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Detecting and Disrupting Criminal Networks. A Data Driven Approach.
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Summary

Detecting and Disrupting Criminal Networks A data-driven approach

It is estimated that transnational organized crime generates around EUR 900 billion a year worldwide, at the cost of numerous human lives, economic development, social stability and democratic peace. The root of this global problem lies within local social settings (e.g. neighborhoods, schools, sport clubs, prisons, nightclubs and casinos) in which different generations of (potential) criminals from various backgrounds find mutual trust to converge into networks. As compared to legitimate networks, criminal networks deliberately operate under covert conditions and outside the boundaries of law. Detecting and disrupting criminal networks is therefore one of the biggest challenges for law enforcement agencies across the globe. The aim of this thesis is to contribute to this endeavor by introducing a data-driven approach to the empirical study of organized crime.

How do criminal networks emerge and evolve?

The first studies of organized crime in the 70s and 80s relied on the image of hierarchical mafia pyramid structures, with strict leadership, ranks, and an internal system of rules and punishment. In the early 90s this image was rejected based of scientific research that showed that organized crime constitutes fluid networks that emerge along social lines of overlapping kinship, friendship and neighborhood ties. Criminal networks do however not emerge randomly, but rely on mutual trust that provides a level of security in the uncertain and unpredictable criminal environment. Over time local networks expand due to a small-world phenomenon that connects them with many other local networks, resulting in regional networks at meso-level. Particular actors within these *meso-networks* may possess strong networking-abilities, high reputation or special skills that make them essential for initiation and continuation of the various criminal value chains (*i.e. crime commission processes*) that run through these meso-networks.

In chapter 2 we analyzed the social framework behind a criminal network (N=86) involved in drugs trafficking. We found that the network gravitates around a strong embedded social structure of kinship and affective ties. Females within this social structure fulfill important internal mediator roles and external gatekeeper functions. This fosters the resilience of the network as a whole and leads to the external expansion of the micro-network into a transnational trafficking operation from the Netherlands to Italy. Actors who fulfill similar brokerage roles in criminal networks further enable connectivity through which various meso-networks across regions, countries, and continents become connected. This leads to the emergence of the macroscopic transnational patterns of criminal cooperation we observe today.
At this macro-level criminal networks are best understood as complex adaptive systems. Similar to complex networks observed in biology, economy, ecology and

computer science, they display *non-linearity*. This means the whole is different then the sum of its parts. All criminal actors in the network can operate autonomously and interact with each other at the same time, resulting in highly unpredictable outcomes. Within complex adaptive criminal systems external pressures, such as law enforcement operations, prompts change in the individual behaviors may result in changes in the structure of the network as a whole. This is known as *self-organization*.

Moreover, within criminal networks these dynamics are marked by a continuous trade-off between efficiency and security in sharing information. Efficiency means the network needs to communicate efficiently amongst its members to coordinate the crime commission process. This contrasts with maintaining undetected by law enforcement (i.e. security) and demands information exchange reduced to a minimum. Criminal networks therefore constantly balance between these two, which makes them 'light on their feet' and therefore highly adaptable to law enforcement interventions.
In chapter 4 we analyzed these dynamics within an empirical meso-network (N= 22.000 actors) by using computer simulation. We found that, following removal of the most central actors, the tradeoff between efficiency and security makes criminal networks stronger and more efficient. This effect increased when multiple actors were removed sequentially. Our results show that nobody is irreplaceable within criminal networks and as a result networks easily adapt after disruption.

The presence of weak ties has a strong effect on this process. Weak ties are defined as the bridges that connect remote parts of the network. Their presence enables the dynamical flow of non-redundant information and resources throughout the network and thus contributes to finding replacements. Strong ties also have an important function in criminal networks. They provide security though an internal network or trusties against detection from the outside. The distribution of tie-strength is therefore an important factor in understanding the structure and emergence of criminal networks.
In chapter 6 we measured and compared three dimensions of tie-strength (structural, temporal and demographical) within a criminal meso-network (N= 5000 actors). We found that weak-ties based on structural positioning (i.e. edge-betweenness) are indeed important for linking sub communities in the network, but not exclusively. Many alternative pathways exist due to small-world effect. Moreover, our study showed that the majority of weak ties is fluid, meaning short duration and rarely observed by law enforcement. They often represent instrumental interactions mostly orchestrated by third-party intermediaries for settling disputes or during the course of one criminal interest (e.g. mutual investment in trafficking illegal drugs). Furthermore, criminal ties characterized by homophily (i.e. similarity) and multiplexity (i.e. more types of relationships at the same time) are significantly more likely to cluster within the meso-network. These clusters form the pools of potential criminal cooperation, suggesting a preference for criminal co-operation of individuals with similar ethnic backgrounds. This could however also be a side effect of the ethnic composition of neighborhood and it does not exclude the presence of mixed ethnicity groups that emerge on a micro-level. Within this highly dynamical underworld more durable old-boys' networks are also detected. Fostered by strong and loyal kinship ties we found that a few of these co-offending ties last over 20 years.

Overall it can be concluded that organized crime is a dynamic and multi-dimensional phenomenon that demands an equivalent dynamic and multi-dimensional approach and response in respectively science and law enforcement.

How to detect and analyze criminal networks?

The empirical findings in this thesis rely on a data-driven approach. This means that the data is analyzed bottom-up to provide resulting in a more unbounded perspective of criminal networks, without restricting the perspective through theoretical constructs that classify the data in advance.

In chapter 2 and 3 we explored the opportunities and limitations of social network analysis (SNA) for studying criminal networks by comparing 34 case studies. SNA is defined as the process of analyzing social structures through the use of network and graph theories. It defines networked structures in terms of *nodes* (actors, subgroups, or things within the network) and *ties, edges, or links* (relationships or interactions) that connect them.

Our findings showed that the main advantage of SNA in the study of organized crime lies in the ability to study microscopic properties of individuals and macroscopic patterns of criminal co-operation independently but also in conjunction. The application of SNA –as compared to manual analysis- is becoming a necessity, especially with the increasing amount of criminal network data that is currently available. The various case studies show that combining different data sources is required to optimize reliability and validity of criminal network representations. On the micro-level there is a significant risk for selection bias, as less data is available. This means that the outcome is strongly affected by the initial priorities of law enforcement data-collection, such as the investigation of few main suspects. The organized crime research field therefore benefits especially from the application of SNA at meso-level, for which more types of available data-sources can be combined (i.e. patrol data, surveillance data, human intelligence, open source intelligence). The quantitative analysis of SNA helps to explore the overall structure of the network and identify its distinctive elements, after which further qualitative assessment of the output on the basis of network- and criminological theory is required to put these results in the relevant context.

In addition to SNA the application of crime scripting was explored in chapter 2 and 3. This involved analysis of the crime commission process by breaking it down into a sequence of chronological phases and events. By combining SNA with crime scripting we found that a deeper of the independencies between actors can be created. From a law enforcement perspective, our study indicated that found that assigning roles to actors based on this combination of methods assists the identification of uniquely skilled actors whom are difficult to replace.

However, the case studies also showed that the combined use of SNA and scripting is mainly used in a manual qualitative way. In chapter 4 we therefore present a novel quantitative approach that combines SNA and scripting into a new measure for network centrality, so called *value chain centrality*. It is based on the notion that the importance of an actor is depended on the number of value chains that will be disrupted following its removal.

Since SNA and crime scripting still provide a static observation of a dynamical phenomenon, the application of computational modeling was explored in chapter 4.This involves a method to simulate complex network behavior with the help of algorithms as input for computer simulations. Empirical criminal network data (n=22.000) is used as input for these simulations to experiment with different scenarios in a virtual criminal environment. We found that by combining intervention algorithms with replacement algorithms in the same model, the effects of four different law enforcement disruption strategies could be simulated on a criminal network. Although these methods are promising for criminal network dynamics research, validation of these models through empirical network research remains indispensible.

Such validation and the validation of network representations and models in general, require a comparison of different data sources. The majority of criminal network studies rely on law enforcement data. Chapter 5 demonstrates how context sensitive text-mining techniques contribute to inference of covert networks, in this case a network of drug-users networks active on social media platforms, i.e. Life journal (N=23 $10^{6)}$. Such methods can be utilized to detect hacking networks, online child pornography networks or *Darknet* drug traffickers to provide insight into their structures outside of the law enforcement context.

Chapter 6 showed that a data-driven approach based on the combination of these three methods could also benefit from a focus on ties instead of nodes. We present a more effective approach to detect criminal networks through surveillance or intelligence, by categorization of ties based on duration and intensity: fluid, manifest, latent and durable. Since fluid and manifest ties chance very rapidly, our results emphasize to redirect intelligence resources on identifying and focusing on the latent and durable ties in the network. This leads to a more robust and sustainable information position over time.

Based on the chapters presented in this thesis it can be concluded that criminal network structures on any level (micro, meso and macro) can not be presumed but emerge. Data-driven analysis of these emerging networks can drive qualitative interpretations and assessment to seek- rather than assume structure. Therefore these findings can be considered a paradigm shift in law enforcement as well as in organized crime research.

How to disrupt criminal networks?

The simulations in chapter 4 show that effectively disrupting criminal networks requires strategic planning and long-term consistent effort. The search for replacements after every intervention (i.e. removal of an actor) increased criminal network efficiency, but also the general visibility of actors at the same time, making them more vulnerable for detection on the long run. While the network tries to recover, important actors on the background become exposed. This effect is amplified when intervention strategies are aimed at targeting specialists within the value chain, who are most difficult to replace. Disruption and detection strategies should therefore be developed in conjunction to create such momentum. Within law enforcement practice this means that intelligence services and intervention units should strategically co-operate more frequently in a 'networked' and parallel strategy to effectively disrupt criminal networks.

However, the fundamental question on the controllability of complex criminal networks remains an open issue beyond the scope of this thesis. Ashby's law of requisite variety states that the controller must have as much variety as the controlled. Such variety within the bureaucratically organized law enforcement is constraint by law, organizational structure and internal culture. More empirical research is therefore needed to understand the complex and continuous interplay between law enforcement and criminal networks, in other words, between hunter and prey (or the other way around).