

Understanding Vehicle Related Crime to Elaborate on Countermeasures Based on ADAS and V2X Communication

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Abstract—Among numerous types of criminal activities, vehicle related crime contributes to personal injury as well as to economic losses. Over the last 10 years vehicle related crime continuously constitutes over 10% of all crime in Germany. However, vehicle related crime is not particularly a German phenomenon but even more a worldwide problem which does not respect national borders. Meanwhile, connected mobility gains importance and vehicles are increasingly equipped with advanced driver assistance systems (ADAS). Additionally, the penetration of consumer electronics (CE) increases constantly. Hence, it seems promising to use these new technologies to tackle vehicle related crime. But to be able to apply these new technologies successfully against vehicle related crime, a systematic approach to understand these crimes in detail is necessary. To address this challenge, we apply two criminological theories, Rational Choice Perspective and Situational Crime Prevention, to the vehicle related context. We also provide an innovative idea for a countermeasure based on information and communication technologies (ICT).

Index Terms—security functions, crime science, ADAS, V2X communication.

I. INTRODUCTION

Crime and fear of crime are pervasive in our society either in discussions with friends and family, in the newspaper, on television or in the worst case even from first-hand experience. They contribute to personal injury, economic losses and reduced quality of life. According to statistics provided by the Federal Criminal Police Office in Germany [1], vehicle related crime has constantly constituted over 10% of the overall crime in Germany during the last 10 years. Being a worldwide ongoing phenomenon following different trends and developments, vehicle related crime affects everyone. After years of decline, the number of offences including especially professional vehicle theft is increasing again in both developed countries and in the emerging markets [2]. Criminals usually adjust their skills to keep step with countermeasures so that, as known from the stock exchange markets, no trend will eternally continue as it started [3]. Hence, it is important to be always a step ahead of criminals.

The penetration of consumer electronics and connected mobility within the automotive field increased over the last years and will further develop in the future. Additionally, the number of vehicles equipped with ADAS rises resulting in a

vast amount of sensors and actuators becoming available in vehicles.

Existing countermeasures dealing with vehicle related crime and fear of crime are mostly concentrated on the own vehicle so that they do not involve other vehicles, driver and passengers, infrastructure or integrated sensors to tackle crime. Hence, we claim that the aforementioned new technologies provide the opportunity to elaborate on innovative countermeasures, which tackle vehicle related crime as well as increase drivers' and passengers' sense of security.

To address this challenge and to elaborate on tailored countermeasures, which make use of new technologies, a systematical examination of vehicle related crime and especially the way crimes are performed is necessary. Thus, we are interested in a conceptual approach to analyze the stages of specific crimes which an offender goes through to commit the crime. Surveying the literature, two criminological approaches, Rational Choice Perspective and Situational Crime Prevention, together provide a conceptual framework to systematically analyze criminal acts. In Clarke's opinion [4] both theories can be used to tackle all categories of crime, and thus vehicle related crimes as well. Additionally, the success of the aforementioned theories has been demonstrated in several studies, which are summarized in [5] and [6]. Therefore, Rational Choice Perspective and Situational Crime Prevention are applied in this paper to discuss the suitability for identification of innovative countermeasures which make use of new technologies.

The following section defines terms and clarifies relations which are necessary for the further understanding of this paper. In the next section both theories, Rational Choice Perspective and Situational Crime Prevention, are discussed including a review of related literature. Before drawing a conclusion, we discuss the use of both theories to vehicle related crime and propose an innovative countermeasure.

II. TERM DEFINITIONS AND RELATIONS

The term vehicle related crime encloses a wide field of different forms of crimes which are in relation to a vehicle. A well-known criminal offense is vehicle theft being typically committed in order to gain temporary transportation, to commit another crime, to joyride, to strip down the vehicle

for resale of parts or to resell the entire vehicle [7]. Regarding vehicle theft, different forms and ways to steal the vehicle exist. The following list shows several opportunities to steal a vehicle, while the list does not claim to be complete:

- Theft of closed and unattended vehicle: The thief has no access to keys. Hence, he must gain physical access into the vehicle and bypass security systems.
- Showroom jacking: Thieves gain access to showrooms and steal the key or even key boxes. Afterwards, they use these stolen keys to get into possession of the according vehicles.
- Home jacking: Home jacking is similar to showroom jacking whereas the thief breaks into a private home and steals the keys.
- Opportunistic theft: The thief uses the inattention or levity of the driver to acquire the vehicle. For example, the owner leaves the keys in an unlocked vehicle or even leaves a running vehicle unattended.
- Fraudulent theft: The thief uses fraudulent methods to acquire the vehicle. For example, the offender pretends to be an employee of a valet parking service.
- Carjacking: The thief uses violence or threat of violence, often in connection with weapons, to get into possession of the running vehicle.

Apart from theft of whole vehicles, further types of crime such as theft of vehicle parts, theft from vehicles and vandalism exist. These crimes also occur in a wide spectrum of different forms and ways. Additionally, the term vehicle related crime includes any malicious attacks against the driver as well as passengers while entering, using and exiting the vehicle. So, in a nutshell, any malicious attacks directed against the driver, passengers and the vehicle causing any sort of damage or property loss and being in a broad sense in relation with a vehicle are considered as vehicle related crimes.

A couple of new technologies already entered or have the potential to enter into the market in the future. We will concentrate on three groups: ADAS, CE and vehicle-to-X (V2X) communication. Today, not only high class but also mid and even low class vehicles are equipped with ADAS. They represent most systems that make use of sophisticated sensors and actuators to support the driver in its driving process and consequently increase vehicle and road safety. A prominent example is adaptive cruise control (ACC), which controls the vehicle speed dependent of the distance to a vehicle in front. To measure the distance to the forward vehicle, either LIDAR (light detection and ranging) or radar sensors are usually used. Lane departure warning systems, which make use of a front camera to track road marking, and dynamic cornering lights, which actively adjust to light into corners, are also considered as ADAS. New technologies do not enter only into the automotive field but also in the consumer market and that even faster. Drivers and passengers are increasingly equipped with CE, which are enclosed in the second set. Especially smartphones play a growing role in daily life and provide growing processing power. V2X communication is the third set of new technologies being of interest for our approach. Using the term V2X communication, we consider

wireless communication, which is generally classified in two groups: vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication. V2V refers to communication between vehicles and V2I refers to communication between vehicles and infrastructure e.g. traffic lights, gas stations, construction side beacons and of course a backend. As mobile devices like smartphones, tablet PCs and notebooks play an increasing role and become permanent companions in our daily life, we extend V2X communication by vehicle to device (V2D) communication, which refers to the wireless communication of vehicles with the aforementioned mobile devices. For our purposes, the technical realization of wireless communication is of less importance at first glance. That means, we do not primarily care in detail how wireless communication is realized as a vast variety of known realizations exist having an increasing penetration. Thus, we simply imply that wireless communication is available.

Since our goal is to elaborate on countermeasures based on ADAS, CE and V2X communication to tackle vehicle related crime, we introduce the term security function. Security functions (not to be mixed up with safety functions) tackle targeted malicious attacks directed against the driver, passengers and / or the vehicle. The goal of security functions is to predict and prevent malicious attacks, warn from malicious attacks, reduce the impact of malicious attacks and / or help to investigate malicious attacks against the aforementioned stakeholders. To achieve their goal, security functions make use of the aforementioned technologies. An additional and non-negligible goal of security functions is to increase drivers' and passengers' sense of security.

To be able to elaborate on security functions, it is necessary to gain a deeper understanding of crime perpetration. We have seen in the beginning of this section that a vast variety of vehicle related crimes exist. Hence, it is important to have a systematical approach to conduct crime analyses and gain ideas for innovative security functions.

III. CRIMINOLOGICAL THEORIES

A. Rational Choice Perspective

The Rational Choice Perspective aims to understand crime from the perspective of the offender [4] and deals with the offender's decisions and choices made to commit a crime. Clarke and Cornish [8], [9], [10], being advocates of the Rational Choice Perspective, suggest several basic propositions. First of all, crimes are committed deliberately and follow a specific purpose. In other words, offenders commit crimes to derive benefits. However, the set of benefits is not limited to cash or material goods. Prestige, sexual satisfaction, fun or excitement can also be benefits from an offender's point of view. An example from the automotive field is vandalism on vehicles where offenders damage the vehicle either to satisfy their aggressions, to show off in front of peers or for other reasons which do not necessarily imply financial benefits.

Second, decisions and choices vary depending on the offense. Therefore, a distinction between crude crime categories like vehicle related crime and burglary is not

enough as these categories are too generic and cover a broad spectrum of offences for which many different skills and methods are needed. To analyze the decision and choice making process, the offence needs to be described as specific as possible to limit the frame. For example, Poyner and Webb [11] researched the influence of housing design and layout on crime, with the result that residential burglaries directed on cash and jewelry show different patterns from burglaries directed on electronic goods. First of all, electronic goods are bulky and need organization of transportation whereas cash and jewelry are much more portable. Second, burglars aiming at cash and jewelry are more flexible concerning escape from the crime scene because it is less likely that they park a vehicle in immediate proximity. Last but not least, dealing with electronic goods requires a more organized network. Consequently, depending on the target different measures are required to prevent domestic burglaries.

Clarke's and Cornish's final proposition focuses on the sequence of decisions and choices an offender makes during crime commission. At this point the script concept, which can be ascribed to Schank and Abelson [12], [13], [14], provides a systematical approach. By definition in [13], "*a script is a structure that describes appropriate sequences of events in a particular context. A script is made up of slots and requirements about what can fill those slots. The structure is an interconnected whole, and what is in one slot affects what can be in another. Scripts handle stylized everyday situations.*" That means, scripts consist of sequences of dependent events so that early events in the sequence are mandatory to enable the occurrence of later events. Furthermore, we have a causal chain of events which are categorized in scenes resembling a theatrical script. The script concept can operate at different levels of abstraction [14]. Abelson and Schank [13] suggest the following terminology to distinguish between different levels of abstraction: universal script, metascript, protoscript, script and track. The universal script represents the most abstract level and track represents the most specific and detailed level. Thus, related scripts can be classified hierarchically. However, the term script is used concurrently, on the one hand referring to a specific level of abstraction and on the other hand referring to a sequence of events regardless the level of abstraction.

A favorite example [15] to illustrate the script concept cited in literature [16], [17] is the so called "restaurant script" provided by Schank and Abelson [13]. The restaurant script structures the procedure of a restaurant visit as follows: entering the restaurant, waiting to be seated, getting the menu, ordering food, eating, getting the check, paying and exiting. The restaurant script might be subdivided for example into the following scenes: entering, ordering, eating and exiting [16]. In the case of the restaurant script a quiet general script is provided. But within the script, we have different tracks: a fast food track, a cafeteria track or plusher upmarket track [16]. In contrast to the general restaurant script, these different tracks involve different procedures dependent on the kind of restaurant. So the different scripts at the track level are subordinated to the general restaurant script.

At this point crime scripts arise. They are specific scripts describing events during crime commission. Although we have

the opportunity to describe the occurrence of events at various levels of abstraction, according to [18], only the track level is generally specific enough to generate suitable information to fulfill the purposes of situational crime prevention.

B. Situational Crime Prevention

Situational Crime Prevention has a long history in criminology since the early 1970s [17]. and achieved the break through with the publication of Clarke's collection of successful case studies in the early [5] and late [6] 1990s, which have shown the successful use of Situational Crime Prevention.

Situational Crime Prevention makes use of measures to reduce crime opportunities focusing on specific forms of crime. Thus, Situational Crime Prevention has a crime specific focus in common with the Rational Choice Perspective. Furthermore, Situational Crime Prevention comprises the immediate setting and aims to increase the risk and difficulty as well as reduce the rewards for the offender. To achieve its goals, the Situational Crime Prevention model provides a list of 25 techniques of situational prevention [19], [20] which are divided in five categories: increasing the effort, increasing the risks, reducing the rewards, reducing provocations and removing excuses. The first category summarizes techniques which increase the effort the offender has to make in order to commit the crime. The second category joins techniques which increase the risk the offender is exposed to during the criminal act. The third category aims at techniques which reduce the rewards and benefits the offender expects to achieve. The fourth category focuses on reduction and avoidance of provocations which may tempt or incite the offender to commit the offense. Techniques in the fifth category aim to remove excuses which offenders may use to justify their criminal acts.

To the best of our knowledge, Table I shows the last state of the opportunity reducing techniques consisting of five categories each with five techniques. The interested reader can find an extensive overview of the 25 techniques including examples in [19].

IV. APPLICATION OF CRIMINOLOGICAL THEORIES TO VEHICLE RELATED CRIME

In this section, we will show how to apply the script concept and the 25 opportunity reducing techniques to methodically analyze the perpetration of vehicle related crimes and to be able to identify security functions. First, the script concept from the Rational Choice Theory is used to structure vehicle related crimes hierarchically and break down offences into event sequences afterwards. In the subsequent step the 25 techniques from Situational Crime Prevention theory are used to systematically traverse through all events to identify possible security functions.

A. Application of the Script Concept to Vehicle Related Crime

As described in section III-A, the script concept can be used at different levels of abstraction [17] so that different families of scripts can be linked hierarchically beginning

TABLE I
25 TECHNIQUES OF SITUATIONAL PREVENTION [19]

Increase the effort (A)	Increase the risks (B)	Reduce the rewards (C)	Reduce provocation (D)	Remove excuses (E)
Target harden	Extended guardianship	Conceal targets	Reduce frustrations and stress	Set rules
Control access to facilities	Assist natural surveillance	Remove targets	Avoid disputes	Post instructions
Screen exits	Reduce anonymity	Identify property	Reduce emotional arousal	Alert conscience
Deflect offenders	Utilize place manager	Disrupt markets	Neutralize peer pressure	Assist compliance
control tools/ weapons	Strengthen formal surveillance	Deny benefits	Discourage imitation	Control drugs and alcohol

See also: <http://popcenter.org/25techniques/>

with more general cases, i.e. abstract categories of crime, to more specific cases, i.e. in detail specified crimes. We will follow the categorization suggested by Abelson and Schank [13] to distinguish between different levels of abstraction (universal script, metascript, protoscript, script and track). The hierarchical categorization is necessary since a suitable analysis is ideally possible at the track level. Hence, we have to categorize vehicle related crimes within the aforementioned hierarchical levels. We suggest the categorization shown in Table II, which does not claim to be complete and consequently provides further leeway.

TABLE II
HIERARCHICAL CLASSIFICATION OF VEHICLE RELATED CRIMES

Universal script	Vehicle related crimes					
Metascript	Theft, burglary, robbery assault, vandalism					
Protoscript	Vehicle theft	Theft of parts	Theft from vehicle	Arson	Mugging	...
Script (motivation)	Joyriding, insurance fraud, strip down ...	Sell parts, personal use ...	Sell valuables, personal use ...	Spontaneous, malicious ...	Sell valuables, personal use, spontaneous
Track (influencing factors)	Location, e.g. (un)attended vehicle, closed structure, lighted, video surveillance ... Time, e.g. day, night ... Approach, e.g. fraudulent, opportunistic, with(out) keys ... Involved persons, e.g. (co)offender, owner					

The most abstract level is the universal script. Hence, we assign all vehicle related crimes to this level. The subsequent level (metascript) contains coarse crime categories:

- Theft: unauthorized taking of personal goods or property of another

- Burglary: breaking into and entering a house or building of another with the intent to steal
- Robbery: unauthorized taking of personal goods or property of another person in his or her immediate presence against the person's will by using violence or intimidation
- Assault: threat with violence or physical attack against another with or without any item e.g. handgun or knife
- Vandalism: unauthorized damage to a person's personal goods or property

Theft encloses all thefts of vehicles and from vehicles including parts, accessories as well as personal valuables. As we defined that vehicle related crime also encloses any malicious attacks against the driver as well as passengers while entering, using and exiting the vehicle, robbery and assault are also mentioned. Furthermore, burglary is part of the group. Considering home jacking, the burglar enters unlawfully the home to get in possession of the keys. Vandalism encloses all crimes that intend to damage property, especially damage to vehicles. At the metascript level, crimes can fall into more than one category and tend to become blurred. Therefore, the metascript row is continuous, and there is no separation between the aforementioned crime categories. For example, considering carjacking the attacker aims to steal the vehicle, which is a theft. But the offense goes hand in hand with an assault against the driver or passengers where the attacker is armed with a firearm, a knife or threatens with violence. Home jacking is similar whereas the burglar enters unlawfully the home to get in possession of the keys. Thus, he commits a burglary before the theft.

The next more specific level (protoscript) contains crime categories which are subordinated to the metascript categories. Examples of this category are vehicle theft, theft of parts, arson of vehicles and mugging.

Next, the script level describes the crime in more detail by defining the offender's motivation for crime commission. For example, a vehicle theft can be committed either to strip down the vehicle, to use the vehicle to commit another crime or to resell the whole vehicle. Referring to arson, the offence can be committed to cause economic damage to someone's property in order to take revenge. But a randomly chosen vehicle can also be damaged for example as a test of courage or to show off.

The last and most specific level (track) includes influencing factors which describe the crime in deep detail. A crime occurring during the night is influenced by another type of surveillance than a crime occurring during the day. Hence, at the track level information about the crime scene, the time of day, involved parties and other relevant singularities are bundled. An extensive elaboration on influencing factors can be found in [21].

We use our hierarchical classification to define a specific crime to show the use of the script concept. As an example, we regard car theft of an unattended car with the offender's

intention to strip down the car and sell the parts. Furthermore, we assume that the car is parked on a public street, and the crime is committed without keys during the night. Influencing factors, describing our crime in more detail, are shown in Table III, which summarizes the aforementioned conditions and assumptions following our hierarchical classification presented in Table II.

TABLE III
HIERARCHICAL CLASSIFICATION OF CAR THEFT TO STRIP DOWN

Universal script	Vehicle related crimes
Metascript	Theft
Protoscript	Vehicle theft
Script	Strip down
Track	Unattended car, street parking, night, no access to keys, no persons except the offender

Next, we need a definition of scenes for our crime. A possible scene definition is provided by Clarke and Eck [22] which was used to elaborate on a crime script for joyriding. The first column of Table IV shows the scenes of this universal script. In the next step, the according scenes are filled with content considering our specific crime. That means, we propose to each scene according events to break down the crime commission process at the track level. The first scene (preparation) includes events describing tasks the offender makes to prepare the perpetration of his crime. The second scene (entering setting) contains events which are made to reach and enter the crime scene. The third scene (enabling conditions) contains events the offender has to undertake locally to prepare the perpetration. The fourth scene (selecting target) contains information about occurrences which influence target selection. The fifth scene (completing offence) is a collection of events describing what the offender undertakes to perpetrate the crime. The next to last scene (exiting setting) includes events describing the escape from the crime scene. The last scene (aftermath) contains events which the offender undertakes to gain benefit from the crime. The events describing our specific crime at the track level, and consequently being our crime script, are shown in the second column of Table IV. The other script levels (metascript, protoscript and script) are omitted in Table IV as the application of the 25 techniques is only reasonable at the track level.

B. Application of the 25 Opportunity Techniques to Vehicle Related Crime

After having specified the events for each scene of our specific crime, the next step implies the identification of according countermeasures. At this point, the 25 opportunity techniques make their contribution. All 25 techniques are traversed with respect to each event within the crime script aiming to identify according countermeasures. So, the 25 techniques are used in collaboration with the events of the crime script as a brainstorming guide to systematically identify existing countermeasures as well as generate new

TABLE IV
CRIME COMMISSION PROCESS OF SPECIFIC VEHICLE RELATED CRIME

Script scenes	Script events	Examples of countermeasures
Preparation	Choose make and model to steal	Vehicle security ratings (D)
	Choose region to find car	-
	Organize / rent shop to hide and strip down car	-
	Get tools (screwdriver, electronic units) to enter and start car	-
Entering setting	Use transportation to travel to region	-
Enabling conditions	Loiter unobtrusively	-
Selecting target	Reject cars in well lighted areas	-
	Choose suitable car	Decal: combat auto theft, watch your car (D)
Completing offence	Enter car (smash window, use screwdriver)	Alarm system (B)
	Remove ignition and steering lock	-
	Use electronic unit to bypass immobilizer and start car	Immobilizer (A)
Exiting setting	Drive with car to rented / organized shop	Vehicle tracking system (B), (Electronic) decal (B)
Aftermath	Strip down car	-
	Sell parts to pawn shops	Component protection (C)
	Clean up remains	-

ideas of security functions. Table IV presents our proposition of countermeasures in the third column. Characters next to each countermeasure refer to one of the five categories in Table I.

The first proposed countermeasure, named vehicle security ratings, refers to rating lists provided by organizations such as Thatcham¹ which rate the security of vehicles. When a vehicle has a high rating, it may be considered as secure and consequently hard to steal. This way, provocation is reduced. The next countermeasure, decals, refers to programs like *watch your car*² and *combat auto theft*³, which arose in the United States. A decal is visibly added to the front or rear windshield of the vehicle showing the police that the vehicle is normally not driven between the hours of 1:00 a.m. and 5:00 a.m. In the case of the *watch your car* program, the owner can also agree to have the vehicle stopped by the police if the vehicle crosses or is less than 1 mile away from the frontier or an international port. The countermeasure alarm system emits a noisy sound to distract the offender and attract attention. Hence, an alarm system increases the effort and mainly increases the risk to be seen and get caught. The integration of an immobilizer

¹<http://www.thatcham.org>

²<http://www.mdautotheft.org/wyc/>

³<http://www.eastpointpolice.org/cat.htm>

increases the effort to start the vehicle as simple hot wiring is not possible. Driving the stolen vehicle, both, vehicle tracking systems (VTSs) and decals increase the risk of the offender to get caught. Component protection makes sure that components can't be used in vehicles with a different vehicle identification number (VIN) than originally integrated. This way, the reward for the offender is reduced as only parts without component protection can be sold or the effort and costs have to be increased in order to bypass this security measure.

Traversing all techniques with respect to all events in order to identify countermeasures, it becomes obvious that there is not a countermeasure for each technique. Vice versa, innovative countermeasures may also arise which do not meet any of the 25 techniques. But both facts are not surprising as the proposed techniques are quite generic in order to cover a wide range of different crimes.

C. Electronic Decal

In Table IV, we mention a security function called electronic decal. The electronic decal transfers the idea of the physical decal into the world of connected mobility. The goal of this security function is to increase the offender's risk to get caught. There is no more physical decal visibly placed on a windshield of the vehicle. Instead, one opportunity is that the owner or authorized persons transfer a detailed schedule to the vehicle's onboard unit (OBU) with information about the times the vehicle is allowed to move. The data transfer can be realized via smartphone, from any computer via internet or basically through direct input in the car. As soon as the vehicle is moved within forbidden times, the vehicle uses its communication unit in two ways. First, the vehicle informs the owner via smartphone about a potential misuse to enable the opportunity for quick reaction, either to deactivate the electronic decal due to an outdated schedule or to report the vehicle stolen. Second, if the owner does not deactivate the electronic decal, the vehicle will continuously broadcast a message with the request to be checked by the police. As illustrated in Fig. 1, passing police vehicles will be initiated to stop and check the suspect vehicle. Moreover, the broadcasted messages can also be evaluated by infrastructure like police stations and border crossings. Other vehicles and infrastructures in range simply discard the message.

The European Telecommunications Standards Institute (ETSI)⁴ has started to elaborate on standards to pave the way for V2X communication. Inter alia, they have defined two basic services to support various use cases, the decentralized environmental notification [23] and cooperative awareness [24] service. However, the standardization process of the cooperative awareness message (CAM) and the decentralized environmental notification message (DENM) is not finished until now and is still an ongoing work in progress. Consequently, we are not able to provide a clear integration of the electronic decal functionality into the message format.

As CAMs are intended to be broadcasted continuously, we suggest to use the cooperative awareness service to realize the electronic decal functionality. Additionally, we suggest

to use a container for data which is not included in CAMs and relevant for the realization of the electronic decal. The optional container is part of the CAM as soon as the vehicle moves within forbidden times. The container includes the start and end time of the period in which the vehicle is not allowed to move. This information is useful as it supports the police to decide whether to stop the vehicle or not. For example, if the time period is two weeks and the vehicle is moved in the middle of the aforementioned period, it might be an indication that the owner is on holiday, and the vehicle is illegally moved. Using the current position, heading and speed, already contained in CAMs, the movement of the suspect vehicle can be shown in the police vehicle. Moreover, information about the vehicle needs to be included so that police is able to identify and pick the right vehicle. Hence, we suggest the license plate number, make, model and color of the vehicle being part of the container. The license plate number seems to be sufficient at the first glance but license plates can be easily changed whereas the effort to change the color is higher. The make and model are even harder to manipulate. Furthermore, the high number of identification attributes increases the redundancy and thus simplifies the vehicle identification for the police. Privacy concerns appear to be less critical in this case, since the vehicle shouldn't be moved anyway.

The electronic decal introduces extended opportunities and advantages compared to the physical decal. First, the electronic decal is not limited to static times. A schedule can be realized to the minute on a daily basis. Second, the owner or any other authorized person is informed as soon as the vehicle is moved outside of predefined times. This way, a quick theft report is possible. Third, as there is no visible decal which informs the offender about this functionality the offender never knows if the electronic decal functionality is enabled or not. Next, the electronic decal makes use of standard components. That means, an onboard communication unit (OCU) is integrated anyway in the course of connected mobility. Additionally, a connection to the vehicle via smartphone or other devices, which provide a connection to the internet, is already or will be available in the near future. Of course, the presented security function needs a motivated and self-disciplined driver who regularly updates the schedule. But even when the schedule is outdated and police stops an "innocent" vehicle, the check is a routine action where the situation can be cleared up quickly by a legal driver. In addition, it is still in police's discretion whether to stop a vehicle or not. Nevertheless, it is better to check once too often rather than once too little.

V. CONCLUSION AND FUTURE WORK

The goal of this work is to propose a way to systematically examine vehicle related crime to get a deeper understanding in order to elaborate on security functions which can make use of new technologies. Hence, we provided a conceptual approach to analyze the stages an offender has to go through to commit a specific crime. We chose the script concept from the Rational Choice Perspective and the 25 techniques of opportunity reduction from the Situational Crime Prevention. In the first

⁴<http://www.etsi.org>

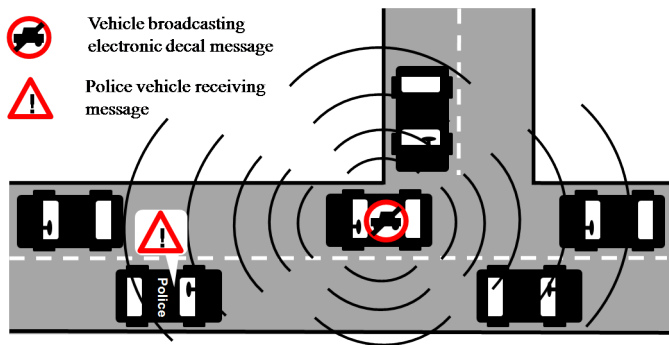


Fig. 1. Electronic decal

step we used the opportunity of the script concept to identify and hierarchically categorize vehicle related crimes. To show the way of application, we analyzed a specific crime on the track level and proposed the use of existing countermeasures. Moreover, we proposed an innovative security function named the electronic decal, which makes use of new technologies.

As mentioned earlier, the script concept and the 25 techniques are advocated to be used against all categories of crimes. On the one hand, this is a huge advantage as a wide field is covered. But on the other hand, not all techniques are suitable for all crimes due to the wide field. There is even an overlap of techniques possible. For example, an increasing effort for the offender may result in an increasing risk for the potential victim. Nevertheless, the attempt to traverse the 25 techniques with respect to a specific crime provides new views to the problem and thus may lead to innovative security functions.

During our work, several points for future work arose. First of all, as the use of crime scripts has to be done ideally at the track level, the amount of specific crimes is high. That means, an elaboration on all possible crimes in deep detail is not an option due to the high complexity. Hence, in our opinion, we have to pick out wisely a manageable amount of specific vehicle related crimes which cover a requested range. Second, to make a realistic crime script, a deep knowledge of the modus operandi (MO) is necessary. That means, we need to reveal the methods, habits, tools and actions used by the offender to execute the crime. Information about the offender's approach to prevent its detection or enable its escape is also of importance. The MO can be determined by interviewing offenders, basically those that got caught. However, their MO needs to be treated with care as caught offenders may be less skilled and used a different MO than those who did not get caught. Third, the approach described in this paper provides a framework to systematically analyze the crime commission process. Consequently, new security functions, which arise from this approach, will mainly tackle the crime itself. However, we are also interested to increase the sense of security of drivers and passengers. Of course, when a function prevents or reduces crime, it may be assumed to improve sense of security. Nevertheless, sense of security is a subjective feeling and does not necessarily go hand in hand with the real development of crime, which is objective and can be estimated by statistics. Therefore, analyses of subjective fears

and feelings, which can be estimated by surveys, are necessary. Last but not least, a detailed analysis of the electronic decal is of interest. Besides privacy issues, points such as a secure way of in-vehicle and communication protocol integration are considered necessary.

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REFERENCES

- [1] BKA. (2011) Polizeiliche Kriminalstatistik 1997 - 2010. Bundeskriminalamt. [Online]. Available: <http://www.bka.de/pks/>
- [2] SBD, *Vehicle Crime in the 21st Century and the Impact of Electronic Theft Methods*, SBD Secure Car Research Std., 2009.
- [3] M. Kilias, "General crime drop: Where? when? why?" in *Criminology in Europe*, vol. 9, no. 1. European Society of Criminology, Apr. 2010.
- [4] R. V. Clarke. (1998) The theory and practice of situational crime prevention. online. School of Criminal Justice Rutgers University. [Online]. Available: http://www.e-docs.eu/content/docs/Situational_crime_prevention.pdf
- [5] —, *Situational Crime Prevention: Successful Case Studies*, R. V. Clarke, Ed. Albany, NY 12203: Harrow and Heston, 1992.
- [6] —, *Situational Crime Prevention: Successful Case Studies*, 2nd ed., R. V. Clarke, Ed. Albany, NY: Harrow and Heston, 1997.
- [7] T. Keister, "Thefts of and from cars on residential streets and driveways," U.S. Department of Justice, Problem-Oriented Guides for Police Series - Problem Specific Guide Series 46, Feb. 2007. [Online]. Available: <http://www.popcenter.org/problems/>
- [8] D. B. Cornish and R. V. Clarke, "Situational prevention, displacement of crime and rational choice theory," in *Situational crime prevention: From theory into practice*, K. Heal and G. Laycock, Eds. London: HMSO, 1986, pp. 1–16.
- [9] R. V. Clarke and D. B. Cornish, "Modeling offenders' decisions: A framework for research and policy," in *Crime and Justice: A Review of Research*, M. Tonry and N. Morris, Eds. The University of Chicago Press, 1985, vol. 6, pp. 147–185. [Online]. Available: <http://www.jstor.org/stable/1248062>
- [10] —, "Rational choice," in *Explaining Criminals and Crime: Essays in Contemporary Criminological Theory*, R. Paternoster and R. Bachman, Eds. Los Angeles, CA: Roxbury Publishing Company, 2000, pp. 27–41.
- [11] B. Poyner and B. Webb, *Crime Free Housing*. Butterworth Architecture, 1991.
- [12] R. P. Abelson, "Script processing in attitude formation and decision making," in *Cognition and Social Behaviour*, J. S. Carroll and J. W. Payne, Eds. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1976, pp. 33–46.
- [13] R. C. Schank and R. P. Abelson, *Scripts, Plans, Goals and Understanding: An Inquiry into Human Knowledge*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1977.
- [14] R. P. Abelson, "Psychological status of the script concept," in *American Psychologist*, 1981, vol. 36, no. 7, pp. 715–729.
- [15] J. A. Galambos, R. P. Abelson, and J. B. Black, *Knowledge structures*. Lawrence Erlbaum Associates, 1986, ch. one, p. 19.
- [16] D. B. Cornish, "Crimes as scripts," in *Proceedings of the international seminar on environmental criminology and crime analysis*, D. Zahm and P. Cromwell, Eds. Florida Statistical Analysis Center, Florida Criminal Justice Executive Institute, 1994.
- [17] D. Cornish, "The procedural analysis of offending and its relevance for situational prevention," in *Crime Prevention Studies*, ser. Crime Prevention Studies, R. V. Clarke, Ed. Monsey, NY: Criminal Justice Press, 1994, vol. 3, pp. 151–196. [Online]. Available: http://www.popcenter.org/library/crimeprevention/volume_03/06_cornish.pdf
- [18] M. J. Smith, "Regulating opportunities: multiple roles for civil remedies in situational crime prevention," in *Civil Remedies and Crime Prevention*, ser. Crime Prevention Studies, L. G. Mazerolle and J. Roehl, Eds. Monsey, New York: Criminal Justice Press, 1998, vol. 9, pp. 67–88. [Online]. Available: http://www.popcenter.org/library/crimeprevention/volume_09/Regulating_Opportunities.pdf

- [19] D. B. Cornish and R. V. Clarke, "Opportunities, precipitators and criminal decisions: A reply to wortley's critique of situational crime prevention," in *Theory for Practice in Situational Crime Prevention: Crime Prevention Studies*, M. J. Smith and D. B. Cornish, Eds. Monsey, New York: Criminal Justice Press, 2003, vol. 16, pp. 41–96. [Online]. Available: http://www.popcenter.org/Responses/crime_prevention/PDFs/Cornish&Clarke.pdf
- [20] R. V. Clarke, "Crime science," in *The SAGE Handbook of Criminological Theory*, E. McLaughlin and T. Newburn, Eds. Thousand Oaks, CA: SAGE Publications, 2010, pp. 271–283.
- [21] S. Tuchscheerer, "Human factors in automotive crime and security," Ph.D. dissertation, University of Technology Chemnitz, 2011.
- [22] R. V. Clarke and J. E. Eck, "Crime analysis for problem solvers in 60 small steps," U.S. Department of Justice, Washington, D.C. 20530, Tech. Rep., Aug. 2005. [Online]. Available: <http://www.popcenter.org/library/reading/PDFs/60steps.pdf>
- [23] *Intelligent Transport systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specification of Decentralized Environmental Notification Basic Service*, European Telecommunications Standards Institute Std., Rev. v1.1.1, Sep. 2010.
- [24] *Intelligent Transport systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service*, European Telecommunications Standards Institute Std., Rev. v1.2.1, Mar. 2011.