# Maastricht University

| Work package number | 1.1. |
|---|---|
| Work package title | **'Shining a light' on the dark number on crimes that undermine the rule of law and modeling more effective data-driven (preventative) interventions.** |
| Work package leader | Ms. mr. dr. drs. Jill E.B. Coster van Voorhout |
| Involved partners | <u>Knowledge chain partners</u>: Maastricht University's Criminal Law and Criminology Department, IAS, and PA. |
| | <u>Societal partners</u>: Banks ABN AMRO bank, Knab and Rabobank; National Rapporteur on Human Trafficking and Sexual Violence Against Children; OCFL/MFL; NEN; NGOs CoMensha, FairWork and La Strada International; Intelligence and criminal justice chain actors FIU-Nederland, Inspectorate of the Ministry of Social Affairs and Employment (ISZW), Public Prosecution Service (OM), Ministries of Justice and Security, Social Affairs and Employment, and Foreign Affairs. |
| Start date | Month 1 |
| End date | Month 48 |

<u>Description of research activities:</u> The research activities are roughly decomposed into two cycles of 18 months which all have the same structure followed by a final year of bringing everything together and consolidating the results. The research activities in the two cycles are somewhat following the timeline below:

• Task 1: methodology: With all knowledge partners and societal partners we determine the datasets, incorporate insights from the previous cycle (if applicable) and build the methodologies, taking into consideration how previous socio-legal research with one bank (ABN) and law enforcement agency (ISZW) developed indicators for big data search strategies on "only" human trafficking for the purpose of labor exploitation, rather than all its forms and (related) money laundering and corruption.

● Task 2: case study: application of the methodologies developed in Task 1 to the relevant case study.

● Task 3: publication: the work will be concluded with one publication in a law journal and one additional publication by the societal partners. We also plan to develop either study material in the curriculum of the Police Academy or a specialized publication for the police/bank/stakeholders as a cross-collaboration between all work packages.

In the first cycle we will focus on the theme of developing indicators for crime (victim) detection, while in the second cycle the emphasis will be on crime scripting. In the final year the toolset as a whole will be finalized and made available to all. The PhD manuscript will be finalized.

<u>Productive interactions (co-design and co-creation)</u>: The aforementioned societal partners (banks, etc.) co-create in focus groups the indicators needed for the search strategies querying big data of the public and private sector. They co-examine the law and case law analysis from which such indicators are induced, co-define crime patterns and causes, evaluate the proposed retributive and proactive law and policy interventions, and ensure that the methods operate conform the

legal, forensic and ethical standards in the domain. Moreover, jointly with the Police Academy insights acquired in this research will be incorporated in relevant training.

Contribution to project: Development of novel methodologies for crime (victim) detection and application to all three un(der)detected crimes and their interplay. Development of training material in order to ensure the practical use of the developed methodologies in practice.

| Work package number | 1.2. |
|---|---|
| Work package title | **Enhanced human rights due diligence** |
| Work package leader | Prof. Martijn Scheltema |
| Involved partners | Knowledge chain partners: Erasmus University Rotterdam's Private Law department, Maastricht University's Criminal Law and Criminology Department, IAS, and PA.<br>Societal partners: cf. WP 1.1. |
| Start date | Month 1 |
| End date | Month 48 |

Objectives: Developing a toolset to provide better insight in human trafficking and modern slavery in international supply chains, not only to benefit victims, but also business and governments. This toolset creates the societal breakthrough really needed in this field, because well-meant approaches still do not result in substantial improvement of the situation of victims of human trafficking and related crimes that undermine democratic societies governed by the rule of law.

Methodology: The core of the United Nations Guiding Principles on Business Human Rights (UNGPs) and revised OECD Guidelines for Multinational Enterprises (OECD Guidelines) is the concept of human rights due diligence [1-2]. It includes six steps as displayed in the following scheme [3]:
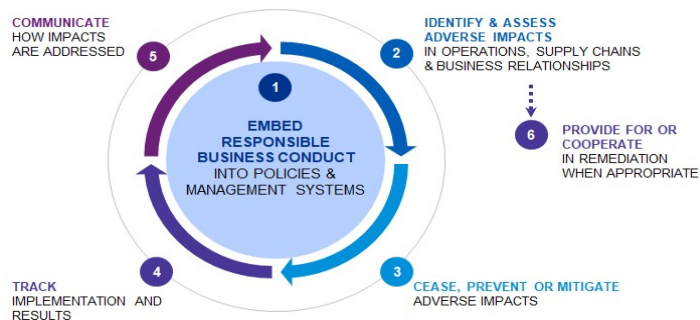


Although HRDD is undertaken, it remains challenging to discover hidden crimes like human trafficking. This **lack of actual knowledge** is an issue for victims, businesses, public prosecutors, public supervisors and legislators alike. Businesses face sanctions (for example, seizure of goods and fines) and reputational damage as a result of being ignorant of what really happens in their supply chains and are unable to provide remedies, which are all required by the UNGPs and OECD Guidelines if they cause or contribute to human trafficking, even if they are unaware of the violation. The same goes for the prosecution seeking to prosecute. Likewise, the legislator and public supervisors assessing compliance with legislation face this issue. An important reason for this is that, to date, public supervisors have no or very little actual insight in what happens in international supply chains and, thus, are unable to effectively monitor those. This makes the effectiveness of the current legislative efforts questionable.

This research therefore aims to contribute to this in the field of crime that undermines democratic societies governed by the rule of law. It combines the legal requirements of HRDD as set forward by the UNGPs and OECD Guidelines, and increasingly adopted in legislation, and artificial intelligence or data-oriented as well as societal and economic research in order **to develop indicators and analysis tools**. Those should provide better insight in the **actual occurrence** of crimes that undermine democratic societies governed by the rule of law in international supply chains, also building on an analysis of criminal networks and economic models behind these crimes. The research builds on previous research in which these indicators and analysis tools have been developed in collaboration with banks to trace human trafficking in the Netherlands, building on financial information provided by those banks (cf. WP1.1.).

Description of research activities: General desk research will be done to assess the most relevant challenges and causes behind them in connection with crimes that undermine democratic societies governed by the rule of law in value chains. Existing criminological research on criminal networks in value chains is also taken into account. From this desk research **two countries and sectors are identified** in which human trafficking is prevalent in value chains. The desk research also aims to **identify root causes** and ways in which networks operated as well as how financial flows around these networks are finding their way into the economy.

The desk research is used to **identify indicators** which may point at individual HRDD risks which may be relevant to identify criminal networks. After this it is assessed with other consortium partners (financial institutions as well as the Prosecution and others) which data may be found to assess whether these indicators are actually observed. Here artificial intelligence and other data analysis tools are explored to assist in this exercise and based on these indicators, identify relevant (financial) data (financial institutions provide) which provides insight in human trafficking risks and networks behind them in value chains. Collaboration with NEN helps identifying how artificial intelligence standards may be developed or deployed to support this endeavor.         Two types of supply chains are further assessed: garment and electronics. Both have divergent characteristics, for example, in the extent to which business is able to exercise leverage in these supply chains. Typically, businesses have better options to exercise leverage in garment supply chains. This also influences the extent to which they are able to map their supply chains and be transparent about them. It is assumed that this also increases the options to collect data from these supply chains. Two case studies (one regarding garment; another regarding electronics) will be conducted in a specific country to test this hypothesis. The next step is to use available (public and financial) data to assess whether it is possible to identify or predict crimes deeper down these supply chains by an indicators and data-driven approach.

In the two case studies in which we will closely collaborate with our societal partners to work on real data, we will consider:

1. Indicators for crime (victim) detection
2. How these feed into enhanced HRDD
3. How algorithmic support for this may be developed.

Productive interactions (co-design and co-creation): The aforementioned societal partners (banks, etc.) co-create in focus groups the indicators needed for the search strategies used in big data from the public and private sector, under the lead per focus group (3.1.). They co-examine human trafficking incidents and issues found in such incidents abroad from which such indicators are induced, co-define crime patterns and causes, evaluate the proposed (retributive and proactive) improvements and enhancement of HRDD and related policy interventions, and ensure that the methods operate conform the legal, forensic and ethical standards in the domain.

Contribution to project: Development of novel strategies for HRDD, making use of increased transparency regarding crimes that undermine democratic societies governed by the rule of law and criminal networks behind them. Development of training material in order to ensure the practical use of the developed methodologies in practice.

| Work package number | 2.1. |
| --- | --- |
| Work package title | **AI for finding crime and criminal network patterns in financial and other big data** |
| Work package leader | Prof. dr. Marcel Worring |
| Involved partners | Knowledge chain partners: UvA's Informatics Institute (including AI, forensic data science), CLHC, IAS, and PA.<br>Societal partners: Cf. WP 1.1. |
| Start date | Month 1 |
| End date | Month 48 |

Objectives: Finding forensically sound, unbiased, and transparent AI methods for detecting and exploring patterns in financial and other big data which might hold evidence of crimes that undermine democratic societies governed by the rule of law.

Methodology: A single financial transaction is a simple transfer of money from one account to another. However, organized subversive crime is often hidden and difficult to detect in the large amount of (banking) data. Our aim is to find crime-related patterns in huge amounts of such transactions, which is a highly complex task. First, in the huge amounts of data the patterns of interest are subtle and only present in a very small part

of the data. Second, patterns become apparent only when using multiple sources of information available on an account, looking at groups of accounts, and taking into account temporal characteristics. Third, evidence must be obtained in a forensically sound and unbiased manner to yield trustworthy evidence to convict people involved in crimes that undermine democratic societies governed by the rule of law, but also lift suspicion from persons when evidence points towards innocence. Finally, patterns are only useful if they are relevant and explainable in court.

An important step in realizing AI methods for pattern detection is the data representation on which to base the methods. The accounts and transactions themselves are typically modeled as a graph where accounts are nodes and transactions are represented as weighted edges. But graphs are limited in what they can describe; they cannot model organized crime networks and their interactions. Recently in AI, **Hypergraph Representations** have become a versatile tool for working with large volumes of complex data. In hypergraphs, edges can connect an arbitrary number of nodes. Regular graphs are simply a hypergraph where every edge connects two and exactly two nodes.

AI models have become extremely successful in solving various tasks and do so by learning from huge amounts of (annotated) data. This immediately creates a bottleneck as obtaining such data in many application domains is difficult if not impossible. COMCRIM is no exception here; data is distributed over different parties and often lacks annotation. An additional complication is that in AI data and code are shared within the scientific community, which is clearly not possible for the sensitive data we work on here. We will therefore focus on the use of self-supervised methods; in particular we will develop **Generative Adversarial Networks** which will have a generator introducing patterns in a real or surrogate dataset and a discriminator to detect the pattern. The generator and discriminator are trained simultaneously and hence both become better over time. In this way the system will be capable of identifying patterns which are increasingly complex and subtle.

Visualizations of the data are essential to help experts interpret the patterns. But these projections and summarizations of the highly complex data will induce an inherent information loss. Having generated data will allow us to study how representative the visualization is with respect to the complex data it originates from. We will therefore research **Faithful Hypergraph Visualization** methods to assure that the evidence obtained is valid and explainable, and make them available in a transparent manner to judges, suspects, defense lawyers and prosecutors alike to assure a fair trial.

We complement the work on artificial datasets with **Case Studies** in which we closely collaborate with our societal partners to work on real data on these real societal questions. This will be on the one hand a validation of the techniques we develop, while at the same time it provides steering of all the research and development in the work package.

Description of research activities: The research activities are roughly decomposed into three cycles of a year which all have the same structure followed by a final year of bringing everything together and consolidating the results. The research activities in the yearly cycles are somewhat following the timeline below (with task 2.1. and 2.2. in parallel):

- Task 1: **pattern definition**. With all knowledge partners and societal partners we determine a set of relevant patterns to work on and datasets in which this could be applied.
- Task 2.1: **method development:** methods to generate, discriminate, and visualize the data and current set of patterns will be developed and evaluated in terms of quantitative measures.
- Task 2.2: **data preparation**: suitable real-life datasets from the societal partners in which the patterns are expected are gathered, integrated, and cleaned.
- Task 3: **case study:** the newly developed methods will be adapted to work on the data which have been prepared and thorough evaluation with expert users will be performed.
- Task 4: **publication:** the work will be concluded with at least a publication in an AI (or AI and Finance) related venue possibly with additional publications and training by the societal partners. After each cycle based on the results a new set of more complex patterns will be defined and new methods for detecting them will be developed. In the final year the toolset as a whole will be finalized and made available to all. The fourth publication of the PhD student will be prepared and the whole thesis will be finalized.

Productive interactions (co-design and co-creation): The aforementioned societal partners (banks, etc.) provide an important role to the project in preparing data for the case studies, defining the domain specific patterns of interest, evaluating the systems in terms of usability and effectiveness, and ensuring that the methods operate in conformity with the legal, forensic and ethical standards in the domain.

Contribution to project: Development of novel methodologies and application to relevant use cases.
Development of training material in order to ensure the practical use of the developed methodologies in practice.

| Work package number | 2.2. |
|---|---|
| Work package title | **Development of Complex Systems Science Methods and Application to Use Cases** |
| Work package leader | Prof. dr. Drona Kandhai |
| Involved partners | Knowledge chain partners: UvA's Informatics Institute (including Computational Science, AI, forensic data science), CLHC, IAS, and PA. Societal partners: Cf. WP 1.1. |
| Start date | Month 1 |

| End date | Month 48 |
|---|---|

Objectives: Finding forensically sound, unbiased, and transparent AI methods for detecting and exploring patterns in financial data which might hold evidence of crimes that undermine democratic societies governed by the rule of law.

Methodology: The detection of anomalous transactions is one of the major challenges faced by financial institutions today. Such transactions may be related to human trafficking and (connected) money laundering and corruption, terrorism financing, sanctions, politically exposed persons especially vulnerable for corruption, and cybersecurity breaches. With more than $350 billion misconduct-related fines since the financial crisis and with Covid-19 having markedly increased cyber risks, developing methods that can address this area is becoming more important than ever (e.g. according to FS-ISAC cyber-attacks against financial institutions increased from 5,000 per week in February 2020 to more than 200,000 per week in April 2020). Current methods for detection of crimes that undermine democratic societies governed by the rule of law are often insufficient, costly, and labor intensive. Moreover, mathematical and computational models for studying the effectiveness of interventions are lacking. In this research project we aim to develop methodologies from the complex systems science research field to tackle these challenges. In particular, we focus on approaches from network science (e.g., Mattsson et al 2021 and references therein), extended with methods inspired by information theory and agent based simulations [1-5].

       Suspicious patterns related to crimes that undermine democratic societies governed by the rule of law can be revealed using network algorithms. When studying transaction networks one has access to only **limited information**, dramatically reducing the possibility of detecting suspicious nodes. A key challenge is presented by the fact that there is no single definition of an unusual transaction (in the Netherlands; cf. in most other countries: suspicious transaction). Moreover, traditional crime detection algorithms require historical anomalous transactions which are available in overwhelmingly small proportions of normal transactions, resulting in large numbers of false positives. These challenges can be tackled by network reconstruction methods (Squartini et al 2018) which can optimally employ the available data to obtain the full network structure. Actual networks can be compared to their reconstructed counterparts in order to detect anomalies such as abnormal links. Thus, instead of focusing on predicting suspicious payments, the emphasis is put on transactions that should be expected as normal. More specifically, a null model of the transaction mechanism will be created and transactions which are exceptionally improbable will be identified as suspicious. Such null models have been used earlier in financial and economic networks to reconstruct networks from partial information with applications in measuring systemic risk (Cimini et al 2015).

       Second, the role of **interventions** in such systems is poorly understood. Here, we differentiate between internal and external interventions. Internal interventions can be observed in for example the case of market abuse in financial markets. Traders can take large positions in securities in different markets to drive the price of underlying assets. These actions are typically hidden, executed in specific ways and therefore difficult to detect. External interventions are typically the results of actions imposed by policy-makers and the legal system. Agent Based Simulations (ABS) provide a natural framework for studying the effect of both types of inventions

for a wide range of system properties and scenarios. ABS has been successfully used as a modeling paradigm to understand the driving mechanisms of the dynamical behavior of a wide variety of complex systems. For example, in finance and economics the role of heterogeneity and the (non-linear) interactions have been explored in different studies in the past two decades (e.g. Qiu et al 2012). In this project we aim to develop ABS approaches for crimes that undermine democratic societies governed by the rule of law. The key challenge here is to identify the different types of agents, i.e. which actors do we want to include and the granularity of their micro dynamics and interactions. For this we work closely with work packages 1 and 3, use the network reconstruction methodology proposed in this work and deploy the AI based methods of work package 2.1 (as a basis for the initial interactions between the agents).

As specific **case studies** in which we closely collaborate with our societal partners to work on real data, we consider:

1. Network reconstruction based algorithms for detection of anomalous transactions.
2. The impact of interventions using ABS.

Description of research activities: The research activities are roughly decomposed into two cycles of 18 months which all have the same structure followed by a final year of bringing everything together and consolidating the results. The research activities in the two cycles are somewhat following the timeline below:

- Task 1: **methodology:** With all knowledge partners and societal partners we determine the datasets, incorporate insights from the previous cycle (if applicable) and build the methodologies.
- Task 2: **case study:** application of the methodologies developed in Task 1 to the relevant case study.
- Task 3: **publication:** the work will be concluded with one publication in a complex system science related venue and one additional publication by the societal partners. We also plan to develop either study material in the curriculum of the Police Academy or a specialized publication for the police/bank/stakeholders as a cross-collaboration between all work packages.

In the first cycle we focus on the theme of network reconstruction for the detection of anomalous transactions, while in the second cycle the emphasis is on ABS and the impact of interventions. In the final year the toolset as a whole will be finalized and made available to all. The PhD manuscript will be finalized.

Productive interactions (co-design and co-creation): The aforementioned societal partners (banks, etc.) play an important role in the project in preparing data for the case studies, defining the domain specific patterns of interest, evaluating the systems in terms of usability and effectiveness, and ensuring that the methods operate conform the legal, forensic and ethical standards in the domain. Moreover, jointly with the Police Academy insights acquired in this research will be incorporated in relevant training.

Contribution to project: Development of novel methodologies and application to relevant use cases.

Development of training material in order to ensure the practical use of the developed methodologies in practice.

| Work package number | 3.1. |
|---|---|
| Work package title | **Toward a self-reflective criminology of the networked offender-victim-facilitator triad that enables human trafficking, money laundering and corruption** |
| Work package leader | Dr. Yarin Eski |
| Involved partners | Knowledge chain partners: VU's Public Administration Department, Maastricht University's Criminal Law and Criminology Department, IAS, and PA. Societal partners: Cf. WP 1.1. |
| Start date | Month 1 |
| End date | Month 48 |

Objectives: Delivering (self-reflective) ethnographic insights concretized in a qualitative, criminological typology of the offender-victim-facilitator triad and its role in adaptive (criminal) networks that engage in human trafficking, money laundering and corruption.

Methodology: Human trafficking can be considered a networked supply chain in which various members assume roles within such a network; each of them having their interactions and their connectivity or secrecy, knowing that the same entities can fulfil more than one role in the network. It is impossible to retrieve a full overview of the structure of crimes that undermine democratic societies governed by the rule of law, but it is possible to make viable estimated statistical guesses from which data can be retrieved for modelling and predicting, as COMCRIM sets out to do, to support combatting the interrelated phenomena of these three offenses. The applicative nature and focus of COMCRIM thus require an overarching methodological approach of data on all three offenses through AI vis-à-vis mathematical and computational models for studying the effectiveness of interventions to those criminal activities.

Part of work package 3.1.'s methodology is to account for the criminological phenomenon of the _dark number_ (Biderman and Reiss 1967; Skogan 1977), as we will never know how much human trafficking, money laundering and corruption takes places and how many offenders, facilitators and victims are involved (see Van der Leun 2017). The dark number, therefore, in this research must be considered a researchable phenomenon itself (see Van Dijk 2010). Also, not every offender, facilitator and victim of, for example, human trafficking sees him-/herself as such. Offenders can consider themselves humanitarians, whereas victims may see themselves as willful survivors. Nor do policing actors always apply these specific classifications correctly where they may classify victims as such, whereas those victims think differently.

These networked, and changing roles and classifications have an effect on the data collected on them, and on modelling and predicting (Caccavale 2013). They will therefore influence the logic of the quantitative approach of COMCRIM (packages 2.1., 2.2. and 3.2.). This work package will account for the inherently limited data used in COMCRIM. It concretely requires a socio-criminological imagination (Mills 1959; Young 2011) of the interacting relation between the (roles in the triad of the) offender, facilitator and victim of crimes that undermine democratic societies

governed by the rule of law. That imagination will continuously reflect on this project's socio-legal (*COMCRIM's research line 1*), computationalnumerical (*COMCRIM's research line 2*) and socio-economic (*COMCRIM's research line 3*) understandings of the triad.

From the imagination a typology shall emerge by continuously ethnographically evaluating the roles, images and understandings that exist among offenders, facilitators and victims, as well as among policing and security authorities, and among the researchers of this project themselves (including the work package leader of 3.1.). The emergent *typology* is thus also a self-reflective exercise installed into COMCRIM. It functions as a methodological tool to facilitate categorical analysis of complex phenomena (Andrist et al 2014; Weber 1949), for which the researcher will inductively and ethnographically study multiple cases. First, in-depth interviews will be undertaken together with and (participant-)observations of relevant (groups of) actors of the triad. Their stories will comprise data-collection of 'thick descriptions' to produce the aimed for typology to provide a comprehensive overview of their (self-)images regarding human trafficking, money laundering and corruption. Moreover, as important are in-depth interviews with relevant policing actors to contrast their stories along 'the policed' triad. Site-visits will enable the (participant-)observations during activities of COMCRIM's societal partners. Finally, the work package will analyze official documents (Eski and Buijt 2017) of police/prosecution and banking files held by the involved public-private partners. This leads to an understanding of how they (think to) recognize the criminal phenomena and produce files that usually form the basis of much statistical criminological) research and the *etic* numbers they produce. The official document analyses shall provide an (discursive) understanding of the *emic-perspective* of those policing actors (Young 2005).

Description of research activities: This project consists of three stages:

- **Task 1 orientation**: the specific case-studies will be theoretically and methodologically decided on, also in close collaboration with COMCRIM's societal partners as well as the other COMCRIM researchers to determine different cases, ideally resulting in at least 3 case-studies.
- **Task 2 fieldwork**: each case-study will be explored by using the above mentioned different ethnographic methods, focusing within each case on the triad, consisting of interviews, (participant) observations with public/private partners and COMCRIM researchers & official dossiers analyses.
- **Task 3 output**: the retrieved findings will be delivered in a research report for the societal partners, the PhD manuscript finalized and three scientific publications (1 methodological and 2 theoretical-empirical) shall be submitted to peer-reviewed journals in the field of expertise of the researcher.

Direct valorization will be established through the Vrije Universiteit (VU) Public Administration Master 'Governing Security' study curriculum.

Productive interactions (co-design and co-creation): The aforementioned societal partners (banks, etc.) will provide fieldwork access to staff for interviewing, for (participant-)observations, and for official dossiers and document analysis.

Contribution to project: A self-reflective, critical criminological typology of the offenders-facilitators-victims triad, including policing and security actors' perspectives *and* that of the COMCRIM researchers themselves, delivering understanding of (the numerical reality of) human trafficking, money laundering and corruption; understanding feeding (directly) back into COMCRIM. Fundamental knowledge by (meta-)theorizing (underlying) political, social, institutional and economic dynamics that shape the adaptive (criminal) networks in crimes that undermine democratic societies governed by the rule of law (cf. research on (street) criminal retaliation (Jacobs 2004), organized gang activity (Harding et al 2018) and illegal drug markets (Curtis & Wendel 2000)). Direct practical usefulness in academic curricula.

| Work package number | 3.2. |
|---|---|
| Work package title | **Development of Statistical Methods appropriate to measurement of Complex Network Diagnostics, using official statistics.** |
| Work package leader | Prof. dr. Frank P. Pijpers |
| Involved partners | Knowledge chain partners: FNWI, CBS, Maastricht University's Criminal Law and Criminology Department, IAS, PA. Societal partners: Cf WP 1.1. |
| Start date | Month 1 |
| End date | Month 48 |

Objectives: Developing statistical diagnostic tools that can be used on official statistical data for social and/or business networks, in order to detect and quantify volumes and value of illicit goods and services in the overall economy.

Methodology: The economy of any country is increasingly interlinked with very many other countries, as a consequence of the globalization of markets which has been ongoing for many decades. Even within countries production chains have become both longer and more branched, so that a description in terms of complex networks is more and more appropriate and necessary. The economy of the Netherlands is not an exception. In fact, due to the open economy of the Netherlands, with a strong role for international trade, services, and logistics, the Dutch economical system is a prime example of this complexity.

Given this background it is also more complicated to trace the black economy and its interface with regular legal economic activities. There is an EU framework for estimating the overall size and contribution to GDP of the black economy, but there is little detail and there are large uncertainties regarding the economic vulnerabilities that such a black economy may introduce which could have serious consequences for security and robustness of Dutch society and its economy.

In the description of work package 2.2. it is mentioned that the detection of anomalous transactions is one of the major challenges faced by financial institutions today. Such transactions may be related to several of the aforementioned types of crimes that undermine democratic societies governed by the rule of law. At a national economical scale, the aggregation of such transactions leads to a branched flow of money through the regular economy. Mathematical and computational models for quantifying the influence of this on the functioning of the economy overall are lacking. In work package 3.2. we aim to develop methodologies from the complex systems science research field to tackle these challenges, which share some of the technical methodology with work package 2.2. In particular, we will focus on approaches from network

science (e.g. Mattsson 2021 and references therein) extended with methods inspired by information theory and agent based simulations [1-5].

When studying transaction networks one has access to only **limited information**, dramatically reducing the possibility of detecting nodes or flows that play a key role in interfacing illicit and legal economic activity. These challenges can be tackled by network reconstruction methods, which can optimally employ the available data to obtain the full network structure (Squartini et al 2018; CBS 2021). By treating regular and irregular economic activity as layers in a multiplex network, this could lead to indicators for the vulnerability of the Dutch economy.

In terms of the social network of people residing in the Netherlands, there is more coverage of some types of social contacts, although also in this domain there are unknowns. The impact of human trafficking and other activities pertaining to crimes that undermine democratic societies governed by the rule of law activities reaches beyond the economic domain into the social domain as well, affecting well-being and other broad indicators of well-being (CBS 2021). It is therefore important to use official statistical data, linked with data on registered crime, to assess the social impacts of crime and the spread of that influence over the social network. This too requires development or adaptation of methods and techniques.                Both at a more micro-level mentioned in work package 2.2., and at meso- and macro levels for the economy, the role of **interventions** in such systems is poorly understood. Here too, we differentiate between internal and external interventions (cf. WP2.2.). Since external interventions are typically the results of actions imposed by policy-makers and the legal system, Agent Based Simulations (ABS) provide a natural framework for studying the effect of both types of inventions for a wide range of system properties and scenarios. ABS has been successfully used as a modeling paradigm to understand the driving mechanisms of the dynamical behavior of a wide variety of complex systems. For example, in finance and economics the role of heterogeneity and the (nonlinear) interactions have been explored in different studies in the past two decades (e.g. Qui et al 2012). In this project we aim to develop ABS approaches for (financial) crimes that undermine democratic societies governed by the rule of law. The key challenge here is to identify the different types of agents, i.e. which actors do we want to include and the granularity of their micro dynamics and interactions. For this we will closely work with work packages 1 and 2, use the network reconstruction methodology proposed in this work and the AI based methods of work package 2.1. (as a basis for the initial interactions between the agents). By aggregating over the population of agents, model-based counterparts of economic and societal indicators can be compared to regular output of official statistics so that improvements can be made, both to the models but also in order to design improvements to indicators to enhance the sensitivity at the national level of the influence of crime.

As specific **case studies** in which we will closely collaborate with our partners to test and calibrate improved methodology on real data, we will consider:

1. Network reconstruction based algorithms for quantifying economic and social impact of criminal activity at a national level.
2. The impact of interventions using ABS.

Description of research activities: The research activities are roughly decomposed into two cycles of 18 months which all have the same structure followed by a final year of bringing everything together and consolidating the results. The research activities in the two cycles are somewhat following the timeline below:

- Task 1: **methodology:** With all knowledge partners and societal partners we determine the datasets, incorporate insights from the previous cycle (if applicable) and build the methodologies.
- Task 2: **case study:** application of the methodologies developed in Task 1 to the relevant case study.
- Task 3: **publication:** the work will be concluded with one publication in a complex system science related venue and one additional publication by the societal partners.  We also plan to develop either study material in the curriculum of the Police Academy or a specialized publication for the police/bank/stakeholders as a cross-collaboration between all work packages.

In the first cycle we will focus on the theme of network reconstruction for tracing the black economy through the regular economy, while in the second cycle the emphasis will be on ABS and the impact of interventions. In the final year the toolset as a whole will be finalized and made available to all.

Productive interactions (co-design and co-creation): The aforementioned societal partners (banks, etc.) provide an important role to the project in preparing data for the case studies, defining the domain specific patterns of interest, evaluating the systems in terms of usability and effectiveness, and ensuring that the methods operate conform the legal, forensic and ethical standards in the domain. Moreover, jointly with the Police Academy insights acquired in this research will be incorporated  in relevant training.

Contribution to project: Development of novel methodologies and application to relevant use cases.
Development of training material in order to ensure the practical use of the developed methodologies in practice.