Rapid DNA technologies at the crime scene

‘CSI’ fiction matching reality

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Chapter 1

Introduction
Rapid DNA analysis has been standard procedure for years in the well-known series ‘CSI’ to identify perpetrators within hours. Although this series is clearly fiction, it is possible that ‘CSI’ predicts the future forensic investigation process. This thesis describes how a mobile Rapid DNA analysis device can be used to act as a potential effective tool in modern day law enforcement. In 2010 the FBI established a Program Rapid DNA analysis for the introduction of rapid and mobile DNA technologies for use by law enforcement (1). As it can be expected that mobile DNA technologies will cause a paradigm shift in the role of forensic institutes and the tasks of professionals in the Criminal Justice System (CJS) we have investigated how mobile Rapid DNA technologies can be used efficiently and successfully in the CJS in the Netherlands. Key figures on the contribution of DNA to the identification of suspects and on the actual success rate of the DNA profiling process in analysing biological traces form a wide range of items illustrate the potential benefit of implementing mobile and Rapid DNA technologies in the Dutch CJS. We show how the possibility to deploy Rapid DNA analysis at the crime scene affects the decision-making processes of Scene of Crime Officers (SoCOs) regarding the selection of biological traces for subsequent DNA analysis. For that reason, we developed a decision model for the use of mobile Rapid DNA technologies by SoCOs. We also point out the need to establish a legal environment conducive to the harmonious introduction of mobile Rapid DNA technologies at the crime scene.

1.1 DNA as Investigative Tool

DNA analysis for forensic purposes became important more than three decades ago when Sir Alec Jeffreys discovered individual specific DNA patterns leading to the well-known forensic DNA fingerprint (2, 3). The use of DNA analysis for intelligence purposes and as scientific evidence in criminal cases has grown tremendously ever since. A lot of research effort has been devoted to exploring the full potential of DNA technology to identify perpetrators, solve crimes, protect the innocent and to identify missing persons (4). Part of this research has concentrated on the analysis of samples containing low levels of DNA. This technology enables the forensic community to obtain informative DNA typing data from a broad spectrum of crime scene samples (5, 6).

1.2 Rapid DNA

Over the last years many studies have been performed to create fully integrated DNA analysis systems with the purpose of speeding up the current DNA analysis process (7-13). This has led to a Rapid DNA Program Office established by the FBI in 2010, to facilitate the development and integration of Rapid DNA technology for use by law enforcement (13). This has led to a Rapid DNA Program Office established by the FBI in 2010, to facilitate the development and integration of Rapid DNA technology for use by law enforcement (13).
enforcement. This programme was set up to create a way to rapidly analyse reference samples of a suspect while the arrestee is still in police custody and to compare his/her profile with the profiles in the Combined DNA Index System (CODIS) database of unsolved crimes (1).

In 2011, the first promising mobile Rapid DNA technologies were launched that are able to perform Short Tandem Repeat (STR) analysis of reference samples (mouth swabs), human tissue samples, and objects with low DNA copy numbers, allowing for the potential analysis of crime scene samples (14). Given these developments, the time was right to set up a large project in the Netherlands with the goal to examine the impact of “bringing science to the crime scene”, with the aim to support the intelligence process in identifying perpetrators (15). The research into mobile and Rapid DNA technologies is part of this project. The project started in August 2012 when Rapid DNA analysis options came into view in the field of forensic science (16). The goal of these new technologies was to create a Rapid DNA analysis system that can be operated by the SoCOs directly at the crime scene and to obtain DNA analysis results within two hours. Some of these developments were discontinued (MiDAS (8)), some took a long time to progress (MinLon (17)), some are still progressing (DNAscan (18), Portable DNA analyzer (19)) and a few actually resulted in working mobile Rapid DNA systems for forensic use (RapidHIT 200 (20), ParaDNA (21)). At the start of this research project it became evident that mobile Rapid DNA technologies are finding their way in the forensic world and without doubt will have an impact on future criminal investigative practices.

1.3 Rapid DNA at the Crime Scene – The Research Question

To assure that criminal investigations will benefit from the full potential of mobile Rapid DNA technology it is important to understand how to use this technology at the crime scene. This raises the following research question:

"What is the impact of implementing mobile Rapid DNA technologies at the crime scene to identify a perpetrator and how can we optimally regulate the process of analysing and obtaining Rapid DNA profiling results to ensure acceptance within the criminal justice system?"

To answer this question, it should be realised that implementing Rapid DNA technology will lead to a technology-driven change in the complex field of the CJS. On the one hand, accelerating the investigative process can be extremely valuable to rapidly identify perpetrators and solve crimes. On the other hand, it is of the utmost importance to prevent any miscarriage of justice due to the wrongful analysis and interpretation of DNA evidence. Many parties are involved in the process of convicting or acquitting a
suspect in a criminal investigation; these are mainly the police, the laboratory, the prosecution, the defence, the court of law, the Ministry of Justice and even the public (Figure 1). All these parties fulfil different roles and represent different values in the criminal justice chain. It is therefore important to realise that the integration of a mobile Rapid DNA analysis option at the crime scene will have an impact on current processes and/or the beliefs of these parties.

To summarise the current forensic DNA process in the Netherlands: it starts with a crime scene where SoCOs perform their investigation and collect DNA traces. After a selection process the DNA trace(s) are upon request of the Public Prosecutor sent to the laboratory for analysis. The outcome of the investigation is submitted to the prosecutor and the police, after which a suspect may be apprehended and the DNA match might serve as evidence in the court of law. Figure 1 shows the relation between the different parties in the criminal justice chain when considering DNA evidence. The prosecution is the authority of the criminal investigation and safeguards the legal process of the CSI and analysis procedures to finally prosecute a suspect. Both the police and the prosecution are mainly focused on rapidly identifying a suspect during the intelligence phase of the investigation and finding evidence to build the case in the evidence phase of the investigation. SoCOs facilitate this process through performing crime scene investigation (CSI) to detect, collect and select traces for DNA analysis. The laboratory facilitates the process of DNA analysis and is focused on obtaining the best DNA analysis results leading to potential matches. The defence is mainly focused on acquitting the suspect, potentially through exculpatory evidence, discovering implications of misjustice or ‘flaws’ in the process and chain of evidence. The court of law is the final decision-maker to convict or acquit. The Ministry of Justice proposes legislation for the rules and regulations under which the CJS and the criminal trial need to operate. And finally, the public either trusts or distrusts the CJS, based on the perceived integrity of the CJS and safety of the community.
1.4 Sub-research Questions

Once the Rapid DNA technology becomes available the current process of collecting, selecting and using the DNA evidence will change and the parties involved may find themselves in a conflict of interests. The police are focused on rapidly apprehending a suspect rather than using the most sensitive and optimal, but often time-consuming, DNA analysis technique used by the laboratory. This underlines the necessity to map the road ahead in the forensic DNA analysis process once the Rapid DNA technology is ready to be integrated. In this respect the following sub-questions were formulated:

1. What is the current DNA success story in terms of identifying a suspect?
2. What are the DNA success rates for various items or traces?
3. Can this knowledge on DNA success rates assist the Rapid DNA analysis procedure?
4. How will SoCOs operate when Rapid DNA analysis is introduced?
5. How can the Rapid DNA technology be used within the current legal situation?
6. How can we optimally regulate the decision-making process when Rapid DNA is used at the crime scene?
7. What is the future perspective of forensic investigations when Rapid DNA analysis at the crime scene becomes feasible?

1.5 Research Project

The research questions above reveal that a technology-driven study will affect all parties within the CJS. There is a need to understand 1) the technological implications of the Rapid DNA analysis system and 2) the behavioural implications at the crime scene when deciding to use Rapid DNA analysis. The challenge in this research is to link technological science, behavioural science and juridical science to obtain a better understanding of the procedural and contextual aspects of applying the Rapid DNA technology. This knowledge can be used to understand the decision-making process and to make future recommendations for the DNA analysis procedures. To optimally approach this topic, the Human Factors Development Approach (Figure 2, (22, 23)) was used as an example to systematically combine the interaction between humans, technology and information. This enables the CJS to better assess the future use of the given technology in practice for decision-making and policy recommendations. The Human Factors Development Approach consists of three phases:
1. The *Analysis phase*, in which the objectives and factors for Rapid DNA analysis are analysed. To paint a broad picture of current and future processes we will take behaviour, capabilities, tasks and the work environment into account.

2. The *Iterative Design & Testing phase* uses the information from the analysis phase to define users’ implications of Rapid DNA analysis and to collect data through human performance observations. In this second phase the requirements for a potential design are formulated and tested with technology users.

3. The *Implementation phase* serves to improve the design for operational use and to test it in actual cases before implementation of the mobile Rapid DNA analysis (22, 23).

This study focuses on the first two phases to formulate a final design for a possible future implementation of Rapid DNA technologies. For the first phase, knowledge regarding the following factors is essential: the current status quo of Rapid DNA analysis, DNA success rates, crime scene practices, decision-making and human factors at the crime scene, the effect of implementing new technologies, Rapid DNA and the law, and rational decision-making. The second phase focuses on Rapid DNA analysis at the crime scene and seeks to develop, test, analyse and document the requirements and objectives needed for working with this new technology. The dissertation ends with summarising and reflecting on the studies performed and considering the knowledge obtained to answer the main research question. In addition, a final design for implementing Rapid DNA technologies at the crime scene is discussed, with a vision on the way forward in crime scene investigation.

<table>
<thead>
<tr>
<th>Human Factors Development Approach*</th>
<th>Mobile Rapid-DNA System</th>
<th>Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Define project goals and system functionality.</td>
<td>- Define factors of influence for Rapid DNA analysis.</td>
<td>Chapter 1</td>
</tr>
<tr>
<td>2. Analyse user capabilities, tasks, and work environment; allocate tasks between humans and system.</td>
<td>- Generate general view on DNA as an investigative tool.</td>
<td>Chapter 2</td>
</tr>
<tr>
<td>3. Document user needs and requirements; develop initial design prototypes and usability goals.</td>
<td>- Define technological implications.</td>
<td>Chapters 3-5</td>
</tr>
<tr>
<td>4. Conduct usability testing studies; evaluate results against performance goals and objectives.</td>
<td>- Define users’ behavioural implications.</td>
<td>Chapter 6</td>
</tr>
<tr>
<td>5. Develop final design specifications for user interface.</td>
<td>- Define legal implications.</td>
<td>Chapter 7</td>
</tr>
<tr>
<td>6. Evaluate interface designs during actual usage.</td>
<td>- Combine behavioural and technological implications to design a support system and test it.</td>
<td>Chapter 8</td>
</tr>
</tbody>
</table>

(*Salvemini 1999, 2015 (22, 23))

**Figure 2.** Human Factors Development Approach used to Outline this Research Towards Integrating Mobile Rapid DNA Systems at the Crime Scene for the use of Scene of Crime Officers.
1.6 Relevant Factors in Rapid DNA Analysis

1.6.1 Status Quo Rapid DNA Analysis

Speeding up crime scene investigations and solving backlogs has since long been a point of discussion in forensics (4, 24-27). In 2002 the UK started implementing what they call ‘DNA fast-tracking’ which is considered an initiative to “reduce the time taken to capture, analyse and match DNA against the national DNA database and the subsequent police response to hits” (25). DNA databases have been shown to have great potential for the criminal investigation, particularly at case level. Matching traces with the DNA database has also proved valuable for broader strategic criminological research to identify unknown offenders, serial offenders and/or co-offenders (28, 29). DNA fast-tracking seems especially useful to speed up the process of identifying a suspect through DNA when there are no direct leads in a criminal case. In the Netherlands such a DNA fast-tracking option is the product called ‘DNA-6 hours’ at the Netherlands Forensic Institute (NFI). This can be used by the police in specific cases to rapidly analyse DNA traces for indicative purposes (30, 31). The current DNA analysis process from crime scene to laboratory is shown in Figure 3 and the turnaround time of this process depends strongly on the time between the crime scene investigation and start of the analysis procedure at the laboratory. The fastest option for standard analysis of a DNA sample at the laboratory is roughly 9 to 12 hours, and it consists of several process steps as shown in Figure 3 (32).

<table>
<thead>
<tr>
<th>Crime Scene</th>
<th>Sample preparation</th>
<th>Cell lysis/ DNA extraction</th>
<th>DNA quantification</th>
<th>Dilution</th>
<th>PCR amplification</th>
<th>Detection and profiling</th>
<th>Profile/database comparison</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>hrs - weeks</td>
<td>hrs - weeks</td>
<td>1 hr 45 min</td>
<td>2 hr 20 min</td>
<td>15 min</td>
<td>3 hr 30 min</td>
<td>2 hr</td>
<td>2 hr</td>
<td>2 hr</td>
</tr>
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</table>

![Figure 3](Image)

**Figure 3.** Current and Future DNA Analysis Process

Studies have shown that reducing the turnaround time could result in earlier identification, which in turn might quicken offenders’ apprehension and incarceration rates and therefore a more substantial impact on crime solving is expected (25, 27, 28). All together this suggests that a fast throughput of forensic DNA samples for analysis is crucial for criminal investigations.

Currently, there are technologies that make it possible to process DNA samples immediately at the crime scene. The objective of such a mobile Rapid DNA analysis
system is to process a DNA sample at the scene, in order to generate intelligence concerning the source of the sample that can be used to identify and capture a suspect within hours, if possible. This possibility could have great value for a criminal investigation. Especially when a suspect is still on the run, the safety of society could be at stake if the suspect is not identified rapidly. By swiftly apprehending the suspect, he or she may still be carrying traces of the crime upon arrest, for instance DNA evidence of the victim or the stolen goods. As a result, a much stronger case could be built, and by taking offenders from the streets more quickly, crime rates could be reduced. This is expressed by Van Asten (2016) (33) “Any criminal investigation is aided by immediate results as it provides police teams with important information to solve the crime in the important initial hours after its discovery. Providing real-time forensic information can, however, be very valuable as it allows these police teams to direct the investigation, use their scarce resources efficiently and effectively and ultimately solve more crimes.”

The mobile Rapid DNA technology seems to open up the option of establishing immediate results on site and to allow investigators to pursue their criminal investigation more quickly and more effectively. Several manufacturers have created computer type Rapid DNA systems for this purpose that require minimal training to be operated (20, 34-36). It merely requires swabbing a trace and inserting the trace sample in the system and having the DNA analysis carried out at the push of a button. This dissertation does not go into the detail of the internal functions of the Rapid DNA systems, but factors of sensitivity, sample consumption and contamination issues are important to take into account when designing future DNA analysis procedures.

The Rapid DNA technology is a fully automated sample-in answer-out profiling system for STR based human identification (35). These systems integrate all laboratory steps as indicated in Figure 3, including data analysis to generate DNA profiles within 2 hours (37), enabling an effective future DNA analysis process. Although all DNA analysis steps are integrated into this one system, the process could result in less sensitive DNA analysis. For crime scene samples it is essential to realise that the quantity of DNA is often low, as ‘touch’ DNA samples are frequently collected from the crime scenes. Touch DNA samples usually contain (much) less than 100 picograms of DNA, requiring the most sensitive analysis options such as Low Copy Number (LCN) DNA analysis (32, 38, 39). Additionally, most Rapid DNA systems lack the possibility of securing part of the sample for re-analysis and mobile analysis should therefore be considered destructive. This could impact the use of Rapid DNA analysis and effect future Rapid DNA procedures. The most recent literature shows that Rapid DNA technologies are progressing to analyse DNA samples as low as 50 picograms of DNA when directly pipetted in the cartridge (40), possibly opening up ways for the future analysis of a wide range of trace samples including touch DNA samples.
1.6.2 DNA Success Rates

As explained in the previous section, the sensitivity of the Rapid DNA analysis systems is lower than the conventional laboratory techniques. The DNA success rate factor will therefore play a vital role in Rapid DNA analysis procedures. Knowledge of success rates is crucial for future decisions on whether to use Rapid DNA or conventional analysis of crime scene samples. A thorough literature review revealed scarce and incomplete knowledge on the DNA success rates of various traces used in criminal investigations (5, 41-46). So far it is known that DNA success rates of different categories of traces vary, but it is unclear how this knowledge will assist the DNA laboratory or the SoCOs in the triage and selection process of DNA traces from the crime scene. This becomes especially important once rapid analysis of DNA samples at the crime scene becomes reality.

The majority of the studies on DNA success rates were merely on a successful analysis of a certain DNA trace in a case, but did not investigate the nature of DNA typing results obtained in combination with the amount of DNA extracted. In general, these studies ranked DNA success rates in terms of body fluid versus contact/touch traces. Based on these studies it can be concluded that body fluids yield the highest success rates and contact traces the lowest. However, DNA results from various traces, taking into account the nature of the DNA sample, the quality of DNA, the quantity of DNA, the DNA profile and matching results should be combined to obtain the complete story on DNA success rates. This is vital knowledge for the triage decision to analyse traces rapidly on the crime scene or at the laboratory.

1.6.3 Crime Scene Practice

SoCOs are often the first responders to investigate the crime scene. They are the ones ‘reading’ the crime scene in search of forensic evidence to build a case. The core business of the SoCOs is to detect, collect, prioritise and select traces for analysis to help identify suspects and/or to serve as evidence in the criminal trial.

For the detection and collection phase of the crime scene practice, Dutch SoCOs are required to follow the systematic 4-phases model: 1) an initial general examination (‘walkthrough’) of the crime scene known as the orientation phase; 2) creating a plan of approach; 3) a trace detection and collection phase known as the forensic examination, and 4) a final walkthrough of the crime scene after which preliminary results are formulated (47-49). The 4-phase model is followed by the process of selecting traces and deciding to forward traces for analysis to the laboratory. This process is typically conducted at the police station where scenarios are formulated and all evidence is weighed before traces are send to the laboratory. Finally, the DNA typing results are used in the criminal investigation, either as ‘forensic intelligence’ to arrest a suspect or serve as ‘forensic evidence’ in court. Structuring the crime scene practice process in this way serves to minimise the possibility of overlooking important traces and to collect...
necessary information to build the case. This process is in accordance with international guidelines for crime scene procedures (50-53). Based on these guidelines and knowledge about common procedures, the complete process from crime scene to DNA profile with the accountable professionals can be summarised as followed:

1. Securing and protecting the crime scene (and its traces)- *police officer*
2. Preliminary non-intrusive orientation on the crime scene including a walkthrough, observation and documentation - *scene of crime officer*
3. Plan of approach including initial views on crime scenarios (hypotheses) of what could have happened to assist in detecting and collecting traces - *scene of crime officer*
4. Detection, collection and documentation of the localised physical evidence at the crime scene - *scene of crime officer*
5. Rounding up the crime scene investigation with a final walkthrough, gathering all evidence and information to be taken to the police station and securing the crime scene - *scene of crime officer*
6. Detailed formulation and documentation of crime scenarios to assist the process of trace prioritisation, selection and decision for further (scientific) analysis - *scene of crime officers (sometimes in cooperation with tactical officers, forensic experts and/or prosecutors)*
7. (Scientific) analysis of the selected traces at the forensic laboratory (i.e. DNA analysis) or police station (i.e. fingerprint analysis) - *forensic analysts*
8. Interpretation of results from the analysed traces - *forensic experts*

For the purpose of Rapid DNA analysis at the crime scene, the current 4-phase model used in the Netherlands for crime scene practice will be incomplete, as the selection and decision process to analyse a trace also must be made at the crime scene. This will probably result in more complex guidelines for SoCOs conducting a crime scene investigation. To detect and collect traces, SoCOs need to recognise the nature of the detected trace evidence and need to recognise and understand the link of a trace with the crime. Once Rapid DNA analysis becomes operational, SoCOs will also need to consider the immediate analysis of the trace at the scene, by quickly assessing the trace’s suitability for analysis and the usefulness of the results in the given context (54). A new model integrating all steps of the process from crime scene to result, as described above, is essential for future Rapid DNA analysis processes, to maintain a secure and consistent chain of custody.

1.6.4 Decision-making and Human Factors
A crime scene investigation is an observer-based process and often performed by just one or a few SoCOs. The selection process of traces at the crime scene is an issue of
subjectivity. It all depends on whether the SoCO detects and recognizes the trace to start with. This indicates that a crime scene investigation is more than a scientific process: “forensic evidence is not simply ‘found’ at a crime scene; it is socially constructed” (55). Making decisions at the crime scene is therefore not only influenced by technical possibilities but also by human factors and capabilities, and the process is therefore prone to errors. To make correct decisions, an expert needs knowledge, skills, good judgment and experience to optimally evaluate and interpret information; but “being an expert does not necessarily mean error-free performance; in fact, almost every specialist domain is subject to error” (56). Nonetheless, at some point decisions have to be made and decisions often have to be made under time pressure, without knowing the ground truth of the crime.

Zero bias is not possible as long as humans investigate crime scenes (57). Therefore, the influence of human factors on decision-making can never be fully ruled out as long as crime scene investigation is a human and thus an observer-based process. Once mobile Rapid DNA analysis becomes operable, it is likely to have an effect on the focus of the SoCOs. This could potentially cause the investigation to focus on finding and analysing alleged perpetrator related traces\(^1\), and as a result overlooking other crime related traces (48).

It is important to examine these issues within an empirical and experimentally-based real world setting (56, 58), and acknowledge the possible impact of human factors on the decision-making process for DNA trace analysis at the crime scene. Understanding these processes is crucial to create better procedures and training, to achieve an optimal use of the rapid technology, and to improve decision quality (59).

1.6.5 Decision-making and Implementation of Technology

The implementation of new technologies is likely to influence the decision-making process. When investigating a crime scene, standard procedures have become embedded and, in combination with experience, have resulted in a certain ‘standard’ on how to do things (60). The interaction between human action, cognitive factors and the use of technology can challenge this standard (61, 62).

The assumption is that a rapid and efficient flow of information through the implementation of new technologies will help improve police work (63, 64). However, there is little literature on the impact of implementing new technologies on the effectiveness and efficiency of a criminal investigation (63, 65-68). Currently, the police often integrates technologies without examining the impact on the outcomes and procedures (64). Technological advances do not always produce straightforward improvements. The effects are complex and sometimes contradictory, and can even

\(^1\) We use the term ‘perpetrator relatedness’ throughout this thesis to indicate the potential connection of the perpetrator and the trace.
reduce police effectiveness (64, 66). Without careful research on the actual impact of new technologies, they may not bring the expected and desired outcomes (64).

The introduction of Rapid DNA technology is expected to enhance forensic intelligence to identify an offender. To avoid problems in the implementation of the Rapid DNA technology, it is imperative for researchers and practitioners to work together to analyse opportunities and consequences before implementation. It is therefore necessary to analyse current routines at a crime scene and to investigate how current crime scene practice may or should change when Rapid DNA technologies are introduced. For this purpose, empirical ‘real world’ experiments need to be designed to test current and future crime scene practice before moving towards implementation.

1.6.6 Rapid DNA and the Law
Before implementing Rapid DNA analysis in the CJS, it is important that the technology and the process are recognised by the legislators.

DNA testing as part of the criminal investigation is embedded in the Dutch Code of Criminal Procedure (Dutch: Wetboek van Strafverordening) and the DNA (Criminal Cases) Tests Decree. In the Netherlands the public prosecutor is the authority to order a DNA test, which is defined as the analysis of cellular material with the sole purpose of comparing DNA profiles. Once the public prosecutor authorises the DNA test of a trace, the trace will be submitted to a forensic laboratory. The current Dutch law stipulates that this DNA analysis must be performed by a designated expert, who is affiliated with a laboratory that has been accredited for this purpose. In addition, the law states that the expert must draw up a report detailing the results of the performed DNA test.

This implies that the use of Rapid DNA technology at the crime scene is bound by law and cannot simply be integrated as such. Therefore, an analysis of the legislative issues relating to current DNA analysis and the future possibilities of Rapid DNA analysis at the crime scene is essential.

1.6.7 Rational Decision Theory
Implementing a new and Rapid DNA technology will not only be a challenge to legislators, but it will also impact the current crime scene practice and decision-making process. The decision to immediately analyse traces can be a risk or an opportunity because the outcome of the analysis can have consequences for the rest of the investigative process (69). Not only can Rapid DNA results potentially lead to tunnel vision when traces are not perpetrator related and innocent people are rapidly identified as suspects, but also if the traces are perpetrator related Rapid DNA analysis can entail risks. On the one hand, performing a Rapid DNA analysis may result in rapid intelligence information; but, on the other hand, it can also lead to the loss of the sample if the amount of DNA in the sample was apparently too low for rapid analysis. To weigh these risks and opportunities, it is important to set a way on how to make decisions for
using the Rapid DNA analysis or not. Rational Decision Theory (RDT) could offer a solution to this issue through acknowledging all possible outcomes and explicitly evaluating the consequences of all these possibilities (70, 71). This can be modelled in a Decision Support System (DSS) that can assist SoCOs in dealing with the Rapid DNA analysis option.

In this case SoCOs are uncertain about what will happen when deciding to analyse a trace with the Rapid DNA technology because the true nature of the trace is unknown. RDT offers a simple way of quantifying the relative consequences of the possible outcomes into a decision threshold that may assist in making decisions on the use of the Rapid DNA analysis. We expect SoCOs to deal with uncertainties, through the use of a DSS, to make evidence-based decisions on the potential fitness of crime scene samples for rapid DNA analysis. The decision depends on the case and trace characteristics, and the Rapid DNA success rate of the trace in question.

Designing a DSS for Rapid DNA analysis based on RDT can help to develop a transparent and knowledge-based decision process, and using this system can result in a better-motivated reasoning, which benefits the thoughtfulness and the transparency of this process.

1.7 Outline and Contents of the Thesis

To study the impact of a Rapid DNA technology at the crime scene eight different studies were conducted. These studies are outlined in Figure 2 and further explained in the next sub paragraphs.

DNA as an investigative tool
This study gives a general view on DNA testing as an investigative tool. For this purpose, it is essential to analyse the role DNA can play in the intelligence process to identify a suspect. Therefore, three key features were monitored in the DNA typing process of DNA traces from crime scene to DNA report: 1) the quality of the profile; 2) the turnaround time of the various steps in this chain; and 3) the number of cold hits. By analysing these features, an initial view and understanding can be generated on the future influence of Rapid DNA analysis to speed up the criminal investigative process. For this, the study on ‘DNA in the criminal justice system: the DNA success story in perspective’ was set up and carried out as described in Chapter 2.

Technological implications
Rapid DNA technologies are less sensitive than traditional laboratory analysis and the inserted sample should be considered as consumed. Consequently, DNA success rates of several DNA evidence samples are essential to obtain solid knowledge on DNA success probabilities. This will permit the development of a design that integrates this
evidence-based knowledge on DNA success rates, to benefit the current forensic crime scene procedure and to optimise the current laboratory DNA analysis process. Therefore, a predictive analysis was performed and discussed in Chapter 3 in the study ‘DNA by the numbers - locations of usable DNA based on 24,466 crime samples’. This predictive analysis led to the study ‘Knowledge on DNA success rates to optimise the DNA analysis process: from crime scene to laboratory’, aimed at gaining scientific evidence-based knowledge on DNA success rates for both laboratory use and for SoCO use in their crime scene procedures, as discussed in Chapter 4. These studies opened the way to further analyse the impact of less sensitive Rapid DNA technologies on various crime scene DNA samples and to design an initial Rapid DNA analysis triaging and selection process as discussed in Chapter 5: ‘Objective data on DNA success rates can aid the selection process of crime samples for analysis by rapid mobile DNA technologies’

Behavioural implications
Here we have defined behavioural implications for the collection, selection and analysis process of DNA traces. By setting up a ‘real-life’ study, the effect of having a Rapid DNA analysis option on the SoCOs crime scene practice and decision-making process could be studied. The purpose of this study was to gain insight into the focus of the SoCO during the crime scene investigation, the SoCO’s awareness of DNA success rates before making decisions, the type of DNA traces collected and analysed, and the effect on making decisions if Rapid DNA analysis is possible. Subsequently, it is important to learn whether the expected DNA success rates as rated by SoCOs match the actual DNA success rates. Together these results can be used to set out the further features necessary to improve the Rapid DNA selection process and to design a decision-making process for Rapid DNA analysis. For this purpose, a mock crime scene of a violent home robbery was created where all participating SoCOs performed the same controlled CSI either with or without a Rapid DNA analysis opportunity. This study on ‘Rapid DNA analysis at a mock crime scene - The impact on collecting and analysing DNA traces’ is discussed further in Chapter 6.

Legal implications
The legislative implications are explored for implementing Rapid DNA analysis at the crime scene. The current DNA analysis procedure is strictly embedded with safeguards in the Dutch Criminal Procedure Code. It is therefore important to analyse the possibilities and impossibilities of the future use of Rapid DNA technologies by SoCOs under the current law; this matter is addressed in Chapter 7, ‘Mobile DNA technologies in crime scene investigation: the legal framework’.
Decision Support System (DSS)
In this study we combined the technological, behavioural and legal implications to design a DSS for the use of Rapid DNA analysis and to test it with SoCOs. In this DSS, the technological implications of the Rapid DNA success probabilities are combined with the behavioural implications of the decision to analyse a trace rapidly, and to design a way for Rapid DNA analysis decisions to be thoughtful and transparent, and to be accepted by the court of law. Therefore, in Chapter 8 ‘Decision support for using mobile Rapid DNA analysis at the crime scene’, the DSS is designed and tested to evaluate performance when mobile Rapid DNA analysis is possible. It is further analysed whether this DSS meets the requirements and objectives for the future handling of DNA crime scene samples by SoCOs.

Future perspective
In the last part of this research we offer the professionals of the CJS with a realistic view on the future of forensics and anticipate the idea of bringing modern technology to the crime scene. The goal is particularly to create an integrated forensic platform and to use technology to connect the laboratory to the crime scene, requiring both the forensic experts and the police to work together on developing technological and user interfaces. This study on ‘The interface between forensic science and technology: how technology could cause a paradigm shift in the role of forensic institutes in the criminal justice system’, as discussed in Chapter 9, supports the final phase of implementation in this research. Through reflecting on all studies performed as part of this thesis and considering the specifications for optimal use within the CJS, the final ‘Rapid DNA analysis decision-model’ is presented in Chapter 10 Reflection and Future Perspective.

1.8 References
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