior to that, however, the concerned individual has to be informed that the biological sample, and all the information coming forth from that sample, will be subject of a comparison to other samples or information coming from these other samples. Furthermore they have to be informed of the fact that their sample and the information coming from it can, in accordance to the law, be recorded and kept.[34]
Code D also foresees some guidelines regarding removal of clothing, and which information should be written down in a report and kept.

The police officer can also invite the concerned individual to present him or herself to the police station for sampling, in the case of a defendant or a convict for whom a sample has yet to be taken or whose sample was not of sufficient quality[35]. The police officer can send out this invitation within one month after the accusatory hearing, the conviction or the day that he or she was informed of the fact that the sample was not of sufficient quality. There has to be a time frame of 7 days for the concerned individual to present him- or herself in the police station. If he or she fails to do so, he/she can be arrested at any time[36].

Neither Code D, nor PACE mentions who is authorised to carry out the scientific laboratory work. Taking into account the history of the scientific police in England, and how close they are to the police in general, it is evident that they would take this job upon themselves.

None of the official documents that are accessible to the public mention either if and/or when the concerned individual is informed about the results of the analysis, or the possibility of a counter expertise. However, both are presumed to be present in the practical application and carrying out of DNA testing.

Table 3: Comparison of procedural provisions

	Belgium	**The Netherlands**	**France**	**England**
Procedure in law?	Yes	Yes	Partially	Partially
Police or Justice?	Justice	Justice	Mainly Police	Police
Sampling by?	Police/doctor	Police/nurse or doctor in case of force	Police	Police
Comparison by?	Accredited lab	Accredited lab	Accredited lab/judicial expert	Labs (FSS)
Counter expertise foreseen by law?	Yes	No	Yes	No

[33] (UK) Art. 63 (9ZA) PACE.
[34] (UK) Art. 6.8 Code D.
[35] (UK) Art. 63A(4) PACE.
[36] (UK) Art. 63A(7) PACE.

4.3.4 Comparison of the respective DNA databases

What databases exist in each country and what information they contain was determined: DNA profiles of collected trace evidence, suspects, convicted offenders etc. The offenses that lead to an inclusion in the database in the case of convictions were then analysed, as well as how long all of these profiles are recorded in their respective databases.

4.3.4.1 *The Netherlands*

There are four different databases containing DNA profiles in the Netherlands.
Firstly the *DNA-databank voor strafzaken* (Criminal Cases DNA database). According to the law this aims to prevent, detect, prosecute and punish criminal acts and to identify human remains. The director of the *Nederlands Forensisch Instituut (*Dutch Forensic Institute – NFI) handles the management of this database. It contains DNA profiles of identified and non-identified individuals. More specifically they are profiles established from collected trace evidence, convicted offenders, suspects, identified and unidentified crime victims, persons who are suspected as missing as a result of a crime and ex-convicted offenders who gave their DNA profile on a voluntary basis. The database contains complete and partial profiles, as well as mixed profiles.

The DNA databases of the Caribbean Netherlands, Aruba, Curacao and Saint-Martin are also managed by the NFI and all collected in the *DNA-databank voor andere Koninkrijksdelen* (database 'other parts of the Kingdom'). These profiles are not systematically compared to the Dutch database, but such comparison is possible in the case of an interregional request.

Furthermore the Netherlands have a Missing Persons database, in which DNA profiles of missing persons are recorded, as well as those of their blood relatives. As such it is the aim of the government to be able to identify human remains based on a reference profile of the missing person or of the blood relatives (upward or downwardly connected). The database contains profiles of the perished unidentified missing persons, objects that belong to them and are prone to contain their DNA and relatives of the missing person. There is a direct match in case of a match with a reference profile or a match between two unidentified profiles, and an indirect match when there is a match with the profile of a relative.

Lastly, the NFI manages the *Databank Intervenanten* (Elimination Database). This database collects all profiles of those who, because of their professional activities, often come in contact with traces or profiles (either directly or indirectly). These profiles can belong to police officers, laboratory personnel, cleaning staff, etc. The goal is to fight contamination of the profiles, which also leads to a more efficient way of leading investigations. The database was established in 2002. In Chapter 4.4 of this report we go further into the establishment of such a database in Belgium.

There is no list of offenses that exclusively lead to an inclusion in the database Criminal Cases. Article 2, par 1 of the Law on DNA analysis for convicted offenders states that as soon as a person is convicted for an offence that is described in article 67, par 1 of the Code of Criminal Procedure, this person is to be included in the database. This means that a person is to be included as soon as he or she is convicted for an offense for which the minimum penalty by law is an imprisonment of minimum 4 years. The Dutch system of determining how long a certain profile is to be recorded and kept is rather intricate and is best summarised as follows:

Table 4: Comparison of conservation periods

CATEGORY	Statutes
Trace evidence	12/20/80 y depending on possible punishment respectively <6j., >6j. or no statute of limitation
Suspect	20 of 30 y depending on possible punishment respectively <6j., >6j. or respectively 12/20 after death.
Previous suspect	12/20/80 y depending on possible punishment respectively <6j., >6j. or no statute of limitation. Minor: 6/10/20 y respectively.
Convicted offender 4-6y	20 y OR 12 y after death.
Convicted offender 6-20y	30 y OR 20 y after death.
Convicted offender 20-40y	50 y OR 20 y after death.
Convicted offender more than 40y or for life	80 y OR 20 y after death.
Ex convicted offenders	20 y OR after request for removal
Deceased victims and missing persons	12/20/80 y depending on possible punishment respectively <6j., >6j. or no statute of limitation.

4.3.4.2 ***France***

The database in France is called the *Fichier National Automatisé des Empreintes Génétiques* (FNAEG). It contains the DNA profiles of the trace evidence found at crime scenes, as well as the DNA profiles of the individuals that were convicted for an offense that is enumerated on the list of offenses leading to inclusion[37]. It also contains the DNA profiles of the persons against whom serious indications of guilt exist, upon request of the Prosecutor of the Republic or of the investigating judge[38].

The French legislator differentiates between two different classifications of 'suspects'. For the highest classification of suspect, the profile can be included in the FNAEG. For the lower classification of suspect[39], the DNA profile is compared only once to the profiles in the FNAEG. If there is no positive match after this one-time comparison, the profile is not to be recorded or kept.

Furthermore, the FNAEG contains the profiles of unidentified human remains and missing persons[40], as well as the blood relatives of these missing persons.

France has a system of exhaustive enumeration of offenses for which a conviction or another criminal procedural measure leads to an inclusion in the FNAEG. This list was originally rather short, but largely expanded due to the *Loi sur la sécurité intérieure* (Law on Homeland Security) of 18 March 2003.

The French legislator foresees a time frame of 40 years during which the DNA profile and all information that belongs with it is kept. For all profiles, with exception of those belonging to convicted offenders, this delay starts the day of the request to be included in the FNAEG. For the convicted offenders, this day starts the day of the conviction itself.[41]

The profiles of the suspects (the highest classification – those whose profiles are included in the database) are normally not kept any longer than 25 years. It is however possible for a case to end in an acquittal based on the fact that the person is suffering from a mental disturbance. In that case the RP notifies the manager of the database, and the profile is kept for 40 years starting the day of the request for inclusion.

The profiles of non-identified bodies are kept until the manager of the database is notified by the RP that there has been a positive identification.

[37] (French) Art. 706-54, par. 1 CPP.
[38] (French) Art. 706-54, par. 2 CPP.
[39] (French) Art. 706-54, par. 3 CPP.
[40] (French) Art. 706-54, par. 4 CPP.
[41] (French) Art. R53-14, par. 1 CPP.

The profiles of missing persons and of their blood relatives are deleted as soon as the manager of the database has been notified of the fact that the person has been found. The relatives of course retain the right to request the deletion of their profile before that time, and the RP and manager have to oblige by this request.

4.3.4.3 *England*

The English DNA database, better known as the National DNA Database (NDNAD), was established in 1995 had has since then become one of the largest DNA databases in the world. It contains the DNA profiles of individuals (identified and non-identified) and of collected crime scene trace evidence. It thus contains two types of profiles: individuals and crimes.
The DNA profiles belonging to the individuals are those of persons who have been arrested or convicted for a crime. The crime profiles are traces that the investigators have found at crime scenes.

There are two other DNA databases in the UK, which were originally embedded in the NDNAD, but are now stand-alone databases: the Missing Persons DNA Database (MPDD) and the Vulnerable Persons DNA Database (VPDD).
Persons who are included in these two databases first have to give their explicit consent to compare their DNA profile to other profiles in this database. It is because of this specific reason that these databases now stand alone.
The MPDD contains the DNA profiles of missing persons, based on samples taken from their personal effects, their blood relatives and non-identified human remains. This allows investigators to potentially identify missing persons and bring peace to their family members.
The VPDD is completely voluntary. The persons who apply to be included in this database feel they are at greater risk of becoming the victim of certain acts of violence, such as honour killings. If the person is then missing, they already dispose of their DNA profile that they can connect to non-identified human remains or to traces that they have found at crime scenes, which can also help investigators solve their case (Home Office, 2012).

The English legislator differentiates between 'recordable' and 'notifiable' offences. Recordable offences are those where the police officers are obliged to enter a file in their national computerised platform, the Police National Computer. In case of a notifiable offence, the police do not have to do this.
An arrest or conviction for one of these recordable offenses leads to inclusion in the NDNAD. Most of the offenses, however, are considered as recordable offences. Even the offence of purchasing or renting a crossbow or part of a crossbow by a person under the age of seventeen (Crossbows Act) can lead to an inclusion.

The time delays during which the DNA profiles are recorded and kept in the UK has often been the subject of discussion. The rules hereof changed greatly through the 2001 amendment of the Criminal Justice and Police Act. The new regulation foresaw retention of the DNA profiles indefinitely, regardless of acquittal, voluntary participation or dragnet participation. This met with a lot of protest and the matter was presented to the ECtHR in 2008 via the case of S. & Marper v. UK[42]. The decision of the European Court forced the hand of the legislator to amend their retention delays, and to bring them to their present form in 2018.

Different retention delays are now applicable, depending on the age of the concerned person and the gravity of the crime for which the person was arrested.

If the concerned individual is an adult over the age of 18, who was arrested but not convicted, the retention delay is 6 years. For a minor in the same circumstances the period is between 3 and 6 years (Krimsky & Simoncelli, 2011). These periods can be prolonged with a new period if the concerned individual is once again arrested for another offense. In that case the new delay starts the day of the new arrest.

As soon as the DNA profile has been established, the biological material is destroyed and at the latest 6 months after the sampling of the biological material[43].

For those who have been convicted, there is no retention delay since the profiles are kept indefinitely.

Table 5: Comparison of databases

	Databases?	**Crimes?**	**Retention delays**
Belgium	Criminalistics Convicted Offenders Missing Persons (?) Elimination Database (See 4.4)	Limitative list of crimes	30 years
The Netherlands	DB Criminal Cases DB other parts of Kingdom DB Missing Persons Elimination Database	Offenses punishable by >4y.	12-80 years
France	FNAEG	Limitative list of crimes	40 years
England	NDNAD: convicted offenders and anyone arrested for *'recordable offence'* + traces MPDD VPDD	*'any recordable offence'*	3-6 years arrested minors 6 years arrested adults convicted offenders: indefinitely

[42] ECtHR 4 December 2008*, S. & Marper.vs.United Kingdom*, Appl. nrs. 30562/04 and 30566/04.
[43] (UK) Art. 64ZA PACE.

4.3.5 Comparison of quality guarantees

The Dutch legislator originally stated that all DNA analyses would be carried out by the NFI laboratory[44]. If this were not possible, the analysis would only be entrusted to a laboratory that was accredited by the Council of Accreditation based on the general criteria mentioned in ISO 17025.

In France as well, accredited laboratories that comply with the requirements of ISO 17025 can carry out DNA analyses. DNA research can also be performed by persons who are on the list of judiciary experts. The requirements concern the safety and precaution of the management (Van den Heuvel, 2005)

In England the Custodian of the Forensic Science Service Ltd. (FSS) determines the standards for the sampling of genetic materials. He also overlooks the development and procedural standards for the analysis of this genetic material (Home Office, 2006).

Table 6: Comparison of quality guarantees

	Accreditation?	**Where?**
Belgium	Yes	Accredited laboratory according to ISO 17025
The Netherlands	Yes	NFI/ Accredited laboratory according to ISO 17025
France	Yes	Judiciary expert/ Accredited laboratory according to ISO 17025
England	Yes	Scientific police under scientific supervision of the *Custodian* of the *Forensic Science Service Ltd.*

4.3.6 Comparison of responses to selected human rights issues

There are a few elements of DNA analysis in criminal cases that risk being an infringement on some fundamental human rights. We have briefly discussed this above in the criminal policy section. We will here subject them to a comparison with our neighbouring countries in order to discover if and how they have met this risk.
We first studied the possibility of coercion in case the concerned individual refuses to give his or her DNA. Do all countries know this possibility or are there alternatives?
We then examined the deletion of DNA profiles from the databases, more specifically if there is a possibility to request this deletion or not. In short, is the Marper judgment respected?

[44] (Dutch) Art. 7 MR DNA-onderzoek in strafzaken.

We then studied which segments of the human DNA, according to the Belgian legislator, are allowed to be analysed for a DNA comparison, if other countries use the same system, and what this means for the protection of the right to privacy.

4.3.6.1 *Coercion*

Coercion entails cases when the authorities are confronted with an individual who refuses to give a DNA sample, based on his right to the integrity of his body. Given the enormous hurdle this refusal could mean for investigations, legislators have solved this potential issue in different ways.

In the Dutch articles 151b Code of Criminal Procedure and 195d CCP the possibility of physical coercion is only allowed in case of a comparative DNA analysis. The law states that this is only possible when this is ordered by either an officer of justice or by the judge commissioner and only when the individual concerned is a suspect of a crime that is punishable by 4 years of imprisonment and against whom serious indications of guilt have been found. If this person thus refuses to give his written consent, the law foresees the possibility of force. The Dutch legislator prefers the sampling of a buccal swab and it should be performed by a doctor or a nurse. Article 5 of the Ministerial Regulation of DNA analysis confirms the possibility of coercion in case the convicted offender refuses to give his DNA sample.

France provides the possibility of coercion for those who have been convicted or against whom other penalising measures have been taken for a crime that is mentioned in the limitative list of crimes and which is penalised by imprisonment of 10 years or more. If at that moment there is a written order of the Prosecutor of the Republic, the sampling can occur even if the concerned individual refuses[45].
In all other cases the French legislator did not opt for the possibility of coercion, but rather to penalise the refusal to provide a DNA sample[46]. There are three different penalties provided for in article 706-54 II of the CCP. The first one states that the mere refusal is punishable by one year of imprisonment and a fine of €15,000. This is also the case for mere suspects, in short anyone. This penalty is augmented when dealing with an individual who has been convicted of a crime. In that case the refusal is punishable by 2 years of imprisonment and a €30,000 fine. The last category is for those who (attempt to) replace their DNA by that of a third party. In that case the crime of refusal is punishable by 3 years of imprisonment and a €45,000 fine. The legislator states that this punishment is added to other potentially inflicted punishments and that they accumulate and cannot be counted into the punishment of the other potentially committed offenses.

[45] (French) Art. 706-56, I., par. 5 CPP.
[46] (French) Art. 706-56, II., par. 1 CPP.

The English legislator principally requests the written consent of every individual of whom the authorities want to sample the DNA. There are a lot of exceptions in the law, however, that are all summed up in article 63 of PACE and in Code D. There are seven categories in total, which are described hereunder:

- A person is arrested for a recordable offence and no sampling has been taken yet or the sample did not suffice to establish a DNA profile
- A person is detained by the police under the order of the justice department and a police officer of certain authority orders the sampling since he can reasonably consider this person to be a suspect in the case for which the sampling is ordered and the DNA profile will confirm or not that he is the donor of the DNA found for this crime.
- A person is arrested for a recordable offense and then released, but a sample has not been taken yet or the sampling was insufficient.
- A person is charged with a recordable offense but there has not been any sampling yet or the sample is insufficient.
- A person has been convicted or has undergone other penalising measures but there has been no sampling yet or the sampling had proven insufficient.
- A person is detained after being acquitted based on the fact that he could not be accountable for this actions because of a psychological impediment.
- A person has been convicted abroad for a crime that, under English law, would count as a recordable offence and there has been no sampling yet or the sampling has been insufficient, plus it has been ordered by a police officer.

Table 7: Comparison of Coercion Possibilities

	Coercion?
Belgium	Yes Offense for which the maximum penalty is 5y of imprisonment or more + direct tie with the establishment of the facts
The Netherlands	Yes Suspect of a crime punishable by 4y of imprisonment or more + serious indications of guilt
France	Yes Convicted for a crime punishable by 10y of imprisonment or more plus an order by the Prosecutor of the Republic No Punishably by 1-3y imprisonment and fines of 15.000 – 45.000 EUR
England	Yes 7 categories of PACE

4.3.6.2 *Elimination of a DNA Profile*

Certain legislation foresaw the possibility of a person for whom the proceedings have been discontinued or who has been acquitted of the crime he was charged with, to request the deletion of his or her profile from the DNA database. These rules have been inspired by the S. & Marper v. UK decision of the European Court of Human Rights[47].

The Marper case concerned the government's retention of the fingerprints, samples and DNA profiles after the criminal procedure against someone has ended. This happened either following an acquittal (in the case of S.) or the discontinuation of the proceedings (in the case of Marper). Once the criminal proceedings had ended, both requested their fingerprints, DNA samples and DNA profiles to be deleted, without any success however. Since the English government did not want to meet their request and they had exhausted all national possibilities to fight this decision, they turned to the ECtHR.

The Court stated that, seeing the amount of personal information is contained in DNA, the retention of it in itself is an infringement of the right to protection of privacy. The possibility of forming conclusions based on DNA regarding ethnic origin made its retention even more sensitive and increased the risks for one's personal life. It did however also state that its retention did have a base in national law. At the same time, section 64 of the PACE Act was not very clear as to the regulation regarding the recording and the use of these personal data. The Court also accepted that the retention of fingerprints and DNA information had a legitimate purpose; the discovery and prevention of crime. In answering the question whether the unlimited retention of the data was necessary in a democratic society, the Court examined the law and customs of the other European Member States. These showed that the retention of the data should be proportionate to the aim for which they were retained and that it should be limited in time.

The Court stated that England, Wales and Northern Ireland appeared to be the only jurisdictions in the Council of Europe that indefinitely retained fingerprints and DNA material, regardless of the age of the concerned person or the nature of the crime. It was thus shocked by the non-discriminatory power of the retention of the data in England and Wales; it did not regard the nature of the suspected offender, the fact that it was not limited in time and that there were limited possibilities for the concerned individual to request the deletion of their information. It concluded there was an infringement of article 8 ECtHR.

The Dutch legislator provides that if there has been an acquittal or a discontinuation of the proceedings, the DNA profile of the concerned individual must be deleted from the database. However, it does not mention any possibility for the person involved to request the deletion of these personal data himself. This is clear from the jurisprudence, where the concerned individual was not deleted from the database and after a positive match in another case, this

[47] ECtHR 4 December 2008*, S. & Marper.vs.United Kingdom*, Appl. nrs. 30562/04 and 30566/04.

person stated that the evidence was fruit of a poison tree since his DNA should have been removed from the database[48].

In France the legislator has foreseen such possibility and embedded it in article 706-54 and R53-13-1 CCP. This request should be addressed to the Prosecutor of the Republic in written form.

Since the Marper judgment concerned the English government and England had for a long period of time kept profiles for an unlimited period of time, it was a hot topic. After the judgment, the Protection of Freedoms Act demanded that the data of innocent people had to be deleted from the NDNAD. This was primarily done automatically, but the concerned individuals do retain the right to request the deletion.

Table 8: Comparison of Marper Compliance

	Belgium	The Netherlands	France	England
Possibility to request deletion provided for by law?	Yes	No	Yes	Yes

4.3.6.3 ***DNA segments susceptible to analysis***

The Belgian legislator has determined that a profile can only be established from so-called 'non-coding' DNA. This term was used in the nineties, when the first draft of the Belgian DNA Act was prepared, and it refers to DNA loci that were not thought to contain any personal information. Since then, science has evolved. It evolves much faster than legislation does, and exponentially so in the 21st century. Today it is established that there is no such thing a 'non-coding' DNA; all DNA contains some personal information of the individual to whom it belongs. As such, there is no clear division between coding and non-coding DNA.

The Netherlands perform phenotyping, and as such it does get certain information from coding DNA, more specifically the DNA markers that give information on the colour of the skin, the eyes and hair colour and the gender.
France specifically foresees comparison based solely on non-coding markers, but it does allow determining the gender of the DNA donor. However, since the evolution towards phenotyping is occurring in France, this should change in order to make phenotyping legitimate. The English authorities are not limited in which markers they can analyse in order to come to a positive identification.

[48] (Dutch) 's Hertogenbosch 20 July 2009, nr. 20-000861-08.

Table 9: Comparison of Analysis-susceptible DNA markers

	Belgium	The Netherlands	France	England
Limited markers?	Yes non-coding	Yes markers regarding gender, hair colour, eye colour and skin colour.	Yes non-coding +gender	No

4.3.7 Summary of the legal and policy research

In this chapter different aspects of legal and policy frameworks were analysed across four countries: Belgium, the Netherlands, France and England. It is no surprise that England has the most far-reaching measures concerning DNA analysis in criminal cases, since it is the birthplace of this forensic tool. The Netherlands take a second place, incorporating novel technologies and expanding the application field of DNA in criminal cases. Belgium finds itself between the Netherlands and France: our legislator is cautious, which is to his merit. This allows us to wait and analyse potential problems our neighbours encounter when adopting new legislation, so that we can do better ourselves.

This has been clear in the new legislator proposals in the past years: a missing persons database has been established for example, as well as the foundations for the database containing the profiles of the Crime Scene Workers. It is through comparison, analysis and forthcoming conclusions that we can establish those databases in an informed fashion.

4.4 THE RELATION BETWEEN DNA AND CRIME SCENE WORKERS

4.4.1 Problem of contamination

The evolution of knowledge, in particular advances in analytical techniques, make it possible to obtain a DNA profile from increasingly small traces (of the order of a few cells) (Lapointe et al., 2015). This means that the probability of finding the DNA of a crime scene worker coming to the scene (first police officer intervener, ambulance, medical examiner, ...) is increased (Fonneløp, Johannessen, Egeland, & Gill, 2016). The interest to fight against such contaminations is therefore proven. Several studies (Basset & Castella, 2018; Lapointe et al., 2015) point to various consequences that contaminations may have on investigations such as errors of investigation, unresolved cases, significant costs of DNA analysis, and lack of public confidence in justice. During the trial, contaminations may also be seen as a problem in the quality of the work of the crime scene workers to the point of altering the value of evidence. These are all elements that plead for the establishment of an Elimination database.

4.4.2 New legal framework

On 17 May 2017, the law on the establishment of a crime scene workers DNA database (hereafter 'NGDB INV') was promulgated in our country.[49]
The main objective of this law is to detect contaminations so that they do not alter the investigation and to make sure that the crime scene workers are not unjustly linked to forensic evidence. From a legal point of view, this objective is therefore twofold since it is presented both to allow justice in general to be effective and to remove the crime scene workers from any link with a criminal investigation. This is the new section 5quinquies of the DNA Act, which sets out the essential characteristics of the crime scene worker database. The federal prosecutor may order the taking of a DNA sample from a crime scene worker. Once analysed, the crime scene worker's DNA profile will be sent to the NICC, responsible for managing the NGDB, where it will be registered in the NGDB INV and systematically compared to the 'Missing Persons' and 'Criminalistics' database profiles to establish direct or indirect contamination. The DNA profiles of the crime scene workers are clearly distinguished from the other profiles since they are recorded under a DNA code number with the mention 'INV'. If a positive link is established, it will be registered. For deletion of data, the profiles are erased by order of the public prosecutor, either automatically or at the request of the intervener when the DNA profile is no longer useful. The maximum amount of time that the DNA profile is stored in the NDDB INV is 50 years. These provisions are not yet in force given the many questions that the implementation of such a database still poses. A working group within the FPS Justice is currently responsible for drafting the law enforcement provisions.

4.4.3 Methodology

To meet the two research objectives, namely, identifying the implementation pathways for the elimination DNA database and collecting crime scene workers perceptions on this subject, three different methods of collecting separate empirical material were used.

Firstly, an analysis of the international scientific literature in this field was carried out in order to study the various researches that have already been done on the subject. Through this research, various approaches to an elimination DNA database were highlighted. It is worth noting that DNA databases in general are very present in the global landscape. Our focus, however, was on research that evoked an elimination DNA database and related issues.

Secondly, through a comparative law analysis, the objective was to highlight the different possible implementations of such a database To do this, the idea was to focus on England and

[49] (Belgian) Act 7 November 2011.

the Netherlands. These are indeed two countries geographically close to Belgium. The Netherlands is interesting to study since the preparatory work of the Belgian law clearly states the inspiration of the Dutch model, which, moreover, gives a large place to DNA. This country is also interesting since it has gradually implemented this DNA database on a voluntary basis. With regard to England, although the legal system is quite different, a protocol (Forensic Science Regulator, 2014) has been established on this subject. It is interesting to understand the mechanisms adopted, and to perceive the differences between these different legislations compared to Belgium. In this country, the protocol is not yet fully implemented. However, it is nonetheless interesting since it is very precise in terms of procedure.

Thirdly, interviews with various crime scene workers were conducted in order to collect their statements on such a database. Among the 33 people interviewed, police officers working for the local and federal police (investigators and operators of technical and scientific police laboratories), firefighters and ambulance attendants, experts in DNA analysis laboratories, magistrates of the Public prosecutors, investigating judges and forensic and emergency doctors were selected. The choice of these categories of interviewees was based on the list that the working group had previously established (GT BD INV, 2017). The interviews were transcribed and analysed using thematic analysis techniques (Paillé & Mucchielli, 2012) on which some liberties were taken by focusing on predefined themes that were raised during the study of the law. In these interviews, the propensity of crime scene workers to be for or against such a DNA data bank was not studied, since regardless of their opinion, the crime scene workers systematically proposed a different implementation of the elimination DNA database than what is currently provided in the Belgian law.

4.4.4 Results

Some thoughts that reflect the difficulties faced by those charged with the implementation of this new NGDB INV are being presented below:

I. The notion of control is inherent in the establishment of such a DNA database in two different forms. First, a new form of control of the quality of the work of the crime scene workers is introduced by this device. The law provides that when a match is established, the positive link between the trace and the crime scene worker is recorded. The recording of all the contaminations established makes it possible to identify when a crime scene worker contaminates a lot of DNA traces. However, the law does not specify anything about the pursuit of such a purpose and the decisions that could be made with respect to such a crime scene worker.

   Then we can also mention the notion of social control. By being indexed in a DNA database, a crime scene worker will be more easily unmasked if he is involved in the commission of a crime for which the DNA was analysed. The law thus creates a new special category of population on which there is now greater control (in the same way as a person registered because of his conviction). It is clear that this remains purely hypothetical since the law of 2017 does not specify in any way what decision must result in a correspondence between a trace profile and a profile of a crime scene worker. Two hypotheses are possible:

1. Either such a correspondence automatically implies the exclusion of that trace on the assumption that it is necessarily a contamination. This first scenario would tend to make an Elimination Database a source of 'criminal immunity' (Lapointe et al., 2015). However, there is no reason to claim that being a crime scene worker allows one to be immune from prosecution.
2. Or such correspondence may lead to the questioning of the crime scene worker. But in what capacity do we need to submit this category of population to a stricter social control?

It is therefore clear that if the solution must necessarily be in the middle between these two ends (the BNDG INV cannot provoke either the stigmatization of the speakers or their immunity), any form of control should be legally framed in order to avoid abuse in the matter. In the protocol of the elimination database in England (Forensic Science Regulator, 2014), a survey is carried out when a match is established between a crime scene worker and a trace. It can be considered as a way to protect the crime scene worker from stigmatization or 'criminal immunity' since the causes of the contamination will be demonstrated as objectively as possible and put on the record. It is remarkable that these essential choices (which investigation? Who decides? According to which procedure?) have not yet been the subject of any kind of political debate to date in our country.

II. In Belgium, as elsewhere (Amankwaa & McCartney, 2018; Basset & Castella, 2018), the declared objective of such a DNA database is to exclude contaminations given the harmful consequences they have on the investigation. However, according to some early research results of this project, the enthusiasm of crime scene workers to have their profile recorded is not unanimous. This seems to reveal either the fear of hidden objectives towards crime scene workers (e.g., as mentioned, a control of the quality of their work, or an increased social control), or a lack of information by the crime scene worker on the subject. Does this at least reveal a lack of precision in formulating the purpose of this legislation?

III. The categories of workers confronted with DNA traces can be very numerous. The working group drew up a list of crime scene workers in Belgium[50] on the basis of criteria which essentially relate to the possibility of contact between the crime scene worker and a DNA trace. This seems to be insufficient since, in addition to the front-line workers and the staff of the trace analysis laboratories, this also applies to support personnel, funeral staff and some health professionals, for example. It is therefore useful to clarify the established criteria. Given the fact that the number of crime scene workers involved can

[50] GT BD INV, « Compte-rendu de la réunion du 31-03-2017 », 31 March 2017.

be quite high, a criterion related to the frequency of contact that could contaminate DNA traces could make the approach more realistic. This seems all the more necessary as the human and financial cost can be significant. In order to be concretely implemented, this DNA database must therefore be evaluated in terms of both feasibility and effectiveness.

IV. Belgian law provides that the federal prosecutor may order a DNA sample from the crime scene workers concerned. However, it does not provide for anything in the event of a refusal to levy a crime scene worker. One option might be that this DNA sampling is an inherent part of the work contract of the crime scene worker whose function involves regular contact with the DNA traces (Forensic Science Regulator, 2014; Scudder & Hamer, 2006). However, what about the crime scene workers already in office? In this regard, another form of possible Elimination Database would be more of a voluntary participation of crime scene workers in the collection of their DNA (Lapointe et al., 2015), which would obviously not guarantee the identification of any contamination.

V. On the question of the retention period of the data, the DNA Act provides for an automatic deletion after a maximum duration of 50 years, without foreseeing a minimum duration. In England, the Forensic Science Regulator (Forensic Science Regulator, 2014) proposed a protocol in which the durations would be calculated according to the end of exercise of the function as well as the type of function of the speaker. The data would then be archived for 30 years. This obviously requires more monitoring and control of data than automatic deletion.

VI. A very present concern when discussing genetic data is the protection of privacy. It is thus a question here of questioning the coherence of the measures adopted in a concern of privacy with the possible options aiming at the concrete implementation of such a database. In Belgium, the 2017 DNA law seems to ensure the protection of privacy by entrusting the management of personal data records of concerned crime scene workers to the national DNA unit under the responsibility of the Federal Prosecutor. In addition, as with other NDDBs, coded management is planned to avoid profile identification outside the federal prosecutor. However, it does not specify what control over the protection of such data should be established in this management mode. Moreover, some research shows that, on the one hand, practitioners are afraid of being stigmatised as a result of what their DNA is likely to reveal about them (Lapointe et al., 2015), but that the adoption of a sufficiently precise law could counteract any form of abuse in the use of DNA profiles (Scudder & Hamer, 2006).

VII. DNA law does not provide for international exchange on the DNA Elimination Database. However, if we consider that the target crime scene workers categories include, for example, the manufacturing personnel of the sampling media, this international exchange may be essential for the identification of contamination.[51] Furthermore, in a context of terrorism or drug trafficking, cross-border crime should be taken into account (Scudder & Hamer, 2006) which could eventually require the creation of an international Elimination Database given the nature of the investigations. It is surprising that this has not been considered at all.

4.4.5 Conclusion

The addition of an NGDB INV by the law of 17 May 2017 in the landscape of identification by DNA analysis certainly shares a laudable political intention, that of improving the quality and the relevance of the DNA results used in the criminal investigation. From an initiative from the parliament, this law rushed into the adoption of this tool to fight against contamination with a lack of maturity. The nature and importance of the seven reflections mentioned briefly in this first commentary show that there are many difficulties before the concrete implementation of this new DNA database. It is a safe bet that the work of our current research shows that a modification of the law itself is essential to overcome the obstacles identified.

4.5 FORENSIC DNA IN THE CRIMINAL INVESTIGATION

4.5.1 Data and methods

To understand how DNA is used in a criminal investigation on a case level, a qualitative research design was used combining a multiple case study and interviews. This part of the research wanted to find an answer to the following research questions:

RQ 1: How does the selection process of DNA work in a criminal investigation?
RQ 2: What factors influence this selection process?
RQ 3: How does DNA analysis contribute to the criminal investigation?
RQ 4: How can this contribution be increased?

Since there is now a general database containing all the information needed to follow a trace from the moment it was collected until it reaches the DNA database the choice was made to conduct a case study where the physical file is was used and read from beginning to end. To conduct this multiple case study, cases were selected based upon the database of the scientific police (LIS). This choice was made because most of the time they are the ones who investigate a crime scene and also, they keep their interventions systematically structured in a database. However sometimes a local police unit collects traces without the help of the scientific police

[51] A very plausible situation, as demonstrated by the famous "Phantom von Heilbronn" case, which kept investigators looking for 16 years in an investigation of 40 traces of contamination of sampling media by an employee of the company manufacturing it: cf. http://www.spiegel.de/panorama/justiz/polizistenmord-phantom-von-heilbronn-existiert-moeglicherweise- gar-nicht-a-615507.html; https://www.stern.de/panorama/stern-crime/polizistenmord-von-heilbronn-raetsel- um - phantom - geloest - 3424112.html.

and those interventions are not systematically registered in a database. We have thus excluded those cases from this study.
This database is however not constructed to do scientific research. It is a tool the scientific police use to register their interventions. It includes cases where traces are collected and those where none are collected. This database contains administrative information as well as a description of the collected traces, the forensic tests that were conducted by the scientific police, the storage of the objects taken as evidence and the automatic construction of documents (e.g., the police report of the intervention).

The LIS database contains one main module divided into different sub modules. The main module contains administrative information like the case number, the judicial district, the date of the intervention of the scientific police, etc. The second module is the 'trace module' where all the collected traces are registered by type of trace (D for DNA, X for micro traces, O for objects, ...) and in the third module all the objects taken as evidence are registered (e.g., the collected objects).

Although there is a national manual on how to fill out the database a lot of difference can be found between the judicial districts and even within one scientific police department. This posed a problem when selecting all the cases with a DNA trace. Some traces where not listed in the database as a DNA trace but as an object for DNA analysis. For the selection of the cases for the case study both types of DNA traces were needed.

When first obtaining a list of cases the list was divided by sub module. We therefore had all the information available but could only manually connect the administrative information with the collected traces per case. Because the list contained over 100,000 cases this was not possible. So a program was written by the scientific police to obtain all the information by case and not by module.

Secondly the DNA database was used to check if the cases that were treated by the scientific police reached the national database. This was necessary since we wanted to study both cases that completed the whole process and cases that dropped out somewhere along the DNA process.

Cases were selected in three judicial districts and for two types of crime.
In each region (Flanders, Wallonia and Brussels) a district was selected. The three districts are similar in size and crime rate in general and on the level of the scientific police. The choice to select a district in each region was made based on the internships that showed differences between the different regions, the analysis of the LIS database and the analysis of the DNA database. There are, for example, more DNA profiles in the DNA database from the Flemish district in comparison to Brussels and Wallonia. The three selected districts are: Antwerp, Brussels and Liège.

For the types of crime a serious crime was selected, on the one hand assuming that all resources will be used to solve this type of crime and identify the perpetrator and therefore use DNA traces (Ribaux et al., 2010). On the other hand a high-volume crime is selected assuming that the choice for a certain type of evidence depends on available resources and practical considerations (Ribaux et al., 2010). Murder and manslaughter were selected as the serious crime and burglary as the high-volume crime. Within their category those crimes are most often handled by the scientific police and they are in the top five of crimes where DNA profiles are stored in the database.

Cases where selected until saturation resulting in 48 cases in the three judicial districts and for the two types of crime.

Table 10: Studied cases by judicial district and type of crime

	Burglary	Murder/Manslaughter
Antwerp	8	6
Brussels	8	5
Liège	13	8
Total	29	19

The cases were first statistically analysed with the SPSS software to get an overall view of what was represented in it. After that a qualitative analysis was conducted.

In a third phase, interviews were completed with magistrates and investigative judges to better understand the results of the case study. A targeted sample was selected since the goal was to further explore the studied cases (Mortelmans, 2010). In each district magistrates at the office of the public prosecutor were contacted: one specialised in burglary cases and one specialised in murder and manslaughter cases. In addition, two investigative judges were selected in each district without making a distinction in specialisation since they handled both types of crime. In Brussels only one of the several contacted investigative judges was willing to cooperate. The same applied for the magistrates in Liège, where only one magistrate of the public prosecutor's office responded to the call. In total (in addition to the exploratory interviews) 10 interviews were conducted. The interviews were transcribed and analysed using Nvivo software.

4.5.2 Results

Results are discussed below for each phase in the DNA process: from the collection of the traces, the decision to analyse traces, the analysis of a DNA trace and the arrival of the profiles in the DNA database. The different methods used will be integrated in the discussion of the results.

1) Collected DNA traces

Only a brief description is given of the traces that were collected in the cases studied since the focus of this study was not the collection of the traces but what is done with the collected traces and how they are used during the criminal investigation.

In all the cases studied, 505 DNA traces where gathered by the scientific police.
Most traces, 95.8%, were collected at the crime scene. Those can be traces at and around the crime scene but also traces found on a victim or suspect (e.g., on the hands of a suspect). Only 4.2% of all collected traces are reference traces, mostly from suspects but also from victims and in one case even from medical staff who entered the crime scene.

In the burglary cases, 135 traces were collected with an average of 4.7 traces in each case mostly traces in stolen cars, followed by traces in houses or companies. In this last category most of the collected traces were objects (62%) like tools that were used to open a door or a window, or bottles and cans. In a vehicle, 80% of the collected traces were so-called swabs on different places like the steering wheel, door, etc.

Micro traces (3%), clothes (5.2%) and blood traces (2.2%) are seldom collected. No reference sample was collected in any case.

In murder and manslaughter cases a lot more traces where collected: 370 with an average of 19.5 traces in each case. Most traces are collected in murder cases (N = 83), manslaughter cases (N = 108 with an average of 27 traces per case) or attempted manslaughter cases (N = 161 with an average of 16.1 traces per case).

It was mostly clothes (30%) and blood traces (28.4%) that were collected. Clothes of a victim or suspects are automatically collected. Swabs from all kinds of substances or objects are often collected (19.5%). In the murder and manslaughter cases 21 reference samples were taken. They were mostly taken from a suspect (71.4%), followed by a victim (19%) and twice from the medical staff (9.5%).

This analysis shows that more traces are collected at a murder/manslaughter crime scene than at a burglary crime scene. It is important to mention that the amount of traces is influenced by the effort the police invest in a case. The policy in a certain police department or judicial district, the amount of people and resources available, the experience of the crime scene worker, etc. define whether or not a crime scene is investigated and which traces are collected. In other words, the analysed cases have already gone through a selection process and the results have to be seen in this light. During the internships it became clear that the main idea is to collect as many traces as possible. However when, for example, there are ten blood traces and it is clear they are all from the same person, not all ten are collected. Also some districts have a certain policy to investigate every burglary case while others only studied certain burglary cases where there was a greater chance of finding a trace.

Most of the traces are collected at the crime scene itself and reference samples are seldom taken and even never in the burglary cases. This is quite remarkable since everyone leaves their DNA and many of the burglary cases included a stolen vehicle that was examined by the scientific police. The origin of the collected traces in those vehicles is therefore never certain and can be from the victim, the owner of the car. Apparently there is a certain assumption that collected traces are from the perpetrators but this will not always the case. Since there is almost never comparison between the traces found and the victim's DNA it is possible that profiles of victims end up in the database.

2) *Analysis of the DNA traces*

When the traces are collected the public prosecutor or the investigative judge has to decide whether or not to analyse a trace and therefore use in his investigation. The do however get advice from the scientific police who fills out a table in which they asses the quality of a trace.

From the 505 collected traces only 132 traces were analysed (26.1%). From all the traces found at the crime scene (N = 484) 114 traces were analysed (23.6%). Only one of the reference samples from suspects did not get analysed because the autopsy showed that the victim died naturally. All the collected samples from victims were analysed. The samples from the medical staff did not get analysed because the analyses of the knife that might have been contaminated by them showed there was no contamination.

Table 11: Amount of collected traces against amount of requests to analyse a trace per type of trace

	Collected	**Request to analyse**
Traces at the crime scene	484	114
Reference sample suspect	15	14
Reference sample victim	4	4
Reference sample crime scene worker	2	0
Total	505	132

Based on the case study and the interviews, several factors that influence the decision to analyse a trace were identified. All those factors influence each other, nevertheless an attempt is made to give an overview of the different factors separately.

a. *DNA Policy*

The case study showed differences among the districts studied. In Antwerp traces were more often analysed and elsewhere traces were less often analysed, especially in Brussels. The interviews showed that each district has a certain policy within the office of the public prosecutor. This policy determines if a crime will be prosecuted or not. The analysis of DNA traces is therefore connected to this policy. If a case is not being prosecuted, all the interviewed magistrates said they would analyse fewer or even no DNA traces.

In Antwerp the policy is even very specific for DNA traces. When a DNA trace has a high chance of obtaining a DNA profile and it is collected in a priority case, the analysis regularly will be requested. Both the types of crime studied are considered priority cases, but burglaries of vehicles are not a priority.

In Brussels on the other hand the influx of cases is very high. Because of this, not every case can be prosecuted. Although there is a policy, magistrates mention that it really depends on the case and its context. It is up to the magistrate to ask himself the question: is this case going to be prosecuted? If not, DNA traces will not be analysed. Crimes like murder and manslaughter are priority crimes. Burglary crimes are priority if there is a certain phenomenon in the district or if there is a connection to other crimes. The impact on society and on the victim is also taken into account.

The policy in Liège is also less specific than in Antwerp. The global policy of the office of the public prosecutor must be followed, but the gravity of the crime and the context matter as well. As in Brussels, murder and manslaughter cases are never filed away but burglary cases may be for cases where vehicles are stolen from the garage of a house (*"vols garages"*)

These policies explain the differences in the case study. For Burglary there was only one case in Antwerp with no request for an analysis: a burglary in a vehicle. Also in Liège, in only one case there was no request. It was a priority case: a burglary in a house where the car was stolen, but the car was found 9 months after the crime. It was therefore not certain if other people had used or entered the car after the perpetrator which might mean that the collected traces were not from the perpetrator. In Brussel four cases had no request for analysis. Three where regular house burglaries and the fourth was a burglary with a vehicle being stolen. But according to their policy these are only treated if the impact is big enough and that is up to the handling magistrate to decide.

According to the respondents, murder and manslaughter are almost always priority cases. However there are files where DNA is not analysed. They are all attempts at murder or manslaughter where DNA could not play an important role. One of the cases, for example, was one where the only traces collected were blood traces from the victim and there was no suspect. Analysing these traces would therefore not solve the case. In two other files the victim did not

want to press charges against the suspect or did not respond to the invitation to be heard by the police. Here not only the policy is important but also the human impact. As one magistrate explained: "*We also look at the human impact: what is the impact on the victim? On that basis we decide which resources we use*."
Apparently at the level of the public prosecutor or investigative judge there is a question about using resources and budget. But when it comes to collecting traces this is less important and the idea is to collect as many traces as possible. So why bother to collect all those traces when they are not used during the investigation?

Thus, policy gives some guidelines but it is not the only factor that plays a role in the decision to analyse a collected DNA trace. It is also the context of the crime and the information available that will guide this decision.

b. Context of the crime

i. Type of crime

The case study showed a difference in the treatment of DNA traces depending on the type of crime. In burglary cases fewer traces were collected but more traces were analysed than in cases of murder and manslaughter. The statistical analysis confirms this determination with a significant difference between traces in burglary cases against traces in murder/manslaughter cases, χ^2 (1, n = 484) = 104.034, p = .000. More traces in the study's burglary cases were in terms of percentages relatively analysed (55.6%) than in murder/manslaughter cases (11.2%).

So there is less selectivity in burglary cases than in cases of murder and manslaughter. This is not directly linked to the type of crime but it more linked to the presence of a suspect. In the following discussion, it is shown that having a suspect or not influences the decision to analyse a trace or not.

ii. Presence of a suspect

In the burglary cases there was never a known suspect at the start of the investigation. Both magistrates of the public prosecutor's office and investigative judges indicate that they analyse all the useful traces if the crime is serious enough or is a priority case and if there is no suspect. They said they analyse most of the good traces (Category 1 or 2) because they are never sure if there are looking for just one perpetrator. By analysing as many as possible they hope to obtain different profiles that result in a DNA match in the DNA database that can identify the perpetrator.

Looking at the murder and manslaughter cases the same finding was made and confirmed with the statistical analysis that showed significant differences between cases with or without a suspect, χ^2 (1, n = 349) = 14.476, p = .000. There are relatively fewer traces analysed when there is a suspect (9.3%) than when there is no suspect (33.3%). The case study showed that traces selected to analyse are more specific when there is a suspect. Only those traces that are needed to build a strong case are being selected. For example in one of the attempted murder cases the victim claimed to have been raped and the suspect denied it. By analysing a DNA trace (from sperm in the victim's vagina) the profile of the suspect was found.

The respondents further explained the difference between the presence or non-presence of a suspect by saying it not only depends on his presence but also on what he is saying, how he was handling himself, the context of the crime and the other types of proof that are available. As in the example above, they said that DNA traces are analysed when the suspect has denied involvement in the case or when stating there were other people involved.

iii. Presence of other evidence

Not only the presence of a suspect is important but also the presence of other evidence. On the one hand there are classic methods like testimony from witnesses, surveillance footage, investigation of phone data or when the suspect is caught in the act. On the other hand you have forensics. The case study showed that first the classic methods were exploited before forensic methods were used. Neighbours were interrogated, surveillance footage and data from stolen phones were examined. In the burglary cases those classic methods led only once to a suspect but he was not registered in the National register and could therefore not be found. Even in the murder and manslaughter cases with or without a suspect the classic methods were first exploited. The only forensic method exploited directly after traces were collected were fingerprints since the police makes this comparison directly. However this never resulted in an identification of a suspect in the cases studied.

Since the classic methods did not lead to a suspect in the studied burglary cases, except for one, it was decided to analyse the collected DNA traces. The cases where no traces were analysed were not priority cases or the DNA might have been contaminated, as in the vehicle found 9 months after the crime was committed. In the murder and manslaughter cases, classic methods were also exploited even when there was a suspect. But when they were not sufficient, DNA traces were analysed. Which traces and how many traces depended on the presence of a suspect and the information they wanted to obtain.

Those findings were confirmed by the magistrates and investigative judges during the interviews. They all say that DNA analysis is only used if it can contribute to the case by bringing new information or if it confirms weak evidence. But classic methods will always be exploited first because DNA is seen as an expensive investigation tool.

They say that if a suspect can be clearly identified with surveillance footage they see DNA as redundant. The same can be said for fingerprints or earprints because like DNA they are unique. However a witness testimony is seen as less reliable. If that is the only thing they have and there are DNA traces available to analyse they will be analysed. If the testimony comes with other evidence, like clear surveillance footage, then it will do.

The difference in whether or not to analyse DNA if other evidence is available depends on the gravity of the crime. Smaller crimes like burglary will hold up with the classic methods, but more serious crimes, especially when they are brought before the assize court, have to be well built, according to the respondents. Therefore their preference in this kind of cases goes to objective evidence like DNA.

iv. Table 14

When collecting traces, the scientific police fills in a table to qualify the DNA potential of the collected piece of evidence. There are 6 possible categories: (1) cellular material of the possible perpetrator (e.g., blood, saliva, hair), (2) carrier of cellular material of the possible perpetrator (e.g., clothes, mask, cigarettes, food or drinks), (3) possible manipulation by the perpetrator, (4) possible manipulation by others (1 person, >1 person), (5) initially not for DNA analysis, (6) bad condition (dirty, rain, heat, moisture,…). They can put a '+' if the category is applicable, a '- 'if not and a '?' when there is doubt.

In the case study it became clear that this table is not always filled in correctly. For example 'Category 1' stands for human cells (e.g., blood, saliva, sperm, …) from the perpetrator. But almost all blood traces, even if it is certain that they are from the victim, are categorised as a 'Category 1' trace. For example in one of the attempted manslaughter cases a man was attacked on the street with a knife. He walked to the police station leaving a trail of blood on the street. The scientific police collected swabs from those traces and gave them a Category 1. Although they did put a '?' in the table stating there was doubt if the traces belonged to the perpetrator, in the original statement and on the surveillance footage it is clear that the blood trail came from the victim. There is also a difference between police units and even within police units in in the way this table is filled. For example in two burglary cases in Brussels a vehicle was found and examined by the scientific police. In both vehicles traces were collected on the steering wheel. In the first case the trace was a Category 1 and in the second case a Category 3. It was the same scientific police unit that collected the cases but different officers. So within the same unit different methods are used to fill in the table. The same situation occurred in the file in Liège. In Antwerp another table is used but there are also differences between cases for the same type of trace in a vehicle. In none of the vehicle thefts was there information available about the perpetrator that could explain the difference in this categorization.

During the interviews the respondents were asked about their perception of this table. The table is seen as scientifically correct and correctly filled out. However every respondent said the table is just a tool to check if what they want to analyse is useful. They always look at the police report first and already make a certain choice about which traces will be useful to analyse or not. In a second phase they look at the table to make sure the chosen traces are qualitatively good enough to analyse. So when a blood trace is from a victim it will not be analysed, they said. When they are asked to read a case and explain what they would do, their responses are confirmed. In the example case, a victim was attacked with a knife and got hurt. She does not think the perpetrator got hurt. The knife was left on the floor with blood traces on it. Blood traces were also found on the floor and walls. None of the respondents would analyse the blood traces on the floor and walls because they think they are from the victim. However some of them would analyse the blood on the knife since it is possible that the perpetrator hurt himself by using it. None of the respondents spontaneously said they would request a reference trace from the victim to compare it to the blood. When it was brought to their attention, they did agree that a reference trace from the victim would be useful in this case but admitted they do not automatically think about it in so-called more minor cases.

One of the magistrates said it was up to the police to inform them about the fact that traces might come from the perpetrator. In this case the blood samples were all listed as Category 1 traces. By reading the police report, however, it was clear that they did not belong to the perpetrator. Other respondents also mention they contact the police or the DNA-laboratory if something is not clear.

c. *Communication between the actors*

In deciding which traces to analyse or not, the respondents say they rely on the advice of the police given in the police report, the quality table and in direct contacts they have. In the case study there was no trace of contact between the public prosecutor's office or the investigative judge and a police unit, a forensic advisor or the DNA laboratory.

During the interviews they did however mention that there is contact, especially in the major cases like the murder or manslaughter. Apparently there is no habit to formalise this contact into a written document. For example in one of the cases studied it was known that a forensics advisor was involved to give advice on how to proceed in the investigation. However no written document could be found of this advice.

A comment often made during the interviews was: *"I'm not a scientist so I do rely on the scientific information that is given me through different channels."* In smaller cases like burglaries in houses or vehicle thefts they say they rely on the information available in the file, such as the police report where the police often suggest which traces can be useful, and the table of the scientific police.
After asking for clarification, the police report they were referring to appears not to be the reports of the scientific police but the reports from the police officer responsible for the investigation. They often interpret the report of the scientific police and prepare a new report for the magistrates with their suggestion or else they inform them during a meeting or over the phone. There is little direct contact with the unit of the scientific police, except in serious murder or manslaughter cases where they organise meetings with all the actors involved. However these people are seen as the experts who know best which traces should be collected and analysed. According to one of the magistrates, traces collected by non-scientific police units are more often contaminated and therefore not useful. They prefer the scientific police to do the collection. They do not however realise that errors in filling out the table occur.

Many factors influence the decision to analyse a trace. Once this decision is made the trace is sent to the DNA laboratory where it will be analysed and may or may not result in a profile.

3) Result of the DNA analysis

For the analysis of this phase of the DNA process only the traces found at the crime scene were taken into consideration since all the reference samples analysed resulted in a DNA profile.

Out of all the collected traces (N = 484) 114 traces were analysed. This resulted in a DNA profile in 65.8% of the analyses (N = 75). A profile can be a single profile coming from one person, a mixed profile coming from two people, a mixed profile coming from more than two people and all the profiles that were established but which are too weak to compare to others.

Table 12: Amount of obtained profiles per type of profile

	Frequency	Percentage
Single profile	35	46.7%
Mixed profile 2p	22	29.3%
Mixed profile +2p	11	14.7%
Profile too weak	7	9.3%
TOTAL	75	100%

The case study showed that different results were obtained depending on the type of traces analysed. For example blood traces seemed to almost always end up in a single profile while swabs often seemed to end up in a mixed profile from two or more people. To verify this idea, a quantitative analyses was made of all the analysed traces and their results.

A difference was made between micro-traces, clothes, objects, swabs and blood swabs. Micro-traces are all kind of traces collected using taping (e.g., on a car seat or on a victim). Clothes are all sorts of clothing collected from the victim, the suspect or clothes found at the crime scene. Objects can be bottles, tools, knifes, guns, etc. found at the crime scene. Swabs are collected on objects (e.g., on the steering wheel of a car or on a bottle) or can be from an unknown substance. Blood swabs are all the swabs taken from blood traces at the crime scene on an object or clothes.

The quantitative analysis shows that the analysed micro-traces never resulted in a DNA profile. All analysed clothes resulted in a profile, but 22.2% of them were too weak for comparison to other profiles and were therefore not useful for the investigation.
Objects most often resulted in a mixed profile of two people (23.1%) but almost 31% of the analysed object did not result in a profile. It is remarkable that most of the analysed swabs did not result in a DNA profile. This can be explained by the fact that most of the swabs were collected within a vehicle where swabs are habitually taken on certain places in the vehicle without knowing for certain if the perpetrator even touched these places or without knowing if

the perpetrator was for example wearing gloves. Since there is often no information on the suspect, the scientific police are guessing, which explains the low result in profiles. Several magistrates say they have the feeling the result is often negative.

Table 13: Type of profile per type of trace

	Micro traces (N = 3)	Clothes (N = 9)	Objects (N = 26)	Swabs (N = 61)	Blood swabs (N = 15)
Single profile	0%	11.1%	19.2%	28.1%	86.7%
Mixed profile 2p	0%	44.4%	23.1%	17.5%	13.3%
Mixed profile +2p	0%	22.2%	15.4%	8.8%	0%
Profile too weak	0%	22.2%	11.5%	3.5%	0%
No profile	100%	0%	30.8%	42.1%	0%

4) The DNA database

The profiles obtained are automatically sent to the DNA database if they meet certain technical conditions. The case study showed that less than half the profiles from traces collected at the crime scene (44%) were sent to the DNA database. The first reason for this drop-out is the fact that the profiles that were too weak for comparison or a mixed profile from too many people (e.g., 4 people) do not fulfil technical conditions and are therefore not sent to the database. Secondly the case study showed that there is also a significant drop out attributable to the fact that within one file the same profile has been obtained from multiple traces. For example in one case for attempted manslaughter, a knife, pants and a sweater were analysed. The knife resulted in a mixed profile with man X in it; the pants and sweater resulted in the same mixed profile. Only the profile of the knife was sent to the database.

Out of all the profiles sent to the database (N = 33), 18.2% resulted in a match (N = 6). This concerns 5 cases of burglary. Profiles that were sent to the database concerning a murder of manslaughter case never resulted in a match. The first case had two trace profiles resulting in a match, each with traces in other cases. The first trace matched with two Belgian cases: a burglary and a violent theft. The second trace matched with a Belgian case of burglary and a French case of burglary. So based on this match, 5 cases can be connected due to DNA analysis. However the identity of the perpetrators remains unknown.

The second file also showed match with two Belgian cases and with a German case. But in this case, the match with the German case was a match with a reference profile from a suspect so the perpetrator could be identified. The third file again showed a match with two Belgian cases but only with profiles of other traces. The fourth case did not obtain a match the moment the trace was sent to the database. Only 18 months after the crime was committed was a match was found, meaning that the perpetrator had committed a new crime, once again leaving his DNA. The same situation happened in the fourth case where a match was obtained with another burglary and a violent theft two years after the crime was committed.

The obtained matches resulted in the identification of a perpetrator only once. The other matches gave useful information on a strategic level but less so on an operational level.

4.5.3 Conclusion

Most traces are collected at the crime scene. Reference traces, especially from non-suspects, are seldom taken. However the qualitative research shows that there are wide differences in practices and that some of the obtained profiles come from the victim instead of the suspect. Traces are analysed assuming they are from a suspect without sufficiently wondering. This is especially the case in high-volume crimes. The decision to analyse a trace is influenced by many factors. Some districts have a policy, others do not. Consequently, it often comes down to the magistrate to make the decision on his own without guidelines or a policy at a national level. The information needed to make a decision (e.g., reports from the police or DNA-laboratory) is not always available in the file and communication between the actors is limited in the day-to-day cases. Since the match rate for unknown offenders in the DNA database is limited it can be wondered whether an adjustment of the procedure and elaboration of policy could lead to an improvement of the use of DNA in the criminal investigation.

4.6 FORENSIC DNA AND OFFENDERS

Regarding the research section on relations between DNA and convicted persons, an analysis of the international literature was conducted to identify specific issues to be taken into account. It appears that the existing studies relate on the one hand to countries in which DNA has been used for a long time (Austria) and on the other hand to countries where the use of DNA is very recent (Portugal). It also appears that the public targeted by the survey is sometimes the general public and sometimes only those who are detained. These elements tend to show that it is not easy to compare these results for Belgium, the DNA device has been in place for a long time but we aim to interview only convicted persons whose DNA has been registered in virtue of this conviction.

At this stage, the results of this component are still too partial to be presented. Significant obstacles were encountered in implementing interviews with sentenced persons. It refers to persons (both men and women) with a final conviction, whose crimes are covered by the list in Article 5 of the DNA Act, excluding internees and minors for reasons of authorization and reliability of the conversation. The Public Ministry unfortunately gave a negative advice which did not allow us to rely on their help to identify the people concerned and to get in touch with them. Other ways (bar associations, Houses of Justice) were also sought to find respondents to our interviews. To date, we have been able to meet only 8 people convicted, 2 through lawyers, 6 through the Houses of Justice responsible for the follow-up of convicts, which remains very little despite the many steps taken. This number of interviews is still too low to base valid results (the objective is to have a minimum of 30 interviews).

The interviews focused on two aspects: On the one hand the question of the perception by the convicted person (How did he/she experience being the subject of a DNA sample collection? What does it mean to know that his/her DNA profile is preserved?). On the other hand, the central question concerned the information available to convicts about what DNA registration is, such as: 1. What are the sources of information for convicts? 2. What knowledge do they have about what is actually registered as DNA for criminal cases?

The NCIC has decided to pursue this aspect of the research beyond the realization of the Be-Gen project. The interviews will therefore be conducted in 2019 in other possible ways (e.g., observation in prison) and a specific report will be produced end of 2019.

4.7 FORENSIC DNA IN SCIENTIFIC RESEARCH

The central research question in this part is how DNA databases can contribute to the study of unknown offenders and their criminal behaviour. As mentioned above, this research question is further operationalised by evaluating the specific characteristic weakness (i.e., the selectivity of the source) and the specific characteristic strength (i.e., the ability to study [links between] unknown offenders and their offending behaviour) of DNA databases as a source of criminological research.

4.7.1 Selectivity

First, by exploring legislation, literature and information on the actors involved, actors and factors were identified which have an impact on the selectivity of the DNA database used in this study (i.e., the Belgian National Genetic Database) (RQ 8). Subsequently, these findings were tested in an empirical study in which the validity of this DNA database was evaluated by comparing the spatial distribution of unsolved crimes in the DNA data with police-recorded crime data from the Belgian General Police Database (RQ 9).[52]

RQ 8: Which actors and factors have an impact on the selectivity of DNA databases?

[52] All statistical analyses were performed using the R software environment (R Core Team, 2018).

DNA profiles are stored in a database based on the assumption that offenders will commit other crimes in the future, so that links can be made between offenders/suspects and traces, between different traces or between different offenders/suspects, eventually leading to identification. Two central questions arise: (1) Which profiles are included in the database? In other words, which (offenders of which) crimes are included in the database? (2) How long are the profiles stored in the database?

The content of the database at a given moment, in terms of type and number of profiles, is thus determined, on the one hand, by the profiles that are stored in the database and, on the other hand, by the profiles that are removed from the database. Moreover, every actor within the criminal justice chain has an impact on the content of the database, whether consciously or not.

Profiles stored in the criminalistics database

The criminalistics database[53] contains (unidentified) DNA profiles collected at crime scenes. In contrast to the convicted offenders database, the legislator has not drawn up an exhaustive list of crimes that can be included in the criminalistics database. In principle, every crime type is eligible. In practice, however, it includes crimes that have a specific crime scene and where it is likely that there has been physical contact between the offender and the victim, or with the crime scene, making it possible that the offender has left DNA behind.

A number of actors are significant when storing DNA profiles of traces in the criminalistics database. First of all, there is the offender. Not all offenders leave their DNA, for example in the form of skin cells, hair or saliva, at the scene of a crime (Develtere, 2014). Offenders are often aware of the traces they may leave behind during their offence. This 'forensic awareness' ensures, for example, that offenders wear gloves to limit DNA traces (Beauregard & Bouchard, 2010).

The offence must, of course, be reported to, or discovered by, the police. In view of the large 'dark number' of unreported crimes, this is perhaps the most important factor in determining which profiles are stored in this database (Biderman & Reiss, 1967). Moreover, the Laboratory of the Technical and Scientific Police (LTWP) or another police service collect these traces not just for the simple reason that a crime is known about and is likely to contain DNA traces. Four levels of knowledge play a role in the decision of the police to visit a crime scene and to collect traces: the strategic, the criminal, the immediate and the physical environment (Ribaux et al., 2010). The strategic environment is shaped by the priorities set out in the Belgian National Security Plan, for example, as well as (limited) budgets and resources. The criminal environment is constituted by knowledge about previous similar cases or criminal phenomena such as organised crime (i.e., forensic intelligence). This knowledge is important to be able to detect all possible (relevant) traces. Knowledge about previous, similar crimes, for example, can increase the chance of finding traces, and the importance of the case can also be higher, given that the offender is possibly a multiple offender.

The immediate environment will also determine whether traces are collected. Where, when and how exactly did the crime happen? The modus operandi and the seriousness of the crime are important when assessing the immediate surroundings. For example, a first study by the medical

[53] Only the criminalistics database is discussed, as it is directly relevant to this research question.

examiner on the crime scene could provide information about whether or not the victim died a natural death. In the event of a natural death, the crime scene investigation (and thus, also, the safeguarding of possible DNA carriers) will be much more limited. Crime scene investigators are often most familiar with the physical environment of the crime scene. For example, public places such as bars are less suitable for collecting DNA traces because of the high number of DNA traces that will be present and the risk of contamination (Ribaux et al., 2010). Of course, in addition to these four levels of knowledge, the experience and training of police officers will also influence the number and type of traces collected at crime scenes.

Once the DNA traces have been collected, the authorised magistrate must mandate a certified DNA laboratory to examine them. The traces that have been collected are not all analysed by default; the magistrate often makes a selection. In addition to operational motives such as whether or not the police advise or request that they be tested (using model 14[54]), budgetary restrictions are often the decisive factor for whether certain DNA samples are analysed. DNA analyses are expensive, which means that some screening takes place. At the end of 2015 both the rates and the description of DNA research in criminal cases were determined in accordance with regulations defined by Royal Decree (Belgisch Staatsblad, 2015). At the same time, the cost of DNA analysis has considerably reduced. On average, the analysis of a trace profile now costs € 273.[55] Before the 2015 Royal decree it was twice as much. Not only has the cost fallen in recent years, it is also striking that magistrates often do not know how much an analysis costs, or greatly overestimate the cost (Stappers, 2018).

The process that recognised DNA laboratories use has three phases. The first phase investigates whether the pieces of evidence will contain sufficient DNA traces to be useful for carrying out DNA analysis. So far, it is not known whether useful DNA traces are present on the pieces of evidence. Assuming they are, the second phase involves extracting and quantifying the DNA and the creation of the DNA profile. The third and final phase consists of interpreting the DNA profile that has been obtained and drawing up an expert report.[56]

The DNA profiles are then forwarded to the NICC's DNA Index System (DIS) service. DIS is the final step before the profiles are stored in the database. The only samples stored in this database are forensically simple profiles originating from one person, or forensically mixed profiles of a maximum of two people. DIS uses the Combined DNA Index System (CODIS) developed by the US FBI to manage, store and compare DNA profiles.

The number and quality of the DNA profiles obtained can be affected at each stage by human error (Ribaux & Talbot Wright, 2014). **Figure 3** summarises this process schematically.

[54] Standard table for the selection and arrangement of trace carriers for possible DNA research, added to the Royal Decree of 2013 (COL21/2013, revised version 8 June 2017).

[55] This price includes: examination of pieces of evidence and taking samples: 30 euro (Art. 4); extraction and quantification of DNA (Art. 6): € 49; creating the genetic profile (Art. 7): €194. The price for drawing up a genetic profile of a reference sample has been €60 since the 2015 Royal Decree, which is also a decrease compared to the old rate of €430.

[56] For more information on DNA analysis, see Butler (2010).

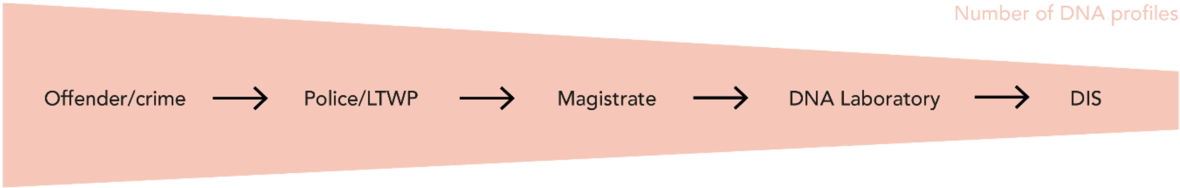

Figure 3: Selection mechanisms and actors involved, from collection to storage of forensic DNA in the NGDB

Profiles removed from the database

For ***practical and financial*** reasons it is likely that some DNA profiles will need to be removed from the database. The management of a database in which profiles are added and never deleted would be a heavy burden. In addition, an unlimited storage period would not seem to comply with the aforementioned human rights. Substantive arguments also play a role in limiting the retention period. For example, Walsh, Curran, and Buckleton (2010) state that solving old offences has a lower priority and is often more difficult than solving more recent offences. Moreover, offenders will no longer be criminally active in the course of time, whether that is because they stop committing crime, die or are taken prisoner; keeping track of their profiles will then no longer be useful. Another reason can be found in Belgian law, which limits the term for which data can be stored to thirty years for both databases[57]. This period corresponds to the statute of limitation for each crime type (the maximum period of time during which a conviction can be obtained), after which it is no longer appropriate to keep the data.

RQ 9: Are DNA databases less valid than police-recorded crime databases for the study of unsolved crimes?

What does this selectivity of the DNA database mean for the validity of the source for criminological research? Tilley and Townsley (2009, p. 375) suggested that "*of themselves, small samples are not much of a problem if the sample is representative*".

Police-recorded crime data are frequently used in scientific research, even though this source also has a high degree of selectivity (e.g., the dark number of crime). However, this research has sought to compare the validity of two data sources and does not address the validity of police data per se; hence the term "less" was included in the research question.

In comparison with police data, DNA data have (to date) only been used to a limited extent in criminological research. Nevertheless, some ground-breaking studies have made use of DNA data, for example Lammers' (2013) study on the probability of arrest and Wiles and Costello's (Costello & Wiles, 2001; Wiles & Costello, 2000) research into offender mobility. Wiles and Costello used DNA data to supplement police data in order also to study unknown offenders and their behaviour. Like other researchers making use of DNA databases, they were particularly

[57] (Belgian) Wetsontwerp houdende wijziging van het Wetboek van strafvordering en van de wet van 22 maart 1999 betreffende de identificatieprocedure via DNA-onderzoek in strafzaken.

interested in the benefits the database offered and they often did not pay sufficient attention to the validity of the data source. This research is therefore unique with respect to previous research, as the validity of the DNA database was explicitly studied.

To answer the research question above, and thus to evaluate the representativity of the DNA data in relation to the police data, the concentration and spread of crimes across the 27 different judicial districts between the two databases were compared.[58] Only unsolved crimes were studied, because the specific added value of the DNA database lies in being able to study unknown offenders and their behaviour.

As the focus of this research is not on the spatial stability/variability of crime over time (see for example Andresen, Linning, & Malleson, 2017) but on the spatial similarity between the Belgian General Police Database and the Belgian National Genetic Database, only data from one calendar year was analysed. The year 2014 was chosen for no substantive reason.
Crimes of aggravated burglary, violent theft, lethal violence and sexual offences committed in 2014 were selected from both databases. Crimes with no identified offenders were selected from the Belgian General Police Database (i.e., the 'police dataset'). Only crimes without reference profiles were selected from the NGDB so that no known offenders were involved (i.e., the 'DNA dataset'). This approach ensured that only unsolved crimes were selected from both databases and resulted in a police dataset of 181,483 crimes and a DNA dataset of 1,913 crimes, all committed by unknown offenders.

The Lorenz curve and the Gini coefficient are used to analyse the crime concentration in the judicial districts in each dataset. Both the Lorenz curve and the Gini coefficient were developed to measure inequality of income or wealth but can be applied to any distribution (Bernasco & Steenbeek, 2017), including crime concentration across judicial districts, as in this research. The Gini coefficient is derived from the Lorenz curve, which graphically presents the concentration of crime. A Gini coefficient of 0 indicates that every judicial district has the same crime level (i.e., complete equality) and a value of 1 indicates that all crime is concentrated in only one district (i.e., complete inequality) (Bernasco & Steenbeek, 2017; Eck, Lee, O, & Martinez, 2017).

The analyses show that in both the police dataset and the DNA dataset crime is concentrated in a limited number of districts. In the DNA dataset about 50% of all crimes occur in fewer than five judicial districts; in the police dataset about 50% of all crimes occur in fewer than four judicial districts (**Figure 4**). However, the rank order of crime percentages over the different judicial districts differs between both datasets. The districts with the highest number of registered crimes in the police-recorded crime data do not necessarily have the highest number of registered crimes in the DNA data (**Figure 5**). For example, only two judicial districts appear in the top five of both datasets.

[58] Until the reform of the judicial landscape in 2014, Belgium had 27 judicial districts. An increase in scale then reduced the number of districts from 27 to 12. In this research, the old structure is used.

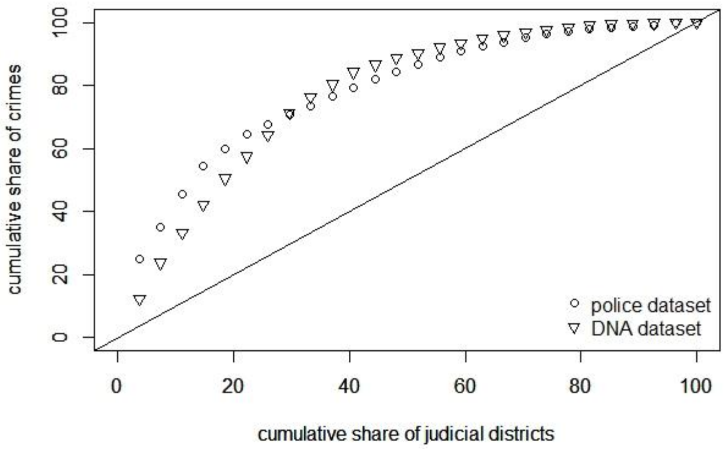

Figure 4: Lorenz curve for the police dataset and DNA dataset

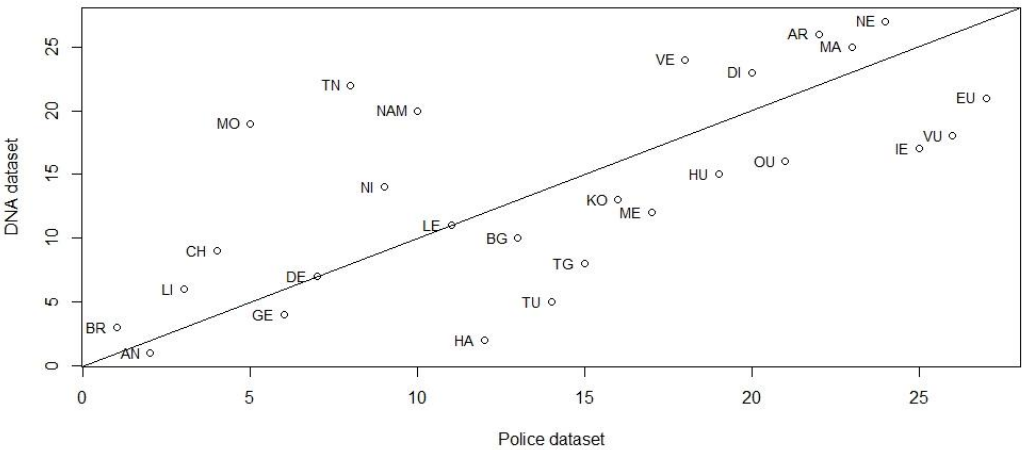

Figure 5: Rank order crime rates in 27 judicial districts in the police dataset plotted against rank order in the DNA dataset (high to low)

The Gini coefficient does not provide insight into the similarity between spatial point patterns in the police dataset and the DNA dataset — for example, whether the districts with the highest crime rates in the police dataset also have the highest crime rates in the DNA dataset. We therefore also conducted a spatial point pattern test (SPPT). The non-parametric spatial point pattern test (SPPT) was developed by Andresen (2009) specifically to test the similarity between the spatial point patterns in two datasets – a base dataset and a test dataset – within specified spatial units of analysis. In criminology, an SPPT is used to study the similarity of spatial crime levels at different spatial units (e.g., de Melo, Matias, & Andresen, 2015), over different time frames (e.g., Andresen, Linning, & Malleson, 2017), and/or between different crime types (e.g., Andresen & Linning, 2012). Several authors have also used an SPPT to evaluate spatial similarity between different data sources. Hibdon, Telep, and Groff (2016), for example, used an SPPT to study the spatial concentration and stability of drug activity in Seattle in police and emergency medical services data. Tompson, Johnson, Ashby, Perkins, and Edwards (2014) used an SPPT to study the spatial accuracy of open crime data compared with police-recorded crime data. In this study, the SPPT is used to examine spatial similarity between the crimes registered in the DNA dataset and the police dataset over the 27 judicial districts. For every judicial district, a pairwise comparison is made of the percentages of crimes in the police dataset (i.e., the base dataset), and the DNA dataset (i.e., the test dataset). Therefore, the SPPT allows a validation of the representativeness of the unsolved crimes stored in the NGDB.

A fictional example illustrates the SPPT: 35% of all crime recorded in the police dataset was committed in Antwerp. According to the DNA dataset, 12% of all crime was committed in Antwerp. The SPPT compares these two relative frequencies with each other and indicates by means of a local S-index whether the difference between the two frequencies is significant. A local S-index is calculated for every judicial district or spatial unit. These local S-indices indicate whether the point count in a specific judicial district is lower in the base dataset (S-index = -1), higher (+1) or similar (0) compared to the test dataset. A global S-index provides insight into the similarity across all spatial units. The global S-index represents the percentage of judicial districts that have a similar spatial point pattern (local S-index = 0).

Three of the four crime types studied (i.e., violent theft, lethal violence and sexual offences) show a high spatial similarity between the two databases (**Figure 6**). In only a limited number of districts there is an over-representation or under-representation of the number of unsolved crimes in the DNA database. Although the spatial pattern may be the same between the police-recorded crime data and the DNA data for violent theft, lethal violence and sexual offences, many judicial districts have a crime count of zero for these crime types in the DNA dataset. In other words, no crimes or (unknown) offenders are registered in these districts on which further analyses can be carried out. Aggravated burglary, on the contrary, exhibits a low spatial similarity. However, there is a strikingly higher proportion of crimes of this type registered in the DNA database than in the police database.

It is difficult to come to an overall conclusion regarding the spatial similarity between the two databases. The results depend on the type of crime and the judicial district level. This highlights the conscious and unconscious selection that came to light when considering the first research question. In addition to providing insight into representativeness, the test also made the different policies between districts tangible, which was not the original aim of the study. For example, the over-representation of aggravated burglary in the DNA database in the (most) Flemish districts corresponds with these districts' more active policy in investigating an aggravated burglary crime scene.

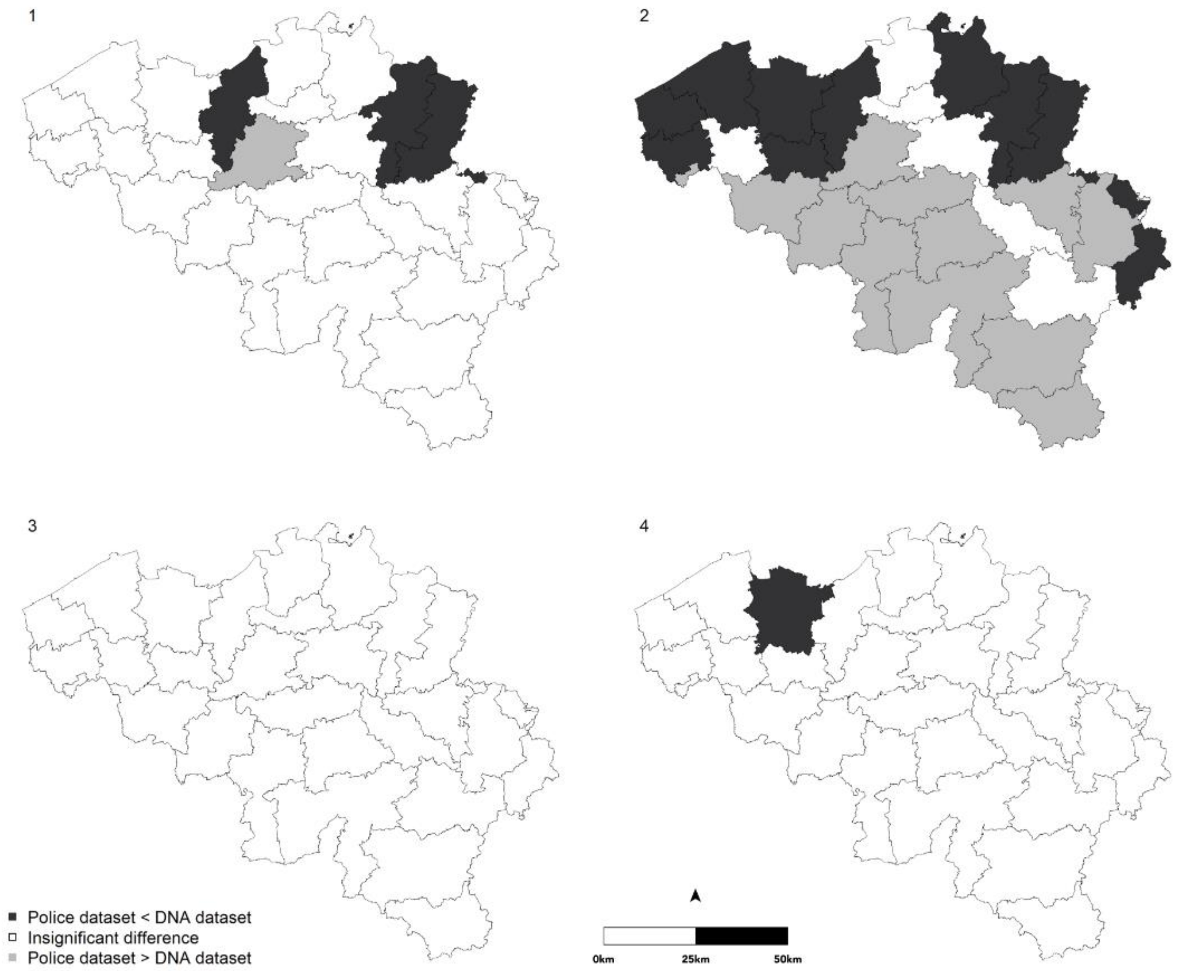

Figure 6: Local S-indices for violent theft (1), aggravated burglary (2), lethal violence (3) and sexual offences (4)

4.7.2 Networks of unknown offenders and their crimes

In this part of the report, the usability of DNA databases was assessed by focusing on the ability to study (links between) unknown offenders and their offending behaviour.

Therefore, two network analysis studies, one at the level of the crime (RQ 10) and one the level of the offender (RQ 11) were performed using an integrated dataset in which police-recorded crime data are supplemented with DNA data. In their seminal work, Wasserman and Faust (1994, p. 20) defined a social network as "*a finite set or sets of actors and the relation or relations defined on them*". These actors can be very diverse: individuals like school children or members of an activist group, but also companies, countries, websites, etc. The relations between these actors can be any type of tie that connects these actors: friendship, kinship or business transactions, for example. Translated to criminological research, the actors can be offenders linked by a co-offending relationship.

RQ 10: *To what extent does the crime picture change when unsolved crimes are included in a network analysis?*

This research question focused on the behaviour of serial co-offenders. Therefore, the prevalence and characteristics of serial co-offences obtained from the police-recorded crime data and the DNA data (i.e., known and unknown offenders) were compared with those obtained from the police-recorded crime data (i.e., known offenders) only. More precisely, the differences between the size and spatiotemporal distribution of crime networks from both datasets were evaluated.

The crime networks were obtained from six years of recorded crime data (2010 through 2015) relating to the four selected crime types from both the NGDB and the Belgian General Police Database: aggravated burglary, violent theft, lethal violence and sexual offences. Only crimes committed by one or more *unknown* offenders were selected from the NGDB.[59] The reverse selection mechanism was applied to the Belgian General Police Database: only crimes committed by one or more *known* offenders were retained. Second, only crime cases that were present in both databases were selected. Not every crime in the Belgian General Police Database is registered in the NGDB – some crime scenes are simply not inspected for DNA traces, and in other crime scenes no suitable DNA traces may be found – but every crime registered in the NGDB *is* registered in the Belgian General Police Database, with or without known offenders. Third, only crimes involving serial offenders (i.e., offenders who committed at least two crimes in the six years under study) were selected from both databases. This resulted in a police dataset of 121 crimes committed by 71 serial co-offenders and a DNA dataset of 544 crimes committed by 232 serial co-offenders. As these figures indicate, the DNA dataset contains far more crimes and offenders than the police dataset, primarily due to the low clearance rates typical of recorded crime data. Finally, both datasets were integrated into a single dataset so that those crimes only committed by co-offenders (i.e., offenders who committed at least one of their crimes in the company of another offender) could be selected. An extra selection criterion was adopted for this integrated dataset, because combining the two datasets creates an uncertainty about whether an unknown offender in the DNA dataset is the same person as a known offender from the police dataset. Therefore, networks that were composed of only two offenders of which one originates from the DNA dataset and the other from the police dataset were excluded. Thus, all remaining networks in the data definitely included crimes committed by serial co-offenders.

Three important findings emerged from this research. First, both the number and size of the networks is larger in the integrated dataset than in the police dataset alone (**Table 14**). The larger

[59] Offender profiles are stored in the NGDB using a code. The corresponding identity of the offender is managed by a third party, the National DNA Cell. As scientific researchers have no access to these data, it was not possible to check for possible matches between unknown DNA profiles and known offenders stored in the police dataset.

networks in the integrated dataset mean that more crimes were committed by serial co-offenders than one can determine only on the basis of the police-recorded crime data. Combining the two datasets allows new links to be identified between crimes from each dataset: serial offenders who are not co-offenders in the police dataset or the DNA dataset can become co-offenders when both datasets are integrated.

Table 14: Description of the three datasets under study

	Police dataset	DNA dataset	Integrated dataset
Number of nodes (crimes)	121	544	654
Number of edges	168	1,496	1,699
Number of networks	30	93	108
Mean network size in number of crimes	4.03	5.85	6.06

Second, the police dataset and the DNA dataset only have a small overlap, indicating that both contain different information. In this research, the Jaccard index is used to measure the similarity between crime networks present in the police-recorded crime data and crime networks present in an integrated dataset containing both police-recorded crime data and DNA data (**Table 15**). The minimum index is 0 (or 0%), which means that both datasets have no data points in common. The index reaches a value of 1 (or 100%) when there is perfect overlap of the two datasets (Simpson, Lyday, Hayasaka, Marsh, & Laurienti, 2013).
Although all edges from the police dataset are present in the integrated dataset, the Jaccard index is very low, with a value of 0.10, as both datasets only share 168 of the 1,699 edges in total. On the contrary, the DNA dataset and the integrated dataset have 87% of all their edges in common, indicating that both datasets are very similar.

Table 15: Jaccard similarities between edges present in the three different datasets

	Police dataset	DNA dataset	Integrated dataset
Police dataset	1.0 (168)	0.05 (85)	0.10 (168)
DNA dataset		1.0 (1,496)	0.87 (1,490)
Integrated dataset			1.0 (1,699)

Notes: Number of edges between brackets.

Third, both the spatial and temporal distributions of the networks in the integrated dataset are greater (**Table 16**). The spatial and temporal variability within the crime networks were assessed by computing normalised diversity indexes. The indexes range between 0 and 1. A value of zero indicates that there is no diversity as all crimes are committed within the same district/year. A value of one indicates that all crimes are evenly spread over the different possible districts/years (Mazerolle, Brame, Paternoster, Piquero, & Dean, 2000, pp. 1153-1154).
In the integrated dataset, the average diversity index for time is 0.49, compared with 0.44 in the police dataset. This already represents a 11.36% larger temporal spread, although the difference

is not significant ($p = 0.41$).[60] The timespan is extended from 2.23 to 2.64 years and the crimes are spread over more years (from 1.9 to 2.26 years on average) ($p = 0.08$). The proportion of networks only active in one year decreases from 33.33% in the police dataset to 27.78% in the integrated dataset. The networks from the integrated dataset are spread across more districts than the police dataset (2.6 versus 2.03) and also the mean spatial diversity index increases significantly to 0.49 ($p < 0.01$).[61]

Table 16: Temporal and spatial spread of the three datasets under study

	Police dataset	DNA dataset	Integrated dataset
Mean (median – S.D.) timespan in number of years	2.23 (2 - 1.22)	2.61 (2 - 1.37)	2.64 (2 - 1.46)
Mean (median – S.D.) unique number of years	1.9 (2 - 0.80)	2.22 (2 – 0.99)	2.26 (2 – 1.10)
Number of networks only active in one year	10 (33.33%)	26 (27.96%)	30 (27.78%)
Mean (median – S.D.) temporal d_{Norm}	0.44 (0.50 – 0.35)	0.48 (0.60 – 0.34)	0.49 (0.63 – 0.34)
Mean (median – S.D.) unique number of districts	2.03 (1 – 1.77)	2.65 (2 – 2.04)	2.6 (2 – 2.08)
Mean (median – S.D.) spatial d_{Norm}	0.37 (0 – 0.45)	0.50 (0.6 – 0.39)	0.49 (0.5 – 0.39)
Number of networks only active in one district	17 (56.67%)	29 (31.18%)	34 (31.48%)

In summary, disregarding unknown offenders means that a substantial number of crimes will be ignored, with a considerable loss of spatiotemporal variation in criminal behaviour as a result. The crime image that can be derived from the behaviour of known offenders differs from the crime image of unknown offenders. Knowing that the DNA database is selective, it is even more striking that the crime picture changes significantly when integrating DNA data with police-recorded crime data. Moreover, this analysis only concerns four offence types. There are no immediate reasons why the crime picture of some other offence types would not change in the same way if unknown offenders were taken into account.

RQ 11: To what extent does the offender profile change when unknown offenders are included in a network analysis?

The final research question of this part focused on the impact on the offender network of integrating DNA data with police-recorded crime data. This research question was approached from the perspective of missing data in network analysis. Generally, random or non-random network errors are applied to a real-world network G(V, E) by deleting a certain fraction of nodes

[60] The one-sample Wilcoxon signed rank test was significant at 0.05 level ($V = 119$).
[61] The one-sample Wilcoxon signed rank test was significant at 0.05 level ($V = 119.5$).

and/or edges. This creates a reduced network G′(V′, E′). By comparing network measures (often centrality measures) of G(V, E) with those of G′(V′, E′), the impact of missing data can be assessed (Kossinets, 2006; Smith & Moody, 2013; Smith, Moody, & Morgan, 2017; Wang, Shi, McFarland, & Leskovec, 2012).

In this research, the real-world networks consist of known offenders from the police-recorded crime data and unknown offenders from the NGDB. The dataset contains six years of recorded crime data (2010 through 2015) relating to the four selected crime types (i.e., aggravated burglary, violent theft, lethal violence and sexual offences). All known offenders involved in crimes that matched these criteria were selected from the Belgian General Police Database, resulting in a police dataset of 73,837 known offenders. The police dataset was enriched with offender data from the DNA dataset to construct the real-word dataset with both known and unknown offenders. Some precaution is needed when combining data from the Belgian General Police Database and the NGDB. The same person may be registered in both as a known offender. Profiles of known offenders (i.e., suspects or convicted offenders) are stored in the NGDB using a DNA code number. However, possible matches between known DNA profiles and known offenders stored in the police dataset could not be checked because access to the corresponding identity of the offender is prohibited for scientific research. This could lead to what Wang et al. (2012) define as false disaggregation in network data. To avoid this type of false disaggregation, only unknown offenders were selected from the NGDB.

By randomly deleting 2, 5, 10, 15, 20, 25, 30, 40, 50, 60, 70% of the nodes (i.e., known and unknown offenders) from this real-world network, eleven reduced networks were obtained. However, the network that only uses police-recorded crime data is also a reduced network compared with the real-world network as the unknown offenders are non-randomly deleted from the real-world network. As such, the network containing only police data is called the ‘real-reduced network’ with an error level of about 18% missing nodes compared to the real-world network.

The impact of random missing nodes versus non-random missing nodes is assessed by measuring the degree and betweenness centrality for each of the different error levels. The *degree* refers to the number of direct links an offender has with other offenders by committing a crime together (Freeman, 1979; Wasserman & Faust, 1994). The minimum degree is 0 (or 0%), which means that the offender committed all his crimes without any co-offender. An offender with degree 0 is called an isolate. The maximum degree is equal to the number of nodes in the network minus 1 (or 100%). Offenders with a maximum degree committed at least one crime with every single other offender in the network. The degree only takes the local position of the actor into account, as it is not concerned by how the other offenders are connected in the network (Morselli, 2009, p. 39; Wasserman & Faust, 1994). *Betweenness* centrality is the proportion of times an offender is located along the geodesics between any two other offenders. In other words: to what extent is an offender the direct link between two other offenders? Unlike degree, the quantity of contacts is not important, but the quality of the connections is. An offender with a relatively low degree may play an important ‘intermediary’ role and so be very central to the network (Scott, 2013, p. 87).

The two centrality measures are evaluated at the global (i.e., network) level, as the goal of this study is to assess whether and how the image of offender networks is different in a network that integrates police-recorded crime data and DNA data, compared to one that is based solely on police-recorded crime data.

Three important findings emerged from this missing data research. First, the real-world network with both known and unknown offenders contains more co-offending relationships compared to the network that only contains known offenders (**Table 17**). New links (i.e., edges) become visible between known and unknown offenders, and also between unknown offenders. Therefore, there may be more co-offenders than can be deduced from police-recorded crime data alone. Moreover, the real-world network contains 8,305 more components[62] (18.56%) than the real-reduced network. These components are composed of only unknown offenders.

Table 17: Characteristics of the real-world network and the real-reduced network

	Real-world network G(V,E)	Real-reduced network G′(V′,E′)
	Police data and DNA data	Police data
Nodes	89,929	73,837
Edges[63]	69,995	48,666
Number of components	53,048	44,743

Second, the higher the error level in the simulated networks, the more the network estimates are affected. For example, an error level of 40 or higher corresponds with a mean degree below one, compared to the average degree of 1.56 in the real-world network with an error level of 0. The same applies to the betweenness centrality.

Third, integrating unknown offenders from the DNA database with the police-recorded crime data on known offenders has an impact on the degree but not on the betweenness centrality of the resulting network. Randomly removing 15% of the known and unknown offenders from the real-world network results in the same degree as non-randomly removing only the unknown offenders from the real-world network (**Table 18**). On the contrary, compared with the error level in the real-reduced network, randomly removing the same percentage of known and unknown offenders from the real-world network results in much lower levels of betweenness (

Table 19). Even randomly removing only 2% of the known and unknown offenders from the real-world network results in a lower betweenness centrality than the 18% error level in the real-reduced network with only known offenders ($p = 0.01$). Known and unknown offenders have a

[62] A component consists of at least two offenders connected to each other, directly or indirectly, but the offenders within a sub-network have no links with other offenders outside the sub-network (Wasserman & Faust, 1994).

[63] The number of edges corresponds to the number of edges present in the simplified networks. Simplified networks do not contain multiple edges between two nodes. In a simplified network, only one edge between two offenders is possible, even if these offenders may have committed multiple crimes together.

different impact on betweenness centrality. In other words, known offenders may be more central nodes than unknown offenders, as far as betweenness is concerned.

Table 18: Degree of real-world network and reduced networks

Network type	Error percentage	Mean degree	Nodes	Mean edge count
Real-world network G(V,E)	0	1.56	89929	69995
Simulated-reduced networks	2	1.53	88130	67223
	5	1.48	85433	63181
	10	1.40	80936	56697
	15	1.32	76440	50584
	20	1.25	71943	44793
	25	1.17	67447	39369
	30	1.09	62950	34304
	40	0.93	53957	25206
	50	0.78	44965	17492
	60	0.62	35972	11200
	70	0.47	26979	6305
Real-reduced network G′(V′,E′)	17.89	1.32	73837	48666

Table 19: Betweenness of real-world network and reduced networks

Network type	Error percentage	Mean betweenness	Nodes	Mean edge count
Real-world network (G(V,E)	0	3715.44	89929	69995
Simulated-reduced networks	2	3368.27	88130	67238
	5	2845.52	85433	63194
	10	2029.64	80936	56702
	15	1328.99	76440	50606
	20	815.97	71943	44811
	25	464.79	67447	39403
	30	241.46	62950	34336
	40	51.83	53957	25208
	50	10.30	44965	17462
	60	2.00	35972	11219
	70	0.42	26979	6317
Real-reduced network G′(V′,E′)	17.89	3723.58	73837	48666

These research findings have implications for both theory and practice. Including the unknown offenders stored in the NGDB in the database resulted in an offender image with not only about 22% more offenders (i.e., nodes) but also about 44% more co-offending relations (i.e., edges), in comparison with a database solely based on police-recorded crime data. Therefore, the generally accepted assertion in criminology that at least half of all crime involves more than one offender (Andresen & Felson, 2010; Felson, 2003; Lantz & Ruback, 2016; Warr, 2002) and that about two-thirds of all offenders commit their crimes with others (Reiss, 1988) is probably an understatement. Furthermore, this research provides a unique view of the position these offenders may take in the whole offending network. Unknown offenders may be more peripheral nodes in the network. The question therefore arises as to whether the unknown offenders remain unidentified by the police because of their peripheral position, or is it, as Sparrow (1991, p. 256) states, just because they stay unidentified by the police that they have a more peripheral position in the network, although they may be more central in reality? This is an important nuance, as in the first case the integrated dataset would give an accurate image of the centrality of the unknown offenders, whereas in the latter case the image would be distorted. It is important to be aware of this uncertainty, because it could mean that arresting unknown offenders has a bigger impact on crime prevention than would be assumed based on their peripheral position in the network.

4.7.3 Conclusion

What do these results mean for the representativeness of DNA databases and their use in criminological research? Their use is clearly limited by the low number of crimes registered in the database, although the most frequently registered crimes in the DNA database were studied in this study. A study that only uses a DNA database will provide very little information about some crime types (e.g., lethal violence). It is important to keep this drawback in mind; but simply rejecting DNA databases as a possible data source is a bridge too far as this research showed that the added value of DNA databases lies in combining them with police databases.
Offender networks made up of both known and unknown offenders may not only be larger but may also have a different structure from networks that only include known offenders. As was the case in the network study on crime level, the network study on offender level emphasised the importance of integrating unknown offenders and their crimes in criminological research.

4.8 EFFECTIVENESS OF DNA DATABASES

When we talk about DNA databases and its applications, it is important to consider its effectiveness and added value for police, society and criminology. We define effectiveness as the degree to which an objective is achieved and thus proves the relevance of the intervention. When considering effectiveness, two more aspects need to be taken into account. First, effectiveness is always measured against a certain purpose. For example, when the purpose of the DNA database is to increase the number of identified suspects, the effectiveness can be measured by the degree to which a DNA profile matches a profile in the DNA database. Second, the content of the DNA database influences its effectiveness. Specifically, the profiles included in the DNA database will determine if the database can reach its full potential and fulfil its purpose. For example, it is not possible to calculate the arrest rate if the inclusion criteria are limited to convicted offenders. Therefore, we decided, in the light of the current project, to include a systematic review on the effectiveness of DNA databases. Our objective was to provide an overview of the most relevant studies in the international literature and make a conclusion on whether DNA databases are effective in relation to its purposes or not.

4.8.1 Methodology

A systematic review is characterised by a very transparent and structured search strategy which gives other researchers the opportunity to replicate the entire research. In the first place, twelve databases were chosen and searched using the following keywords and Boolean operators: [DNA] AND [databa*] AND [effect* or effic* or result or evaluation or impact] NOT [chem* or biolog*]. Apart from these databases, we also consulted the website of four institutions that all conduct research on the topic, namely the European Network of Forensic Science Institutes, the UK Home Office, the Belgian National Institute for Criminalistics and Criminology and the Dutch Wetenschappelijk Onderzoek- en Documentatiecentrum.

Five eligibility criteria were defined for the inclusion and exclusion of studies. First, the studies must have an empirical character, by which we mean that the authors actually measured the effectiveness. Opinion pieces, book reviews and evaluations of legislation were excluded for the systematic review. Second, the subject of the study must concern forensic DNA databases. DNA databases for other purposes, such as medicine, were excluded, as well as other forensic databases, such as the database for fingerprints. Third, for every study that was eligible according to the full text, a quality assessment was done. The study had to score at least 50% on this test in order to be eligible for inclusion. Forth, since the use of DNA as forensic evidence was first introduced in 1985 by Alec Jeffreys (Roman, Walsh, Lachman, & Yahner, 2012), we only selected articles that were published since 1985 and up to March 2018 included (when the literature search was terminated). Last, due to limitations in language proficiency, only articles in English and Dutch were eligible for inclusion.

After eliminating duplicates, the search resulted in 8871 articles of which 4515 were stored in Endnote. A first hand search was already conducted when browsing the databases, eliminating medical and biological studies. The selection procedure consisted of three stages. In the first stage, we selected articles based on their title, which resulted in 739 articles. After that, the abstracts of the selected studies were read, which resulted in 88 articles. Last, we read the full texts of these articles, resulting in 18 included studies. After scanning the bibliographies of the included studies, one more study was included for the systematic review. This study was not found in the searched databases but met the inclusion criteria of the systematic review. A summary of the 19 final included studies is provided in **Table 20** and a flow chart of the selection procedure and the applied criteria in **Figure 7**.

For every included study, we filled in a data-extraction sheet which focused on the more general details of the studies, as well as the study design and key results. Furthermore, we created a questionnaire which was thematically organised in order to compare and synthesise the findings. We preferred to conduct a synthesis of the results because the study designs and methods used differ greatly. The goal of this systematic review was to offer a comprehensive overview of the existing evidence.

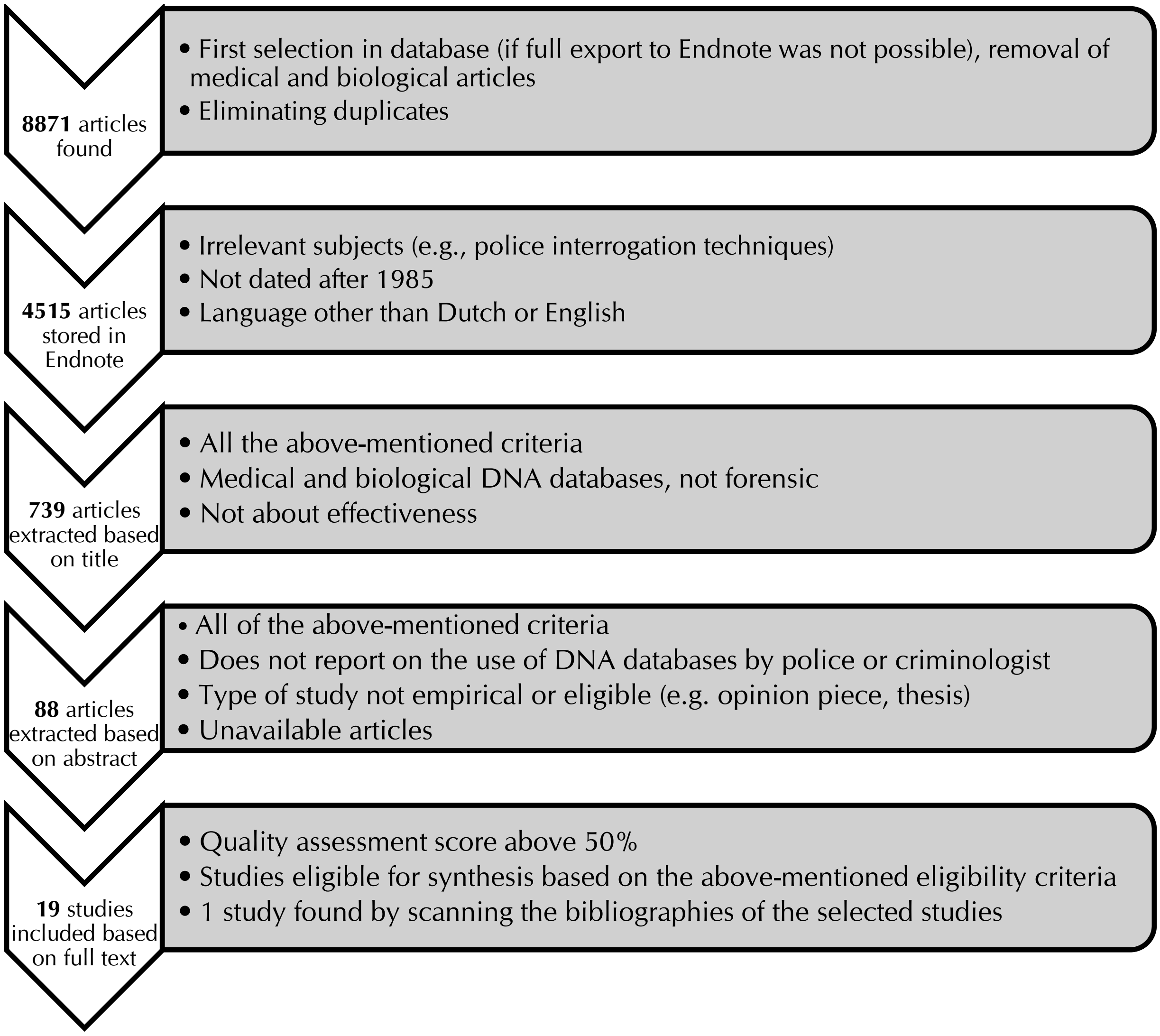

Figure 7: Flow chart of the selection procedure and the applied criteria

4.8.2 Results

The effectiveness of a DNA database is measured according to the purpose it fulfils. Based on the included studies, three purposes of forensic DNA databases were identified. The three categories of purposes are: DNA databases as a detection and clearance tool for police and prosecution (i), DNA databases as a deterrent tool (ii) and DNA databases as a scientific data source for criminologists (iii). The individual study findings are summarised in **Table 20** as well as the study design used and researched purpose. The use of DNA databases resulted in positive outcomes in almost all included studies regardless of study design and researched purpose. Some authors made more nuanced conclusions on the effectiveness of DNA databases. These results are discussed in more detail in this section of the report. In the synthesis of the included studies, references to the applicable study ID is given between squared brackets.

First, DNA databases are an effective tool for police and prosecution to detect suspects and clear crimes. More specifically, the detection and clearance effect can be evaluated by four measurements, the identification rate [6, 7, 12-14, 16], the arrest rate [14, 15], the charge and prosecution rate [6, 14] and the conviction rate [6]. When looking more closely into the findings of the studies, we can see that most studies report a positive result, although some are more nuanced when making a statement about the effectiveness of DNA databases. In order to illustrate the positive and more nuanced results, two studies are considered here in more detail. Roman, Reid, Chalfin, and Knight (2009) [14] conducted a randomised controlled trial in which they explored the added value of DNA analysis for property crimes. They randomly assigned cases to the treatment group (i.e., DNA traces were collected and analysed) and the control group (i.e., DNA traces were collected but not analysed). Their hypothesis that "*processing DNA evidence from high-volume crime scenes would result in more suspects identified and arrested*" (p. 350) was confirmed by the results. For the treatment group, a suspect was identified in 31% of the cases, which is more than twice as many cases as in the control group (12.8%). 21.9% of the treatment cases resulted in an arrest, compared to only 8.1% in the control group and there were more than twice as many treatment cases that were accepted for prosecution than control cases. Dunsmuir, Tran, and Weatherburn (2008) [6] evaluated the effect of an expanding DNA database on the charge and conviction rates. In 2001, New South Wales (Australia) began collecting and storing the DNA of all prisoners which resulted in an expansion of the DNA database. The authors examined whether an expansion of the DNA database had a positive influence on the charge and conviction rates. The study concludes that the results depend strongly on the crime type, but the expansion of the DNA database does increase its effectiveness on a broad scale. Nonetheless, regarding the conviction rates, significant negative effects were found but no explanation was given.

The second purpose of DNA databases is the deterrent effect, by which the involved authors hypothesise that the knowledge of being recorded in the DNA database deters offenders from future crimes, because the probability of detection and punishment increases. Two measurements are used to evaluate the deterrent effect of DNA databases, being the recidivism rate [1, 4, 17] and the crime rate [4, 5]. The overall results are positive, especially when looking at the recidivism rate. Bhati (2010) [1] found that there is evidence for the specific deterrent effect of DNA databases, especially for robbery and burglary. Tegner Anker, Doleac, and Landerso (2017) [17] found that for offenders who were charged after the expansion of the Danish DNA database, the probability of a new conviction decreased with 42% in the first year and the probability of recidivism reduced with 43% in the first year. They conclude that "*DNA profiling leads to significant deterrence of future crime while also increasing the likelihood of offenders being detected*". At the same time, for some crime types (i.e., violent crimes) the results showed a perverse effect in the disadvantage of a deterrent effect. Doleac (2016) [5] examined the individual and aggregate effect of DNA databases on criminal behaviour and crime rates. She found that offenders released after the expansion of the DNA database law had a 17% reduced chance (statistically significant) for a new conviction in serious violent offense cases and a 6% reduced chance (marginally significant) in serious property offense cases. The results for the aggregate effect show that the expansion of the DNA databases decreased violent crimes by 45% and property crimes by 35%, both statistically significant. A later study of the same author [6] nuanced the positive effects of DNA databases on crime rates after studying the cross-state effects of DNA database expansion. Doleac (2017) reported an increase of own-state violent and property crime rates when another state added an additional offender profile to the DNA database by which the proximity of states does have an influence on the effect size.

Third, some criminologists have already made use of forensic DNA databases to study criminal behaviour, mostly criminal career [8, 9, 18] and spatial behaviour [2, 3, 10, 11, 19]. All authors agree on the effectiveness of forensic DNA databases as a criminological data source to respond to some limitations of other data sources, such as the absence of unknown offenders in police recorded crime data. DNA databases contain information about unknown offenders which makes it possible to link different crimes and crime scenes without having an identified suspect. De Moor, Vandeviver, and Vander Beken (2018b) [3] evaluated the added value of DNA data by comparing the outcomes of the Belgian police recorded crime database and the Belgian DNA database in terms of criminal networks and the spatiotemporal distribution of the involved crimes. They found that combining the two databases showed more and larger networks of crimes and the spatiotemporal spread was larger compared to the police database alone. In their study, Lammers, Bernasco, and Elffers (2012) [9] used data from the Dutch DNA database to examine whether the seriousness of previous crimes, the amount of previous crimes and possible specialization in crime type affected the probability of arrest by comparing crime series of identified and unidentified (i.e., unknown) offenders. The results show that these characteristics do have an influence on the probability of arrest: for every extra committed crime, the probability of arrest increases with 19%, complete versatility in crime type increases the probability of arrest with 184%. Only the seriousness of the committed offenses has no significant influence on the probability of arrest. The authors concluded that DNA databases give researchers "*the opportunity to study the characteristics of crime series of offenders who were never arrested and compare these with characteristics of crime series of offenders who were arrested*" (p. 17).

Table 20: Summary of included studies

Study ID	Study	Country	Period of used data	Studied crime types	Design	Purpose and *measurement*	Findings
1	Bhati (2010)	USA	1996-2004	Robbery, burglary property-, violent- and drug-related crimes	Quasi-experimental design, comparing released offenders with DNA in the database and released offenders without DNA in the DNA database	Deterrence: *Recidivism rate*	DNA databases are an effective deterrence and detection tool
2	De Moor, Vandeviver, and Vander Beken (2018a)	Belgium	2014	Violent theft, aggravated burglary, lethal violence and sexual offenses	Quasi-experimental design, comparing the DNA database and the police recorded crime database	Criminological knowledge: *Criminal career*	DNA databases are more effective in studying the crimes committed by unidentified offenders than other criminological data sources
3	De Moor et al. (2018b)	Belgium	2014	Violent theft, aggravated burglary, lethal violence and sexual offenses	Quasi-experimental design, comparing a combined dataset with the police recorded crime database	Criminological knowledge: *Spatial behaviour*	Combining the DNA database and the police recorded crime database give a more complete view on criminal networks than the police database alone
4	Doleac (2016)	USA	2000-2010	Violent- and property crimes	Quasi-experimental design, comparing released offenders post-expansion of the DNA database and released offenders pre-expansion of the DNA database	Deterrence: *Recidivism rate*	DNA databases do have a deterrent effect on convicted offenders for violent and property crimes
5	Doleac (2017)	USA	2000-2014	All crimes	Quasi-experimental design, comparing own-state crime rates and DNA database policies and other-state crime rates and DNA database policies	Deterrence: *Crime rate*	Expanding the own-state DNA database results in increased crime rates in nearby states
6	Dunsmuir et al. (2008)	Australia	1995-2007	Assault, sexual assault, breaking and entering, robbery, motor vehicle theft and stealing from motor vehicles	Time series	Detection and clearance: *Identification, charge and prosecution, conviction rate*	DNA databases do result in more cleared cases, but also result in less convictions. The results strongly depend on the considered crime type
7	House, Cullen, Snook, and Noble (2006)	Canada	Unknown	Sexual murder and sexual assault	Descriptive design	Detection and clearance: *Identification rate*	DNA databases are not used to their full potential as they can only identify offenders who are already included in the database, so the identification rate remains low
8	Jeuniaux, Duboccage, Renard, Van Renterghem, and Vanvooren (2016)	Belgium	2014	Burglary, robbery, unknown, crime group, murder and miscellaneous	Descriptive design	Criminological knowledge: *Criminal career*	DNA databases offer more opportunities than only identifying offenders, they also offer insight in criminal networks
9	Lammers et al. (2012)	The Netherlands	2002-2009	Violent crimes, sex offenses, burglary, theft and theft of or from a car	Quasi-experimental design, comparing crime series of unidentified offenders (DNA available in DNA database) and crime series of	Criminological knowledge: *Criminal career*	DNA databases are unique data sources for criminological research when studying unidentified offenders

					identified offenders		
10	Lammers and Bernasco (2013)	The Netherlands	2002-2009	Violent crimes, sex offenses, burglary and high-volume crimes	Quasi-experimental design, comparing crime series of unidentified offenders (DNA available in DNA database) and crime series of identified offenders	Criminological knowledge: *Spatial behaviour*	DNA databases are unique data sources for criminological research when studying unidentified offenders
11	Lammers (2014)	The Netherlands	2002-2009	Violent crimes, sex offenses, burglary and high-volume crimes	Quasi-experimental design, comparing crime series of unidentified offenders (DNA available in DNA database) and crime series of identified offenders	Criminological knowledge: *Spatial behaviour*	DNA traces offer reliable links between (unidentified) offenders and crime scenes. Arrest data seem less selective than assumed, as DNA data result in the same conclusions
12	Leary and Pease (2003)	UK	2000-2001	Unknown	Descriptive design	Detection and clearance: *Identification rate*	The effectiveness of DNA databases is not necessarily linked with its size, but more with the proportion of those recently included in the database
13	Mapes, Kloosterman, and de Poot (2015)	The Netherlands	2011	Serious crimes (armed robbery, sexual assault, …) and high-volume crimes	Descriptive design	Detection and clearance: *Identification rate*	DNA databases are effective in the identification of suspects
14	Roman et al. (2009)	USA	2005-2007	Residential and commercial burglary	Experimental design, randomly assigning property crime cases to the treatment group (collecting and analysing DNA traces) and the control group (collecting, but not analysing DNA traces)	Detection and clearance: *Identification, arrest, charge and prosecution rate*	DNA databases do increase the probability of identification, arrest and prosecution in cases of property crimes
15	Schroeder (2007)	USA	1996-2003	Homicide	Quasi-experimental design, comparing homicide cases with DNA analysed and used before making an arrest and homicide cases without DNA evidence	Detection and clearance: *Arrest rate*	DNA databases do not increase the probability of clearance in homicide cases
16	Taverne, Nijboer, Abdoel, and Farooq (2013)	The Netherlands	2005-2012	High-volume crimes and serious offenses	Descriptive design	Detection and clearance: *Identification rate*	DNA databases do increase the probability of identification of an offender
17	Tegner Anker et al. (2017)	Denmark	2003-2007	Violent-, property crimes, sex offenses, other penal offenses (drugs, …) and violations of the Weapon Act	Quasi-experimental design, comparing offenders convicted after the DNA database expansion and offenders convicted before the DNA database expansion of 2005	Deterrence: *Recidivism rate*	DNA databases increase the probability of detection and have a deterrent effect on future crime
18	Townsley, Smith, and Pease (2006)	UK	2003	Violent crimes, sexual offenses, robbery, theft and drug offenses	Descriptive design	Detection and clearance: *Criminal career*	DNA databases offer an interesting data source for criminological research as they include unidentified offenders
19	Wiles and Costello (2000)	UK	1997	Volume crimes	Descriptive design	Criminological knowledge: *Spatial behaviour*	The results of DNA databases confirm the results of police recorded crime data when investigating the travel patterns of unidentified offenders

4.8.3 Conclusion

We can conclude that the majority of the included studies report positive results and thus, DNA databases are an effective tool for police, society and criminology. However, one important remark must be made: the effectiveness of DNA databases depends on the purpose it tries to fulfil and the profiles included in the database. Both aspects influence the answer to the question whether DNA databases are effective. Two examples can be given. First, the effectiveness of DNA databases does not apply to all crime types, as can be seen in the study of Dunsmuir et al. (2008) [6]. Different arguments can be given for this result, such as the fact that not all crime types generate DNA traces at a crime scene or the fact that some jurisdictions do not prioritise the extraction of DNA traces for certain crime types. As a result, we can state that there is some selectivity in the data of the DNA database, which can influence the results. Second, although criminologists prefer to work with DNA databases as a data source to study unidentified offenders, it is not always certain if the profiles included in the database are indeed that of the offender and not for example that of the victim, a witness or a police officer. A last remark concerns the future of DNA databases. What is the most effective DNA database for police, society and criminologists? Would a National DNA Database with the profiles of all citizens included be effective? Important to consider are the issues of privacy and proportionality. In order to legitimise the existence, the use and the possible expansion of DNA databases, more research on its effectiveness is recommended.

4.9 GENERAL CONCLUSIONS

Our research allows a new and multidisciplinary look on a subject (forensic DNA) in full evolution. This evaluation, which was conducted on three distinct yet coordinated levels, shows that (1) on the operational front many actors are still unfamiliar with different aspects of DNA, that the coordination between the different stages of the process is not optimal and that the practice is not identical depending on the geographical location of where the DNA is samples and analysed. On the strategic front (2) the research allows to emphasise the informational potential of DNA, its importance and the fact that it is momentarily underutilised. The added value of DNA linked to police data particularly shows that this leads to a better understanding of unknown offenders. The comparative study of the legal landscape and political discourse in the political aspect of the research (3) shows that the provisions adopted in Belgian legislation are characterised by extreme caution and restrictive solutions. The focus group discussions and analysis of the applied criminal policy confirm this conclusion. The fact that we are for example limited to working solely on so-called 'non-coding' DNA, is a considerable hurdle in implementing new technologies and applications.

In observing the technical and scientific evolutions as well as the social practices in the exploitation of forensic DNA, the triple approach on an operational, strategic and judicial-political level can bring forth concrete recommendations. These simultaneously take into account democratic values that support the different legal options, the perceptions of persons of whom the DNA is recorded, practical constraints for the judicial actors and the Justice Department, new social practices relating to DNA, as well as the added value for the efficacy of the tool and the exploitation of its informational potential for the Justice Department.
The research group finally takes this opportunity to bring forward serious obstacles relating to the access of data, both police and DNA data, for the sake of scientific research.

4.10 RECOMMENDATIONS

Based on the scientific results of WP1 (4.4 The Relation Between DNA and Crime Scene Workers, 4.5 Forensic DNA in the Criminal Investigation, 4.6 Forensic DNA and Offenders), WP2 (4.7 Forensic DNA in Scientific Research, 4.8 Effectiveness of DNA databases) and WP3 (4.1 Normative and Legal Framework, 4.2 Security Policies, 4.3 Comparative Legal and Policy Framework Regarding DNA), concrete and practical recommendations are formulated. These meet needs that have been discovered during the research and offer solutions for encountered problems.

Our global approach in the Be-Gen project is to establish a legal framework that covers all existing social situations. There are both new and existing elements that are susceptible to improvement in order to come to normative provisions that cover all areas of forensic DNA.

First the new practices are discussed, before going on to existing practices and finally finishing with the organisation of the scientific research and political reasoning.

4.10.1 New practices

The Act of 22 March 1999 concerns identification through DNA analysis in criminal cases. This implies that the legal framework cannot be applied in situations other than those with judicial aims and the identification of individuals. There are, however, applications that present themselves without any other policy being made.

4.10.1.1 *Outside judicial aims*

- **Complete absence of a legal framework for administrative identification via DNA analysis.**

DNA can be an indispensable identification tool in certain situations outside the judicial/correctional landscape. An airplane crash or train derailment for example are both tragic accidents that generate a lot of victims. In situations like these, DNA is indispensable for the Disaster Victim Identification (DVI) unit of the federal police yet finds itself completely outside of the correctional framework. Our country is not fully prepared to deal with such tragic accidents and the identification via DNA analysis should be the subject of a specific legal framework designating the decision making authorities, the instances coordinating the analyses, the access to the results, the cost bearer of such analyses, etc.

RECOMMENDATION 1:
Create a legal framework for administrative identification via DNA analysis.

- **Complete absence of integrated reasoning taking into account other social practices already using DNA.**

Scientific progress simplifies the usage of DNA and increases its accessibility. Two examples truly show the need for a general reasoning taking into account such applications:

- **Medical Practices:** genetic medicine forces the medical sector to use the DNA of an increasing number of citizens. Certain specific laws are adopted in order to regulate these practices. Nevertheless the dissemination of DNA among numerous medical instances implies the existence of genetic databases.
- **Recreational DNA:** This practice that is widespread in Anglo-Saxon and Asian countries is gaining a foothold on the European continent as well. Commercial enterprises offer to give citizens more information about their genealogical history if they provide them with their DNA in order to study their genome. Through this, voluntary DNA databases are created, which in turn can contain a large number of citizens outside of any correctional/judicial or medical purpose.

These examples show the existence of social non-judicial practices that lead to the progressive establishment of DNA databases, sometimes outside any legal framework whatsoever. On the one hand the restrictive legal framework in which identification via DNA analysis in criminal cases is embedded is in sharp contrast to these new databases that sometimes escape all governmental supervision (why so many protectoral provisions in the judicial application but none in the recreational one?), and on the other hand these extra-judicial DNA databases constitute a pool of genetic material and information that could interest the judicial authorities without the relations between these purposes (sometimes badly or not defined) being organised.

RECOMMENDATION 2:
Conduct a global policy and approach on the availability of genetic materials coming from situations other than judicial/correctional.

4.10.1.2 *Within judicial aims*

Several new practices present themselves to the judicial and policing authorities without the legislator seeming to regulate them. These practices or new technological possibilities, however, sometimes have a great potential to be of help for investigators.

- **Criminal Analysis integrating DNA data**

DNA databases have an added value in the study of serial co-offenders, even more so when combined with police-recorded crime data. The results of WP2 indicate that known and unknown offenders may have different offending patterns. New theoretical insights into offending behaviour follow from the analysis of an integrated dataset and police forces can benefit from the new insights obtained from an integrated dataset, both to prevent and solve crimes. As such, the proposal to integrate police-recorded crime data and DNA data is important for both theoretical and operational research.

First, a network analysis of the integrated dataset can help discover networks and possibly prevent crime. The analysis illustrates that the integration of the police-recorded crime data and the DNA data not only expands the networks visible in police-recorded crime data, but also reveals crime networks that were not visible in the police-recorded crime data. Consequently, offenders who appeared to be of marginal importance in the police database may have a central role in the integrated database or vice versa. This new information may guide the police in their investigation. Arresting those key offenders may result in a disruption of the network (Berlusconi, 2017) and it can also prevent other actors from committing new crimes as they may have lost their 'partner in crime'. Second, an integrated dataset increases the opportunities for crime 'scenario building' (van der Hulst, 2009) – reconstructing what might have happened and identifying who was involved. Identifying unknown offenders for example becomes more feasible when it is discovered that they have committed a crime with a known offender. Unknown offenders present in DNA databases could also resolve a missing link between other known offenders in police-recorded crime data. Offending groups (i.e., 'Who offends with whom?') become visible, as do the broader accomplice networks of offenders indirectly connected to each other (i.e., 'Who [probably] knows whom?') (Chattoe & Hamill, 2005). Studying a pattern of crimes committed by an unknown offender may also create new leads. Furthermore, the fact that offenders are committing their crimes in more districts and time periods than previously thought means that the police should look beyond the crime case initially brought to their attention, to a broader time scope, but also to a broader geographic area. Thus cooperation between police forces from different judicial districts will be needed before the benefits of an integrated dataset can be fully exploited (De Moor, 2018).

RECOMMANDATION 3:
Using the existing data in DNA databases for purposes other than mere comparison.

- **Rapid DNA**

Another evolution, more so on the technological than on the biological aspect, is the development of new tools. The possibility of Rapid DNA, for example, is one of them. The FBI describes it as the fully automated – hands free – process of developing a DNA profile from a reference sample buccal swab. It requires no human intervention and delivers a profile within two hours. There is still a lot of quality assurance testing to do before we can even think about giving it the same status as a profile generated in an accredited laboratory. However, it is important to anticipate such technologies. It could be more cost-efficient and would allow police authorities to get a DNA profile much faster than they do right now.

RECOMMENDATION 4:
Prepare legislation and actors for the integration of the Rapid DNA tool specifically, and for future advanced tools in general.

- **Familial Search**

It is perfectly possible to carry out familial searches with the DNA profiles that are momentarily stored in the NGDB. This would mean that if the DNA of a perpetrator is found and then compared to the profiles in the database with the intent of carrying out an active familial search (partial likeness), investigators would be directed to his or her next of kin if they have already been recorded.

This comes with a variety of risks. It first could mean an infringement on the right to privacy, since there are subsidiary ways to find the perpetrator of a crime and its proportionality can be argued. Secondly, it could mean a risk to discrimination since a person could be identified faster if their kin are in the database, which could especially be the case in poorer sections of the population. This would, in turn, give a wrong impression of which layers of the population are responsible for crime.

Given the right protectoral provisions, however, the legislator can prepare for the integration of this use of forensic DNA in the legal framework.

RECOMMANDATION 5:
Anticipate and prepare the adoption of legal provisions enabling the possibility of familial searches within a legitimate framework.

- **Using morphological DNA**

DNA research as a whole is a scientific field with primarily scientific purposes. Nevertheless, whenever new knowledge is gained in the field of DNA research, this can be also have a forensic value. There is a good number of actors in the field developing forensic tools that can be applied on DNA research, and who specialise only in the forensic applications of DNA. So not only do we expand our knowledge on DNA on a daily basis, but also the possibilities of what we can do with what we already know.

The application of forensic DNA in Belgium is momentarily limited to mere DNA comparison. The DNA profile of one known individual (reference profile) is compared to the DNA profile of a collected sample (trace profile). Based on this comparison, there either is a match or there isn't. For this comparative application, the legislator has determined that the profile can only be established from so-called 'non-coding' DNA. This term was used in the nineties, when the first draft of the Belgian DNA act saw the light. It refers to DNA loci that were presumed not to contain any personal information. Since then, science has evolved. It evolves much faster than legislation does, and exponentially so in the 21st century. Today it is established that there is no such thing a 'non-coding' DNA; all DNA contains some personal information of the individual to whom it belongs. As such, there is no clear division between coding and non-coding DNA.

Even though the legislator had the best of intentions when introducing this limitation with the aim of protecting one's privacy, it has since then stood in the way of carrying out different other applications that are possible in the field of forensic DNA analyses. The main application is that of phenotyping; based on a collected DNA trace, researchers can statistically calculate the most likely eye, hair and skin colour. The field of phenotyping is booming, and we are expecting to be able to determine even much more than this. One could think of the shape of the face, the lifestyle, the height,… In a world surrounded by CCTV cameras however, where we already feel like we are always watched by Big Brother, caution is advised when developing laws that regulate such application. It is our opinion however, that this technological evolution is one that cannot be ignored and must be translated into law before applying it outside of a legal framework. In light of this, the legislator should step away from its fictional differentiation between coding and non-coding DNA and replace it by effective provisions protecting the individual's private life.

Some machines are capable of doing Next Generation Sequencing (NGS), also called deep or high-throughput sequencing. This process has revolutionised research into the human genome, since it can analyse up to 250 markers in a much shorter time span than the current machines. It provides scientists with much more information than is otherwise available from an analysis.

Other applications in the field of forensic DNA are still not yet provided for by law; ARN DNA, mitochondrial DNA and Y analyses.
It is better to establish laws that are congruent with reality. We have to be able to include these new applications, new knowledge and new technologies into the regulatory framework, all the while aiming to also include effective and realistic protectionary provisions for the individual's right to privacy and fundamental rights in general. Otherwise, we will be pushed to the fringes of the legal framework, which in itself is a danger to the fundamental rights and freedoms of all citizens.
Our comparative analysis can help in identifying possible hurdles, anticipating them and developing a legal framework that may not necessarily put us at the forefront, but does allow us to keep up with modern technological and scientific evolutions.

RECOMMANDATION 6:

Establish proportionality criteria to replace the non-coding DNA criteria that we are applying today but which is no longer correct.

4.10.2 EXISTING PRACTICES

4.10.2.1 *Distinct judicial practices according to the judicial area.*

There is a need for a more harmonised policy throughout all of the laboratories an policing instances. While all of the laboratories are accredited and conform to quality standards, the management and policy in each of the laboratories is different, leading to discrepancies. They would also appreciate feedback from police, so that they can improve their workings and optimise their cooperation.

RECOMMANDATION 7:
Establish the criteria aiming to define a national criminal policy on the use of DNA in order to harmonise the optimal practices of exploitation of DNA.

4.10.2.2 *The victims are not taken into account in the process of DNA analysis:*

This has a double effect – insufficient detection of contamination by victims on one hand and, on the other, accumulation of profiles of victims in the Criminalistics database, which is a potential infringement of the right of the victims.

RECOMMANDATION 8:
Define a clear policy to prevent DNA profiles of victims being recorded in the Criminalistics database.

4.10.2.3 *Informational deficit for the persons subjected to a DNA sampling and analysis in a judicial setting.*

Despite the provisions foreseen in Belgian law that state that the persons who undergo DNA analysis must be informed, the results show that this information is incomplete, not very clear and misunderstood by the concerned individuals. The convicted offenders in particular, who see their DNA being recorded for a long period of time, recommended that the DNA recording based on article 5 of the DNA law be considered as a judicial measure that has to be imposed by the judge during the conviction.

4.10.2.4 *Lack of evaluation on the management of the genetic materials in the judicial context.*

The laboratories are accredited by the Minister of Justice. A global phenomenon is happening whereby certain multinational companies buy analysis laboratories, including some accredited Belgian labs. However, no evaluation whatsoever is taking place to assure that the national legal framework is still adequate in the light of this evolution.

4.10.2.5 *Adaptation of the Elimination Database*

The addition of an Elimination Database by the law of 17 May 2017 in the landscape of identification by DNA analysis certainly shares a laudable political intention, that of improving the quality and the relevance of the DNA results used in the criminal investigation. Starting as an initiative from the parliament, this law rushed into adoption this tool to fight against contamination with a lack of maturity. The nature and importance of the seven reflections mentioned briefly in this first commentary show that there are many difficulties facing the concrete implementation of this new DNA database. It is a safe bet that the work of our current research shows that a modification of the law itself is essential to overcome the obstacles identified.

RECOMMENDATION 9:
Distinguish between two distinct purposes of DNA legislation, one aiming at IDENTIFICATION and the other at investigatory ORIENTATION. Define in each purpose and for each specific application of the DNA the precise criteria of proportionality and subsidiarity.

4.10.3 Organising the scientific evaluation and political reasoning

The Be-Gen research is a time-bound project. The comments and recommendations will be outdated in a few years. In the absence of a permanent reasoning that makes it possible to follow rapid evolutions and to anticipate the political and normative issues at stake due to these evolutions, two aspects have to be improved in order to guarantee a political reasoning that is enlightened, coordinated and continuous.

1. The research has made it possible to discern numerous obstacles in the research, more specifically the absence of a clear legal framework that enables exploitation, for research purposes, of the data that is indispensable for such an evaluation.

RECOMMENDATION 10: **Adapt the respective legal frameworks on police data and on judicial DNA data in order to allow these deep-seated scientific evaluations, both quantitatively and qualitatively.**

Among all the numerous specific aspects of the research only the top was scraped during the Be-Gen project and they deserve to be studied in detail. Research in this domain must be continued in order to help the legislator, the executive authority and the judiciary authorities to define the political options.

RECOMMENDATION 11: **Define a research programme with all priorities and finance it.**

2. The law that is in force at the moment provides that the Minister of Justice should be consulted by a national DNA Commission of which the composition is stated in a Royal Decree. This Commission's task is solely to enlighten the Minister on the technological and scientific evolutions. Its composition should be varied and it should convene regularly, but unfortunately such commission does not yet exist. The stakes, however, are high as shown by the numerous examples of evolutions that have been emphasised in this report. Certain neighbouring countries suggest an instance that integrates at the same time the technological and scientific information, judicial competences and ethical reasoning (such as the commission in the reasoning on scientific evolutions in the French parliament for example). Belgium also disposes of certain follow-up commissions of multidisciplinary nature (e.g., IVG).

RECOMMENDATION 12: **Re-enforce the follow-up of technological and scientific evolutions in DNA analyses and create a structure that is in charge of permanent multidisciplinary reasoning for this purpose.**

5. DISSEMINATION AND VALORISATION

5.1 SPECIFIC EVENTS OF THE PROJECT

➢ **Day on « New types of evidence / Les nouveaux modes de preuve »**(Brussels, 14 November 2016).

This conference was organised as part of the GERN project "Usages des nouvelles technologies dans les domaines de la sécurité et de la justice pénale" /"Use of new technologies in the areas of security and criminal justice". It received financial support from GERN, NICC, the NormaStim project (ANR 14-CE30-0016-001) and UMR 8103 ISJPS. This workshop aimed to question the use of technologies in the search for criminal truth, at the crossroads of two axes. On the one hand truth and certainty and on the other hand the standardization of techniques, practices and behaviours. To answer these questions, the results of several researches, recent or ongoing, were shared:

1. Be-Gen: Understanding the operational, strategic and political implications of the National Genetic Database in Belgium (Belspo Project No. BR/132/A4/Be-Gen).
2. ANR NormaStim: Neuroscience from experiment to daily clinic - Legal, philosophical and sociological issues of Deep Brain Stimulation (ANR 14-CE30-0016-001).
3. GIP DNA Law: Criminal proceedings using genetics (contract GIP Justice 14-34).
4. GIP Injunction to care: Multidisciplinary study of treatment orders in a regional metropolis (contract GIP Justice 14-06).
5. ANR FITEGE: Genetic Databases and Witnesses - Genealogy, Social issues, Circulation (ANR 14-CE29-0014).
6. GIP Nancy: The use of genetic characteristics in judicial proceedings: study of ten years of practice in Meurthe-et-Moselle (2003 - 2013) (contract GIP Justice 14-35).

➢ **GERN Seminar "**Understanding the operational, strategic and political implications of forensic DNA-results of the Be-Gen research project" (Brussel, 2 March 2018). This Interlabo was organised in the context of the Interlabos of GERN (European Group of Research into Norms) and received financial support from GERN, NICC and the Be-Gen project (BRAIN program - Belspo project No. BR/132/A4/Be-Gen).

This seminar was featured in the last phase of the Be-Gen research. As is typical for the GERN Interlabos, this day provided a first look at the results of the ongoing research at a key moment, aiming at disseminating the first Be-Gen project conclusions a few months before its finalisation.

➢ **National DNA conference**: DNA in the criminal justice system – Which applications brings the future (Brussels, 26 April 2018)
DNA in criminal justice - to which practices in the future? This question was the central topic of the conference. The program proposed a restitution of the results of the Be-Gen research aimed at the actors in the field of disposing of the conclusions of the Be-Gen project.

➢ **Parliament hearing: Chamber committee of justice** (Brussels, 21 November 2018):
Presentation to maximise the valorisation of the research results and the recommendations. (http://www.lachambre.be/doc/CCRA/pdf/54/ac1002.pdf)

5.2 SPECIFIC NETWORKS

Close contacts were maintained during the research with researchers from the following projects:

ANR FITEGE: Genetic Databases and Witnesses - Genealogy, Social issues, Circulation. Funded by the National Research Agency (ANR 14-CE29-0014),
http://fitege.hypotheses.org/.

GIP Nancy: The use of genetic characteristics in judicial proceedings: study of ten years of practice in Meurthe-et-Moselle (2003 - 2013). Research conducted by the University of Lorraine. Funded by the Research Mission Law and Justice (GIP Justice contract 14-35).

GIP DNA law: Criminal proceedings using genetics. Research conducted by the University of Paris I, Panthéon-Sorbonne. Funded by the Research Mission Law and Justice (contract GIP Justice 14-34).

5.3 SCIENTIFIC COMMUNICATIONS

2018

- De Moor, S., Vandeviver, C., & Vander Beken, T., DNA Databases as Data Sources for Criminological Research. European Society of Criminology, Abstracts. Presented at the Annual Conference of the European Society of Criminology, 31 August 2018.
- Stappers, C., Forensic DNA: An Analysis of the Use in a Criminal Investigation. Presented at the Annual Conference of the European Society of Criminology, 31 August 2018.
- Struyf, P., Vandeviver, C., De Moor, S., Renard, B., & Vander Beken, T., A Systematic Review of Dna Data in Criminology: Innovative Results in An Innovative Way? European Society of Criminology, Abstracts. Presented at the Annual Conference of the European Society of Criminology, 31 August 2018.
- Praile, P., Kempenaers, M. et Renard, B., Les banques de données génétiques d'intervenants. De l'indifférence du sort des citoyens à l'indignation du contrôle sur les intervenants ?, Congrès AICLF, Lausanne, 4 juin 2018.
- Renard, B., Stappers, C., De Moor, S. et Gallala, I., Les banques de données génétiques en Belgique. Résultats au terme d'une évaluation opérationnelle, stratégique et politique, Poster, Congrès AICLF, Lausanne, 3-5 juin 2018.
- Renard, B. et Vuille, J., L'ADN en justice pénale et son encadrement légal en Europe. Un même outil, des options différentes des législateurs, Congrès AICLF, Lausanne, 4 juin 2018.
- De Moor, S. & Vander Beken, T., DNA databanken als bron voor criminologisch onderzoek. Nationale Studiedag Be-Gen, Brussel, 26 april 2018.
- Gallala, I. & De Hert, P., Focus Group Discussies & de aanzet tot aanbevelingen in politieke kwesties. Nationale Studiedag Be-Gen, Brussel, 26 april 2018.
- Praile, P., Une nouvelle banque de données des Intervenants – perception et analyse. Journée Nationale ADN, Bruxelles, 26 avril 2018.
- Gallala, I., Forensisch DNA: een rechtsvergelijkend onderzoek, Nationale Studiedag Be-Gen, Brussel, 26 april 2018.
- Renard, B., Be-Gen: histoire, projet et perspectives. Journée Nationale ADN, Bruxelles, 26 avril 2018.
- Renard, B., Evolutions dans les applications de l'ADN et réactions politiques. Journée Nationale ADN, Bruxelles, 26 avril 2018.
- Stappers, C., DNA in strafzaken : een analyse van het gebruik. Nationale Studiedag Be-Gen, Brussel, 26 april 2018.
- Struyf, P., De finaliteit en effectiviteit van DNA databanken. Nationale Studiedag Be-Gen, Brussel, 26 april 2018.
- De Moor, S. & Vander Beken, T., DNA databases as data sources for criminological research, Interlabo GERN, Brussel, 2 March 2018.
- Gallala, I., Forensic DNA - comparing legislations. Interlabo GERN, Brussel, 2 march 2018.

- Gonzàlez F.G. & Gallala, I., Perspectives européennes valorisation des données et vie privée – quelques enjeux politiques majeurs. Interlabo GERN, 2 Mars 2018.
- Praile, P., Une nouvelle banque de données des Intervenants – perceptions et questionnement. Interlabo GERN, Bruxelles, 2 mars 2018.
- Renard, B., L'identification par analyse ADN au pénal en Belgique – évolution et cadre actuel. Interlabo GERN, Bruxelles, 2 mars 2018.
- Renard, B., La perception par les personnes condamnées de l'enregistrement de leur ADN. Interlabo GERN, Bruxelles, 2 mars 2018.
- Stappers, C., The use of DNA : a quantitative and qualitative analysis. Interlabo GERN, Brussel, 2 March 2018.

2017

- Gallala, I.: Analyse de droit comparé - utilisation d'ADN en matière pénale. Institut National de Police Scientifique – Collaboration INCC/FNAEG/INPS, Lyon, 18-20 décembre 2017.
- Renard, B., Situation légale en Belgique – Evolutions et pratiques, Presented at Collaboration INCC/FNAEG/INPS, Lyon, 18-20 décembre 2017.
- Stappers, C., Les implications opérationnelles des analyses génétiques en matière pénale. Presented at Collaboration INCC/FNAEG/INPS, Lyon, 18-20 décembre 2017.
- Gallala, I.: Regulating Emerging Forensic DNA Technologies – how to work with the legal toolbox. Forensics 2017 Conference, Lisbon, 20-24 November 2017.
- De Moor, S.: Using DNA data to address the problem of missing data in criminal network analysis. American Society of Criminology, Philadelphia, 15 November 2017.
- Gallala, I.: The implications of regulating forensic DNA technologies: a European vs. American approach. American Society of Criminology, Philadelphia, 15 November 2017.
- Stappers, C., To analyze a trace: When do DNA-traces contribute to a forensic case, American Society of Criminology, Philadelphia, 15 November 2017.
- De Moor, S., Vandeviver, C., & Vander Beken, T., Spatial similarity of crime patterns of unknown offenders in DNA data and police recorded crime data. European Society of Criminology , Abstracts. Presented at the Annual Conference of the European Society of Criminology, 15 September 2017.
- Renard, B., Evolutions techniques et perspectives normatives dans le fichage des profils ADN en Belgique , Colloque sur « ADN et preuve au pénal », Université de Lorraine, Nancy, 9 juin 2017.
- De Moor, S., Integrating police recorded crime data and DNA data to study serial co-offending behaviour. Presented at the Stockholm Criminology Symposium, Stockholm, 20 June 2017.
- Gallala, I.: Regulating emerging forensic DNA technologies: the toolbox. Presented at the Stockholm Criminology Symposium, Stockholm, 20 June 2017.

- Stappers, C., DNA in the criminal investigation: the decision-making process and its contribution to the case. Presented at the Stockholm Criminology Symposium, Stockholm, 20 June 2017.

2016

- RENARD, B., La mise en norme des pratiques expertales et judiciaires : standardisation, assurance qualité et procéduralisation sur le terrain de l'ADN en justice pénale en Belgique, Séminaire sur " Les nouveaux modes de preuve " - Journée dans le cadre du programme " Usages des nouvelles technologies dans les domaines de la sécurité et de la justice pénale " du GERN, Bruxelles, INCC, 14 novembre 2016.
- Stappers, C., L'ADN en justice pénale: une analyse au niveau de la police technique et scientifique. Séminaire sur " Les nouveaux modes de preuve " - Journée dans le cadre du programme " Usages des nouvelles technologies dans les domaines de la sécurité et de la justice pénale " du GERN, Bruxelles, INCC, 14 novembre 2016.
- Gallala, I.: The implementation of Prüm - Are we ready for a central European DNA database? Conference: Reacting to surveillance by security agencies and private companies, Berlijn, 13-14 May 2016.
- Renard, B. et Jeuniaux, P., L'ADN en matière pénale : le coût de l'analyse génétique et ses modalités de traitement, Colloque sur « l'utilisation de l'ADN dans les procédures judiciaires : étude de 10 années de pratiques en Meurthe-et-Moselle », Université de Lorraine, Nancy, 23 mars 2016.
- Renard, B. et Jeuniaux, P., Sur la mise en œuvre et l'évaluation de l'échange de données ADN criminalistiques d'après le Traité de Prüm, Séminaire FITEGE, Université de Nanterre, Paris, 26 janvier 2016.

2015

- Stappers, C. et Renard, B., Evaluation of the Operational Benefits of Prüm. Presented at PIES 2015 Conference on Forensic DNA Data Exchange, Brussels, 29 September 2015.
- Jeuniaux, P., De Moor, S., Bernasco, W., Huet, M., Van Daele, S., Vander Beken, T., Leplingard, A., et al., Exploiting Forensic DNA data to draw pictures of organized or transnational crime(s). Stockholm Criminology Symposium, Abstracts. Presented at the Stockholm Criminology Symposium, 10 June 2015.
- Renard, B., De Moor, S., Gallala, I., Stappers, C., Be-Gen: Understanding the Operational, Strategic and Political Implications of the National Genetic Database. Poster presented at Vijfde Criminologisch Forum Vlaamse Vereniging voor Criminologie (VVC), Leuven, 2 June 2015.
- Gallala, I., Junk Science or not? An analysis of Belgium's new criteria regarding forensic expertise in light of the US Supreme Court's Jurisprudence. The AHRC Network 'Technoscience, Law and Society: Interrogating the Nexus': Articulating Science, Technology and Law - Regarding, Reflecting, and Remaking Society, Kent, 9-10 April 2015.

- Gallala, I., De Moor S., & Stappers, C., Be-Gen: Understanding the operational, strategic and political implications of the National Genetic Database. Criminologisch Forum Vlaamse Vereniging voor Criminologie, Poster. Presented at the Criminologisch Forum Vlaamse Vereniging voor Criminologie, 2-6 January 2015.

2014

- Gallala, I. et Renard, B., Le droit, traducteur des enjeux des dispositifs socio-techniques? Etude de cas à propos de l'identification par analyse génétique en justice pénale, Colloque sur «Regards croisés sur les objets et pratiques scientifiques et technologiques», Réseau Droit, Sciences et Techniques et l'Institut des Sciences Sociales du Politique, Cachan, 11 décembre 2014.

5.4 PHD DISSERTATIONS

The research results of the Be-Gen project are also valorised in three PhD dissertations:

- De Moor, S. (2018). Forensic DNA databases as data sources for criminological research - Ghent University.
- Stappers, C. (in preparation). DNA-onderzoek in strafzaken: de effectiviteit en efficiëntie van het gebruik - University of Leuven.
- Gallala, I. (in preparation). The Crossroads of DNA Analysis in Criminal Cases and Human Rights Issues – Vrije Universiteit Brussel.

6. PUBLICATIONS

2018

- De Moor, S., Vandeviver, C., & Vander Beken, T. (2018). Integrating police-recorded crime data and DNA data to study serial co-offending behaviour. European Journal of Criminology, 15(5), 632-651. https://doi.org/10.1177/1477370817749499.
- De Moor, S., Vandeviver, C., & Vander Beken, T. (2018). Are DNA data a valid source to study the spatial behavior of unknown offenders? Science and Justice,58(5), 315-322. https://doi.org/10.1016/j.scijus.2018.04.003.
- Gallala, I., & Renard, B. (2018). Les banques de données ADN en Belgique, Justice en ligne (mis en ligne le 1er juillet 2018), http://www.justice-en-ligne.be/article1075.html?utm_source=moteur_jel&utm_medium=textuelle&utm_campaign=recherche.
- Jeuniaux, P., De Moor, S., Robert, L., Renard, B., Stappers, C., & Vanvooren, V. (2018). Reconstruction and Study of Offending Trajectories through Forensic Evidence: An Illustration Using a Forensic DNA Database. In Q. Rossy, D. Hécary-Hétu, O. Delémont, & M. Mulone (Eds.), The Routledge International Handbook of Forensic Intelligence and Criminology (pp. 177–190). London ; New York: Routledge, Taylor & Francis Group.
- Renard, B. et Praile, P. (2018). La création d'une banque de données ADN « intervenants »… difficultés et effets de la chasse aux contaminations, Les Cahiers du CRID&P, n°3. https://uclouvain.be/fr/instituts-recherche/juri/cridep/actualites/creation-d-une-banque-de-donnees-adn.html.

2017

- De Moor, S., Vander Beken, T., & Van Daele, S. (2017). DNA Databases as Alternative Data Sources for Criminological Research. European Journal on Criminal Policy and Research, 23(2), 175-192. https://doi.org/10.1007/s10610-016-9327-9.
- Stappers, C., Vanhooydonck, B., Vanvooren, V., Duboccage, L., & Renard, B. (2017). De Belgische DNA-gegevensbanken: beantwoordt de nieuwe DNA-wet aan de verwachtingen van de beheerder?, Panopticon. Tijdschrift Voor Strafrecht, Criminologie En Forensisch Welzijnswerk, 38, N°6, 416-432.

2016

- Gallala, I., & De Hert, P. (2016). Databank met àlle vingerafdrukken: noch proportioneel, noch betaalbaar. Tijdschrift voor Mensenrechten, 14(1), 3.
- Gallala, I., & Renard, B. (2016). La preuve génétique dans les enquêtes pénales : la reine des preuves ?, Justice en ligne, http://www.justice-en-ligne.be/article937.html?utm_source=moteur_jel&utm_medium=textuelle&utm_campaign=recherche (mis en ligne le 22 décembre 2016).
- Jeuniaux P., Duboccage L., Renard, B., Van Renterghem, P. et Vanvooren V. (2016). Establishing networks in a forensic DNA database to gain operational and strategic

intelligence. Security Journal– Special Issue about Traceology : Fusing Forensic Science and Criminology for Security, 29(4), 584–602. http://doi.org/10.1057/sj.2015.31.

- Renard, B. et Gallala, I. (2016). Le droit, traducteur des enjeux des dispositifs sociotechniques ? Etude de cas à propos de l'identification par analyse génétique en justice pénale en Belgique, Dossier thématique sur Regards croisés sur les objets et les pratiques scientifiques et techniques, Les Cahiers Droit, Sciences et Technologies, 6, 23-41. http://journals.openedition.org/cdst/473.
- Stappers C., De Moor S., Gallala I., Jeuniaux P., Vanvooren V., Renard B. (2016). DNA-databank veroordeelden : ethische kwesties en juridische keuzes. Fatik: Tijdschrift voor Strafbeleid en Gevangeniswezen, 33(149), 5-11.

2015

- Jeuniaux, P., Renard, B., Duboccage, L., Steuve, S., Stappers, C., Gallala, I., De Moor, S., Jonckheere, A., Mine, B., De Greef, C., Vanhooydonck, B., Kempenaers, M., Van Renterghem, P., & Vanvooren, V. (2015). Managing forensic DNA records in a divided world: the Belgian case. Records Management Journal, 25(3), 269-287. http://dx.doi.org/10.1108/RMJ-05-2015-0018.
- Jeuniaux, P., Dubbocage, L., Renard, B., Van Renterghem, P. & Vanvooren, V. (2015). Establishing networks in a forensic DNA database to gain operational and strategic intelligence. Security Journal- Special Issue about Traceology : Fusing Forensic Science and Criminology for Security, 29(4), 584-602. http://doi.org/10.1057/sj.2015.31.
- Renard B., De Moor S., Gallala I., Stappers C. (2015). L'ADN criminalistique sous la loup. Science Connection, 47, 42-46.
- Renard B., De Moor S., Gallala I., Stappers C. (2015). Forensisch DNA onder de loep. Science Connection, 47, 42-46.
- Stappers C., Renard B. (2015). Be-Gen, Een onderzoek over forensisch DNA. Politiejournaal, 8, 16-19.
- Stappers C., Renard B. (2015). Be-Gen, Une recherche sur l'ADN Criminalistique. Journal de la Police, 8, 16-19.

2014

- Renard, B. (2014). The Relevance of Actor Network Theory (ANT) for Research on the Use of Genetic Analysis for Identification in Criminal Justice (Chapter 8), in Robert D. and Dufresne M. (Ed.), Actor Network Theory and Crime Studies – Explorations in Science and Technology, Ashgate Editions, 113-126.

7. ACKNOWLEDGEMENTS

The Be-Gen research team would like to thank Emmanuèle Bourgeois and Aziz Naji from BELSPO for managing and providing follow up to the project.

The research team would like to thank the Follow-up Committee (see Annexe 2) for their valuable input during the different stages of this project.

The research team is thankful to all organisations that helped by granting access to the necessary data (DNA data, police records and criminal records). Special thanks are extended to the DIS service of the NICC, the Federal Police DJSOC and the Technical and Scientific Police.

The research team would like to thank the different institutions where observations were carried out: Central Directorate of the Technical and Scientific Police (DJT), the National DNA Cell, and the DIS service of the NICC, NICC DNA laboratory, the Laboratory of the Technical and Scientific Police (LTWP) of the judicial district of Antwerp, Ghent, Brussels and Liège.

The research team would also like to thank all the participants of the interviews and focus group discussions.

The research team express its gratitude to the interns from UCL and KU Leuven for contributing to this research and to Magali Deblock and Silke Steenwegen from the NICC for their administrative support.

Special thanks to Patrick Jeuniaux (NICC – DIS) for his help, encouragement and feedback during the whole project.

BIBLIOGRAPHY

Literature

Adderley, R., Townsley, M., & Bond, J. (2007). Use of data mining techniques to model crime scene investigator performance. *Knowledge-Based Systems*, 20(2), 170–176. https://doi.org/10.1016/j.knosys.2006.11.007

Alarid, L. F., Burton Jr., V. S., & Hochstetler, A. L. (2009). Group and solo robberies: do accomplices shape criminal form? *Journal of Criminal Justice*, 37, 1-9.

Amankwaa, A. O., & McCartney, C. (2018). The UK National DNA Database: implementation of the Protection of Freedoms Act 2012. *Forensic Science International*. https://doi.org/10.1016/j.forsciint.2017.12.041

Andresen, M. A. (2009). Testing for similarity in area-based spatial patterns: A nonparametric Monte Carlo approach. *Applied Geography*, 29(3), 333-345. doi:10.1016/j.apgeog.2008.12.004

Andresen, M. A., & Felson, M. (2010). The impact of co-offending. *British Journal of Criminology*, 50, 66-81.

Andresen, M. A., & Linning, S. J. (2012). The (in)appropriateness of aggregating across crime types. *Applied Geography*, 35(1-2), 275-282. doi:10.1016/j.apgeog.2012.07.007

Andresen, M. A., Linning, S. J., & Malleson, N. (2017). Crime at Places and Spatial Concentrations: Exploring the Spatial Stability of Property Crime in Vancouver BC, 2003–2013. *Journal of Quantitative Criminology*, 33, 255-275. doi:10.1007/s10940-016-9295-8

Basset, P., & Castella, V. (2018). Lessons from a study of DNA contaminations from police services and forensic laboratories in Switzerland. *Forensic Science International: Genetics*, 33, 147–154. https://doi.org/10.1016/j.fsigen.2017.12.012

Beauregard, E., & Bouchard, M. (2010). Cleaning up your act: Forensic awareness as a detection avoidance strategy. *Journal of Criminal Justice*, 38(6), 1160-1166.

Berlusconi, G. (2017). Social Network Analysis and Crime Prevention. In B. LeClerc & E. U. Savona (Eds.), *Crime Prevention in the 21st Century: Insightful Approaches for Crime Prevention Initiatives* (pp. 129-141). Cham: Springer International Publishing.

Bernasco, W. (2006). Co-offending and the choice of target areas in burglary. *Journal of Investigative Psychology and Offender Profiling*, 3, 139–155.

Bernasco, W., & Steenbeek, W. (2017). More Places than Crimes: Implications for Evaluating the Law of Crime Concentration at Place. *Journal of Quantitative Criminology*, 33(3), 451-467. doi:10.1007/s10940-016-9324-7

Bhati, A. (2010). *Quantifying the Specific Deterrent Effects of DNA Databases*. Washington, D.C.: Justice Policy Center, Urban Institute.

Biderman, A. D., & Reiss, A. J. (1967). On Exploring the "Dark Figure" of Crime. *The Annals of the American Academy*, 374(1), 1-15.

Bitzer, S., Albertini, N., Lock, E., Ribaux, O., & Delémont, O. (2015). Utility of the clue — From assessing the investigative contribution of forensic science to supporting the decision to use traces. *Science & Justice*. https://doi.org/10.1016/j.scijus.2015.05.005

Bitzer, S., Ribaux, O., Albertini, N., & Delémont, O. (2016). To analyse a trace or not? Evaluating the decision-making process in the criminal investigation. *Forensic Science International*, 262, 1–10. https://doi.org/10.1016/j.forsciint.2016.02.022

Bond, J. W., Phil, D., & Hammond, C. (2007). Value of DNA evidence in detecting crime. *Journal of Forensic Sciences*, 52(1), 128–136. https://doi.org/10.1111/j.1556-4029.2006.00323.x

Butler, J. M. (2010). *Fundamentals of forensic DNA typing*. Amsterdam Academic Press/Elsevier.

Chattoe, E., & Hamill, H. (2005). It's Not Who You Know—It's What You Know About People You Don't Know That Counts. Extending the Analysis of Crime Groups as Social Networks. *British Journal of Criminology*, 45(6), 860-876.

Costello, A., & Wiles, P. (2001). GIS and the journey to crime. An analysis of patterns in South Yorkshire. In A. Hirschfield & K. Bowers (Eds.), *Mapping and analysing crime data. Lessons from research and practice* (pp. 27-60). London: Taylor & Francis.

Crispino, F. (2008). Nature and place of crime scene management within forensic sciences. *Science & Justice*, 48(1), 24–28. https://doi.org/10.1016/j.scijus.2007.09.009

Dahl, J. Y. & Saetnan, R., " "It all happened so slowly" – On controlling function creep in forensic DNA databases", *International Journal of Law, Crime and Justice*, 2009, vol. 37, 83-103.

De Greef, C. (2008). Genetische identificatie. In P. Boel, V. De Cloet, J. De Kinder, J. Mahieu, & D. Van Varenbergh (Eds.), Handboek forensisch onderzoek: de mogelijkheden van het forensisch onderzoek (pp. 135–156). Brussel Politeia.

de Melo, S. N., Matias, L. F., & Andresen, M. A. (2015). Crime concentrations and similarities in spatial crime patterns in a Brazilian context. *Applied Geography*, 62, 314-324. doi:10.1016/j.apgeog.2015.05.012

De Moor, S. (2018). *Forensic DNA databases as data sources for criminological research* (Dissertation). UGent, Gent.

De Moor, S., Vandeviver, C., & Vander Beken, T. (2018a). Are DNA data a valid source to study the spatial behavior of unknown offenders? *Science & Justice*.

De Moor, S., Vandeviver, C., & Vander Beken, T. (2018b). Integrating police-recorded crime data and DNA data to study serial co-offending behaviour. *European Journal of Criminology*, 00(0), 1-20. doi:10.1177/1477370817749499

De Wree, E., Vermeulen, G., & Christiaens, J. (2006). *(Strafbare) overlast door jongerengroepen in het kader van openbaar vervoer*. Antwerpen: Maklu.

Develtere, R. (2014). *Vingersporen versus DNA*. Paper presented at the DNA Symposium, Brussels.

Doleac, J. L. (2016). The Effects of DNA Databases on Crime. *American Economic Journal: Applied Economics*, 9(1), 165-201.

Doleac, J. L. (2017). How do State Crime Policies Affect Other States? The Externalities of State DNA Database Laws. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2892046

Dunsmuir, W. T., Tran, C., & Weatherburn, D. (2008). Assessing the impact of mandatory DNA testing of prison inmates in NSW on clearance, charge and conviction rates for selected crime categories. Retrieved from Sydney: http://www.bocsar.nsw.gov.au/Pages/bocsar_publication/bocsar_pub_byyear.aspx#2008

Eck, J. E., Lee, Y., O, S., & Martinez, N. (2017). Compared to what? Estimating the relative concentration of crime at places using systematic and other reviews. *Crime Science*, 6(8). doi:10.1186/s40163-017-0070-4

ENFSI. (2016). *DNA database management review and recommendations* (DNA Working Group) (p. 84). Retrieved from www.enfsi.eu

Evans, C. (2007). *The Casebook of Forensic Detection: how Science solved 100 of the World's Most Baffling Crimes*. New York, Berkley Books.

Felson, M. (2003). The process of co-offending. *Crime Prevention Studies*, 16, 149-167.

Fonneløp, A. E., Johannessen, H., Egeland, T., & Gill, P. (2016). Contamination during criminal investigation: Detecting police contamination and secondary DNA transfer from evidence bags. *Forensic Science International: Genetics*, 23, 121–129. https://doi.org/10.1016/j.fsigen.2016.04.003

Forensic Science Regulator. Protocol: DNA contamination detection - The management and use of staff elimination DNA databases, FSR-P-302 Codes of Practice and Conduct § (2014).

Forensic Genetics Policy Initiative (2010). *DNA* Databases and Human Rights. Retrieved from http://dnapolicyinitiative.org.

Fraser, J., & Williams, R. (2009). *Handbook of Forensic Science*. Routledge.

Freeman, L. F. (1979). Centrality in Social Networks: Conceptual Clarification. *Social Networks*, 1, 215-239.

GT BD INV. (2017, March 31). Compte-rendu de la réunion du 31-03-2017.

Hennink M., Hutter I. & Bailey A. (2010), *Qualitative Research Methods*, SAGE.

Hibdon, J., Telep, C. W., & Groff, E. R. (2016). The Concentration and Stability of Drug Activity in Seattle, Washington Using Police and Emergency Medical Services Data. *Journal of Quantitative Criminology*, 33(3), 497-517. doi:10.1007/s10940-016-9302-0

Home office (2006), *Standards, Systems and Assurance,* Retrieved at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/117788/ndnad-ann-report-2006-07-sec4.pdf.

Home Office (2010), *Code of Practice for the Identification of Persons by Police Officers,* Retrieved at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/253831/pace-code-d-2011.pdf

Home Office (2012), *National DNA Database Strategy Board: Annual Report 2012-2013*, Retrieved at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/252885/NDNAD_Annual_Report_2012-13.pdf

House, J. C., Cullen, R. M., Snook, B., & Noble, P. (2006). Improving the Effectiveness of the National DNA Data Bank: A Consideration of the Criminal Antecedents of Predatory Sexual Offenders. *Canadian Journal of Criminology and Criminal Justice*, 48(1), 61-75.

Jeuniaux, P., & Renard, B. (2012). Les coûts de l'ADN: Les dépenses en matière d'expertise génétique dans le système pénal belge, de 2000 à 2010. Report #29. Bruxelles: Institut National de Criminalistique et de Criminologie.

Jeuniaux, P., Duboccage, L., Renard, B., Van Renterghem, P., & Vanvooren, V. (2016). Establishing networks in a forensic DNA database to gain operational and strategic intelligence. *Security Journal*, 29(4), 584-602. doi:10.1057/sj.2015.31

Jeuniaux, P., Renard, B., & Vanvooren, V. (2012, August). *A statistical analysis of DNA profile networks to support criminal investigation*. Den Haag.

Kocsis, R. N., & Irwin, H. J. (1998). The psychological profile of serial offenders and a redefinition of the misnomer of serial crime. *Psychiatry, psychology and law*, 5(2), 197-213.

Kossinets, G. (2006). Effects of missing data in social networks. *Social Networks*, 28(3), 247-268. doi:10.1016/j.socnet.2005.07.002

Krimsky S. & Simoncelli T. (2011), *Genetic Justice: DNA Databanks, Criminal Investigations and Civil Liberties,* Columbia Press University, p. 185.

Lammers, M. (2013). *Catch me if you can. Using DNA traces to study the influence of offending behaviour on the probability of arrest*. Vrije Universiteit Amsterdam, Amsterdam.

Lammers, M. (2014). Are Arrested and Non-Arrested Serial Offenders Different? A Test of Spatial Offending Patterns Using DNA Found at Crime Scenes. *Journal of Research in Crime and Delinquency*, 51(2), 143-167.

Lammers, M., & Bernasco, W. (2013). Are mobile offenders less likely to be caught? The influence of the geographical dispersion of serial offenders' crime locations on their probability of arrest. *European Journal of Criminology*, 10(2), 168-186.

Lammers, M., Bernasco, W., & Elffers, H. (2012). How Long Do Offenders Escape Arrest? Using DNA Traces to Analyse when Serial Offenders Are Caught. *Journal of Investigative Psychology and Offender Profiling*, 9(1), 13-29. doi:10.1002/jip.1353

Lantz, B., & Ruback, R. B. (2016). The Relationship Between Co-Offending, Age, and Experience Using a Sample of Adult Burglary Offenders. *Journal of Developmental and Life-Course Criminology*, 3(1), 76-97. doi:10.1007/s40865-016-0047-0

Lapointe, M., Rogic, A., Bourgoin, S., Jolicoeur, C., & Séguin, D. (2015). Leading-edge forensic DNA analyses and the necessity of including crime scene investigators, police officers and technicians in a DNA elimination database. *Forensic Science International: Genetics*, 19, 50–55. https://doi.org/10.1016/j.fsigen.2015.06.002

Leary, D., & Pease, K. (2003). DNA and the Active Criminal Population. *Crime Prevention and Community Safety*, 5(1), 7-12. doi:10.1057/palgrave.cpcs.8140135

Litoselleti L. (2003), *Using focus Groups in Research,* A & C Black.

Ludwig, A., & Marshall, M. (2015). Using crime data in academic research: issues of comparability and integrity. *Records Management Journal*, 25(3), 228-247. doi:10.1108/rmj-05-2015-0017

Machado, H., Cunha, M. I. P. da, Miranda, D., & Santos, F. (2011). *Stained Bodies: prisoners' perceptions of the DNA database for criminal investigation purposes and their perspectives of social reintegration*. Retrieved from http://dnadatabase .ces.uc.pt/list documents.php

Malsh, M., de Keijser, J., Luining, E., Weulen Kranenbarg, M., & Lenssen, D. (2016). Hoe hard is DNA bewijs? Internationaal-vergelijkend onderzeoek naar de interpretatie van DNA-profielen. *Nederlands Juristenblad*, 91(18), 1261–1266.

Mapes, A. A., Kloosterman, A. D., & de Poot, C. J. (2015). DNA in the Criminal Justice System: The DNA Success Story in Perspective. *Journal of Forensic Sciences*, 60(4), 851-856. doi:doi:10.1111/1556-4029.12779

Mapes, A. A., Kloosterman, A. D., & de Poot, C. J. (2015). DNA in the Criminal Justice System: The DNA Success Story in Perspective,. *Journal of Forensic Sciences*, 60(4), 851–856. https://doi.org/10.1111/1556-4029.12779

Mazerolle, P., Brame, R., Paternoster, R., Piquero, A. R., & Dean, C. (2000). Onset age, persistence, and offending versatility: comparisons across gender. *Criminology*, 38(4), 1143-1172.

McCartney C. I., Wilson T. J. & Williams R. (2011), Transnational Exchange of Forensic DNA: Viability, Legitimacy and Acceptability, *European Journal on Criminal Policy and Research,* 17(4), 305-322.

Meulenbroek, A. (2009). *De essenties van forensisch biologisch onderzoek: humane biologische sporen en DNA*. Zutphen: Paris.

Morgan D. L. (1998), *Focus Groups as qualitative research*.

Morselli, C. (2009). *Inside criminal networks* (Vol. 8). New York: Springer.

Mortelmans, D. (2010). Het kwalitatief onderzoeksdesign. In *Kwalitatieve methoden en technieken in de criminologie* (pp. 73–118). Leuven; Den Haag: Acco.

NFI. (2013). *Het jaarverslag 2012 van de Nederlandse DNA-databank voor strafzaken* (p. 25). Nederlands Forensisch Instituut. Retrieved from http://dnadatabank.forensischinstituut.nl/dna_dossier/jaarverslagen_dna_databank/index.aspx

Paillé, P., & Mucchielli, A. (2012). *L'analyse qualitative en sciences humaines et sociales. Paris: Armand Colin*. Retrieved from https://www.cairn.info/l-analyse-qualitative-en-sciences-humaines--9782200249045.htm

Ponsaers, P., & Pauwels, L. (2007). Naar een optimalisering van de toegankelijkheid van criminografische data op lage aggregatieniveaus in België? . *Panopticon*, 28(3), 1-5. Prainsack, B., & Kitzberger, M. (2009). DNA behind Bars: Other Ways of Knowing Forensic DNA Technologies. *Social Studies of Science*, 39(1), 51–79.

Reiss, A. J. (1988). Co-offending and criminal careers. *Crime and Justice*, 10, 117-170.

Renard, B. (2008). *Ce que l'ADN fait faire à la justice. Sociologie des traductions dans l'identification par analyse génétique en justice pénale*. (Thèse de doctorat). Université catholique de Louvain.

Ribaux, O., & Talbot Wright, B. (2014). Expanding forensic science through forensic intelligence. *Science and Justice*, 54, 494-501.

Ribaux, O., Baylon, A., Lock, E., Delémont, O., Roux, C., Zingg, C., & Margot, P. (2010). Intelligence-led crime scene processing. Part II: Intelligence and crime scene examination. *Forensic Science International*, 199(1–3), 63–71. https://doi.org/10.1016/j.forsciint.2010.03.011

Roman, J., Reid, S. E., Chalfin, A. J., & Knight, C. R. (2009). The DNA field experiment: a randomized trial of the cost-effectiveness of using DNA to solve property crimes. *Journal of Experimental Criminology*, 5(4), 345. doi:10.1007/s11292-009-9086-4

Roman, J., Walsh, K., Lachman, P., & Yahner, J. (2012). *Post-Conviction DNA Testing and Wrongful Conviction*: Urban Institute.

Schroeder, D. (2007). DNA and Homicide Clearance: What's Really Going On? *The Journal of the Institute of Justice & International Studies*, 7, 279-298.

Scott, J. (2013). *Social network analysis* (3rd ed.). Los Angeles: Sage.

Scudder, N., & Hamer, D. (2006). Exclusionary DNA of forensic workers and Australian forensic procedures legislation. *Current Issues in Criminal Justice*, 18(1), 125–146.

Simpson, S., Lyday, R., Hayasaka, S., Marsh, A., & Laurienti, P. (2013). A permutation testing framework to compare groups of brain networks. *Frontiers in Computational Neuroscience*, 7(171). doi:10.3389/fncom.2013.00171

Smith, J. A., & Moody, J. (2013). Structural Effects of Network Sampling Coverage I: Nodes Missing at Random. *Social Networks*, 35(4). doi:10.1016/j.socnet.2013.09.003

Smith, J. A., Moody, J., & Morgan, J. (2017). Network sampling coverage II: The effect of non-random missing data on network measurement. *Social Networks*, 48, 78-99. doi:10.1016/j.socnet.2016.04.005

Sparrow, M. K. (1991). The application of network analysis to criminal intelligence: An assessment of the prospects. *Social Networks*, 13, 251-274.

Stappers, C. (2018). *DNA in strafzaken: een analyse van het gebruik*. Paper presented at the Journée Nationale ADN – Nationale Studiedag DNA, Brussels.

Taverne, M. D., Nijboer, J. F., Abdoel, M. F., & Farooq, S. (2012). *DNA in de databank: de moeite waard? Een procesanalyse binnen de strafrechtsketen met het oog op de effectiviteit en efficiëntie van de toepassing van de Wet DNA-onderzoek bij veroordeelden*. [Onderzoek WODC, Universiteit Leiden, Faculteit Rechtsgeleerdheid]. Retrieved 29 July 2015, from http://www.rijksoverheid.nl/documenten-en-publicaties/rapporten/2013/03/04/dna-in-de-databank-de-moeite-waard.html

Tegner Anker, A. S., Doleac, J. L., & Landerso, R. (2017). *The Effects of DNA Databases on the Deterrence and Detection of Offenders*. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2811790

Tilley, N., & Townsley, M. (2009). Forensic science in UK policing: strategies, tactics and effectiveness. In J. Fraser & R. Williams (Eds.), *Handbook of forensic science* (pp. 359-379). Cullompton: Willian Publishing.

Tompson, L., Johnson, S., Ashby, M., Perkins, C., & Edwards, P. (2014). UK open source crime data: accuracy and possibilities for research. *Cartography and Geographic Information Science*, 42(2), 97-111. doi:10.1080/15230406.2014.972456

Toom, V., *Dragers van waarheid: Twintig jaar forensisch DNA-onderzoek in Nederland*, Kluwer, Deventer, 2011

Townsley, M., & Sidebottom, A. (2010). All offenders are equal, but some are more equal than others: variation in journeys to crime between offenders. *Criminology*, 48(3), 897-917. doi:10.1111/j.1745-9125.2010.00205.x

Townsley, M., Smith, C., & Pease, K. (2006). First Impressions Count: Serious detections arising from Criminal Justice Sample. *Genomics, Society and Policy*, 2(1), 28-40.

United Nation Office on Drugs and Crime [UNODC]. (2009). *Crime scene and physical evidence awareness for non-forensic personnel*. New York: United Nations.

Van Campenhoudt, L., Chaumont, J-M. & Franssen, A. (2005), *La Méthode d'analyse en groupe. Applications aux phénomènes sociaux*, Paris, Editions Dunod.

Van Campenhoudt, L., Franssen, A. & Cantelli, F., 2009, "La méthode d'analyse en groupe: explications, applications et implications d'un nouveau dispositif de recherche", *Theories et Recherches.*

Van den Heuvel C. *et al (2005), Forensisch DNA-onderzoek: een rechtsvergelijkende verkenning.*

van der Hulst, R. C. (2009). Introduction to Social Network Analysis (SNA) as an investigative tool. *Trends in Organized Crime*, 12(2), 101-121. doi:10.1007/s12117-008-9057-6

van Koppen, P. (2011). *Overtuigend bewijs. Indammen van rechterlijke dwalingen*. (Nieuw Amsterdam).

Vander Beken, T. (2007). Toegang tot data van politie en justitie: nog moeilijker dan het al was? *Panopticon*, 28, 80-82.

Vander Beken, T., & Van Daele, S. (2012). De gunst van de poortwachters: reflecties over wetenschappelijk onderzoek met persoonsgegevens uit de strafrechtsbedeling. In E. Devroe, L. Pauwels, A. Verhage, E. M., & M. Cools (Eds.), *Tegendraadse criminologie*. Liber Amicorum Paul Ponsaers (pp. 275-285). Antwerp: Maklu.

Vandeviver, C., Neutens, T., Van Daele, S., Geurts, D., & Vander Beken, T. (2015). A discrete spatial choice model of burglary target selection at the house-level. *Applied Geography*, 64, 24-34.

Wallace, H. (2006). The UK National DNA Database: balancing crime detection human rights and privacy. *EMBO Reports*, *vol. 7,* 26-30.

Walsh, S. J., Curran, J. M., & Buckleton, J. S. (2010). Modeling forensic DNA database performance. *Journal of Forensic Sciences*, 55(5), 1174-1183.

Wang, D. J., Shi, X., McFarland, D. A., & Leskovec, J. (2012). Measurement error in network data: A re-classification. *Social Networks*, 34(4), 396-409. doi:10.1016/j.socnet.2012.01.003

Warr, M. (2002). *Companions in crime. The social aspects of criminal conduct*. Cambridge Cambridge University Press.

Wasserman, S., & Faust, K. (1994). *Social Network Analysis: Methods and Applications*. New York: Cambridge University Press.

Weerman, F. M. (2001). *Samenplegen. Over criminele samenwerking en groepsvorming*. Nijmegen: Ars Aequi Libri.

Weerman, F. M. (2003). Co-offending as social exchange: Explaining characteristics of co-offending. *British Journal of Criminology*, 43, 398–416.

Wiles, P., & Costello, A. (2000). The 'road to nowhere': the evidence for travelling criminals. Retrieved from London: library.college.police.uk/docs/hors/hors207.pdf

Press

Decré, H. (2018, November 16). 17 Jaar lang spoorloos, nu gevonden in anoniem graf in klein dorpje in Wallonië. *Vlaamse Radio en Televisie*. Retrieved at www.vrt.be.

Porter, H. (2009, May 25). The rising odds of false DNA matches. *The Guardian*. Retrieved from www.theguardian.com

X. (2018, March 12). Federale Politie heeft 138 dossiers rond niet-geïdentificeerde doden. *Het Laatste Nieuws*. Retrieved at www.hln.be

Belgian legislation

Act of 5 August 1992 on the function of the Police, *BS* 22 December 1992.

Act of 8 December 1992 on the protection of privacy, *BS* 18 March 1993.

Act of 22 March 1999 concerning the identification through DNA analysis in Criminal Cases, *BS* 20 May 1999, 17547.

Act of 7 November 2011 concerning the amendments to the Code of Criminal Procedure and the Act of 22 March 1999 regarding the identification through DNA analysis, *BS* 30 November 2011, 70716.

Act of 21 December 2013 amending the Code of Criminal Procedure and the Act of 22 March 1999 concerning the identification through DNA analysis for the establishment of a DNA database 'Missing Persons', *BS* 30 January 2014, 8360.

Act of 10 April 2014 for the amendment of article 8 of the Act of 22 March 1999 concerning the identification through DNA analysis to facilitate the international exchange of DNA data, *BS* 30 April 2014.

Act of 10 April 2014 introducing probation as a stand-alone punishment in the Criminal Code and amending the Code of Criminal Procedure and the Act of 29 June 1964 concerning the delay and probation (1), *BS* 19 June 2014, 35758.

Act of 28 June 2015 for the amendment of the Act of 21 December 2013 amending the Code of Criminal Procedure and the Act of 22 March 1999 regarding identification through DNA analysis in order to establish a DNA database Missing Persons regarding the date of entry into force (1), *BS* 30 June 2015, 37587.

Act of 1 February 2016 amending different provisions concerning infringement of honorability and voyeurism, *BS* 19 February 2016.

Act of 9 April 2017 amending the Act of 21 December 2013 concerning the establishment of a DNA database 'Missing Persons', *BS* 4 May 2017.

Act of 17 May 2017 amending the Code of Criminal Procedure and the Act of 22 March 1999 concerning the identification through DNA analysis for the establishment of a DNA 'Elimination Database', *BS* 31 May 2017.

Royal Decree of 4 February 2002 concerning the execution of the Act of 22 March 1999 regarding identification through DNA-analysis in Criminal Cases, *BS* 30 March 2002, 14461.

Royal Decree of 17 July 2013 concerning the execution of the Act of 7 November 2011 regarding the amendments to the Code of Criminal Procedure and the Act of 22 March 1999 regarding the identification through DNA analysis, *BS* 12 August 2013, 52393.

Royal Decree of 27 November 2015 concerning the execution of article 6 of the programme act (II) of 27 December 2006 regarding the determination of the rates in criminal cases for the expert's report in genetic analysis commissioned by a judicial authority, *BS* 30 November 2015, 72965.

Draft Act concerning the amendments to the Code of Criminal Procedure and the Act of 22 March 1999 regarding the identification through DNA analysis, n° 53-1504.

Foreign Legislation

(UK) Police And Criminal Evidence Act 1984.

(French) Act 17 June 1998 concerning the fight against crimes of a sexual nature (Loi relative à la répression des infractions de nature sexuelle)

(French) Act 18 March 2003 on homeland security (Loi sur la sécurité intérieure).

(Dutch) Act 1 September 1994 on DNA-analysis.

(Dutch) Act 16 September 2004 concerning the DNA-analysis on Convicted Offenders (Act DNA-Analysis Convicted Offenders)

(Dutch) Decision 27 August 2001 concerning detailed regulation on the use of DNA-analysis in Criminal Cases (Decision DNA-analysis in Criminal Cases)

(Dutch) Regulation 17 October 2001 concerning DNA-analysis in Criminal Cases.

(Dutch) Guideline 9 February 2012 concerning DNA kinship analysis.