Trafficking and Trust

Understanding the role of trust in a criminal supply chain

MSc Thesis

Engineering & Policy Analysis

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Preface

Smuggling illegal goods is something we as Dutch citizens are confronted with almost daily in newspapers. Articles about thrilling amounts being seized and violence associated with smuggling is no surprise anymore. Still, a staggering amount of illegal goods ends up on the streets. It was a fascinating topic to work on, diving deeper into the smuggling process and understanding the way criminals operate.

During this thesis project I have been guided by three external supervisors from the Dutch National Police. I would like to thank Erik and Esther for their time and fun insights on the legal and criminal processes in the port of Rotterdam. Also thank you for your patience, while I was processing all this information to understand what really was happening. And Paul, for believing in the potential of the project.

Furthermore, I would like to thank my graduation committee from the TU Delft. Isabelle, my daily supervisor, guided me through the process of creating a Msc. thesis on a weekly basis and was always available in case I got stuck. I would also like to thank her for her understanding in difficult periods and encouraging me to distance myself from perfectionism in my model. We also enjoyed a fun trip into the harbor that we concluded with a beer afterwards. And Jan Kwakkel, who always had enlightening ideas during supervisory meetings that guided me in doing research. I would also like to thank Natalie, for discussing the psychological part of my research with. It was something totally new to me, but you made me comfortable with the concepts within no-time. Furthermore I would like to thank Alexander Verbraeck, for jumping in and providing an additional critical reflection allowing me to improve the value of my study.

Lastly I would like to thank all of my family and friends. During my whole time at the university you have been of great support. Especially the last months for encouraging me and making me believe in myself. It has not been the easiest period, but you guided me through it and gave me great advice when I needed it most. Without your support, finishing my studies would have been more of a struggle.

To the reader of this report, I hope you enjoy reading it. Besides academic material it provides you with interesting insights on criminal operations. But remember, do not try that at home.

Ryan van der Plas
14 August, 2022

Executive Summary

This report contains an English as well as a Dutch summary which have the exact same content.

Trust between criminals is potentially important for the decisions they make in criminal supply chains. Some authors found the importance of trust in criminal supply chains in a general way, but did not dive deeper into the matter to discover its real relevance. Additionally, some experts think trust is not as important as these authors conclude. The eventual smuggling of illegal goods is established by many decisions, potentially influenced by trust. Therefore, this research aims at providing insights in the role of trust on criminal decision-making in criminal supply chains. Furthermore, it also sheds light on intervening in the criminal supply chain to decrease trust between criminals, and analyzing whether such interventions could have disruptive effects.

The research is conducted on a case study that covers a criminal supply chain from South America to the port of Rotterdam, with a focus on the port of Rotterdam. Publicly available information in combination with views of experts were used for gaining insights in this criminal supply chain. Additionally, a literature study is performed on trust and two decision-making models: (1) the risk vs. gain trade-off and (2) transaction-cost economics theory. This allows for sketching the decisions in the criminal supply chain that are influenced by trust between criminals.

The research makes use of an agent-based modeling approach. An agent-based model allows for observing emergent system behavior arising from individual decisions in a system made based on a pre-specified set of behavioral rules for the individuals incorporated in the model. The simulation model is implemented for beginning shipping networks that develop trust over time and where their decisions, according to the decision-making models, are influenced by interpersonal trust. As the criminal supply chain itself and quantifying abstract mental processes are highly uncertain, experiments with the model have been run for several scenarios with different levels of importance of trust. Additionally, three interventions were identified for testing effectiveness: (1) creating distrust, (2) stopping criminals from being able to avoid customs checks, and (3) making customs checks later before the estimated time of arrival of ships are known. To evaluate the model results, several key performance indicators were identified. Since the research aims at providing insights in the role of trust on criminal decision-making in criminal supply chains, the key performance indicators have been split into two categories: (1) supply chain performance, and (2) trust.

The experiments with the model showed that for both decision-making models under the current parameterizations of the scenarios, trust did differ between scenarios but supply chain performance did not. Moreover, the results of both decision-making models were identical. This finding indicates that trust did not matter for the decision-making of criminals taking part in illegal activities in the criminal supply chain from South America to the port of Rotterdam, under this set of scenarios. The interventions showed similar results, but additionally showed that interventions could indirectly affect trust in criminal networks. In combination with increased interceptions, interventions could speed up the process of reaching the tipping point where trust could be pivotal in the decision-making of criminals.

The results can be generalized in broader criminal supply chain context. In all supply chains trade-offs are being made. The finding that relatively high gains accompanied by certain personal preferences in weighing gains, risks and costs, makes the role of trust in criminal decision-making irrelevant applies in general to supply chain trade-offs. Furthermore, increasing interceptions in the criminal supply chain indirectly affects the trust in others, as doubt about their competence in successfully shipping illegal goods may arise. Supply chain interventions could possibly indirectly have disruptive effects on the criminal decision-making through the trust channel.

This research also had its limitations. Since it was considering a criminal supply chain, little data and knowledge was available, hindering validation of the model. However, the criminal supply chain structure was constructed with views of experts and checked afterwards. Furthermore, abstract mental

processes as trust and decision-making are hard to quantify, and as discovered often context dependent. Therefore, model outcomes have a high uncertainty and do not quantitatively represent reality. However, qualitative findings about the influence of trust on the criminal supply chain can be used for understanding as all combinations of input parameters could represent a situation in reality. Since the current research varied input parameters only with three scenarios, deep uncertainty analysis could provide additional qualitative insights about the possible influences of trust. Profit margins and individual preferences in trade-off variables could be varied over a wider range of values for the current criminal supply chain.

Samenvatting

Dit rapport bevat zowel een Engelstalige als Nederlandstalige samenvatting waarin exact hetzelfde vermeld wordt.

Vertrouwen tussen criminelen is mogelijk van belang voor beslissingen die ze maken in criminele logistieke ketens. Sommige auteurs bevonden dat vertrouwen in criminele logistieke ketens belangrijk was in een generieke manier, maar hebben geen verder onderzoek naar vertrouwen gedaan om de echte relevantie van vertrouwen te ontdekken. Daarnaast denken sommige experts dat vertrouwen niet zo belangrijk is als deze auteurs beweren. Het uiteindelijke smokkelen van illegale goederen komt tot stand door veel beslissingen, beslissigen die potentieel beïnvloed worden door vertrouwen. Daarom richt dit onderzoek op het voortbrengen van inzichten in de rol van vertrouwen in criminele besluitvorming in criminele logistieke ketens. Verder laat dit onderzoek ook zien wat ingrijpen in de criminele logistieke keten doet met het verminderen van vertrouwen tussen criminelen, en analyseren of zulke interventies potentieel verstorende effecten kan hebben.

Het onderzoek baseert zich op een case study die de criminele logistieke keten van Zuid-Amerika naar de haven van Rotterdam beschouwt, met een focus op de haven van Rotterdam. Publiek beschikbare informatie in combinatie met de expertise van experts worden gebruikt voor het verkrijgen van inzichten in deze criminele logistieke keten. Daarnaast is een literatuurstudie uitgevoerd in vertrouwen en twee besluitvormingsmodellen: (1) de risisco-winst afweging en (2) transactiekosten-theorie. Hierdoor wordt inzicht verkregen in de beslissingen in de criminele logistieke keten die beïnvloed worden door vertrouwen tussen criminelen.

Het onderzoek maakt gebruik van een agent-gebaseerde modelleermethode. Met de agent-gebaseerde modelleermethode kan inzicht verkregen worden in emergent systeemgedrag dat onstaat uit individuele beslissingen in een systeem, die gebaseerd zijn op een set vooropgestelde gedragsregels voor individuen die in het model zijn opgenomen. Het simulatiemodel is geïmplementeerd voor beginnende smokkelnetwerken die ontwikkelen door de tijd heen en waar beslissingen volgens de besluitvormingsmodellen, worden beïnvloed door vertrouwen tussen personen. Doordat het modelleren van een criminele logistieke keten op zichzelf en het kwantificeren van abstracte mentale processen hoogst onzeker zijn, zijn de experimenten met het model uitgevoerd voor enkele scenario's met verschillende relevanties van vertrouwen. Daarnaast zijn drie interventies geïdentificeerd om de effectiviteit daarvan te bewerkstelligen: (1) het creëren van wantrouwen, (2) het onmogelijk maken voor criminelen om douane blokkades te omzeilen en (3) het later bekendmaken van douanecontroles voordat het schip arriveert in de haven. Om de modelresultaten te evalueren, zijn er enkele indicatoren voor de systeemprestaties geïdentificeerd. Omdat het onderzoek zich richt op het verkrijgen van inzichten in de rol van vertrouwen op criminele besluitvorming in criminele logistieke ketens, zijn deze indicatoren opgedeeld in twee categorieën: (1) logistieke keten prestaties en (2) vertrouwen.

De experimenten met het model lieten zien dat voor beide besluitvormingsmodellen onder de huidige parametrisatie van de scenario's, vertrouwen verschilde tussen de scenario's, maar de prestatie van de logistieke keten werd niet beïnvloed. Bovendien waren de resultaten van beide besluitvormingsmodellen identiek. Deze bevinding duidt erop dat vertrouwen geen rol speelt in de besluitvorming van criminelen die deelnemen in illegale activiteiten in de criminele logistieke van Zuid-Amerika naar de haven van Rotterdam, onder deze set van scenario's. De interventies lieten gelijke resultaten zien, maar lieten daarnaast ook zien dat deze interventies indirect vertrouwen tussen criminelen konden ondermijnen. In combinatie met verhoogde onderscheppingen kunnen interventies het proces versnellen om het omslagpunt te bereiken waar vertrouwen doorslaggevend kan zijn in de besluitvorming van criminelen.

De bevindingen kunnen gegeneraliseerd worden in de bredere context van criminele logistieke ketens. In elke logistieke keten worden afwegingen gemaakt. De bevinding dat relatief hoge winsten in combinatie met zekere persoonlijke voorkeuren in het wegen van winsten, risico's en kosten, de rol van

vertrouwen in criminele besluitvorming irrelevant maakt, geldt in het algemeen voor afwegingen in logistieke ketens. Verder beïnvloedt het verhogen van pakkansen indirect het vertrouwen in anderen, doordat twijfel over hun bekwaamheid in het succesvol verschepen van illegale goederen kan ontstaan. Interventies in de logistieke keten kunnen mogelijk verstorende effecten hebben op criminele besluitvorming door het vertrouwenkanaal.

Dit onderzoek had ook limitaties. Omdat het onderzoek een criminele logistieke keten beschouwde, was er weinig informatie en kennis beschikbaar, wat de validatie van het model ten opzichte van de werkelijkheid bemoeilijkte. Daarentegen is de criminele logistieke keten gemodelleerd met behulp van inzichten van experts en vervolgens gecontroleerd voor consistentie met de werkelijkheid. Daarnaast zijn abstracte mentale processen moeilijk te kwantificeren en vaak context afhankelijk. Daarom zijn de modelresultaten erg onzeker en komen de kwantitatieve uitkomsten niet overeen met de werkelijkheid. Echter kunnen de kwalitatieve bevindingen over de invloed van vertrouwen op de criminele logistieke wel gebruikt worden voor nieuwe inzichten, omdat alle combinaties van invoerwaarden een situatie in de echte wereld kunnen weerspiegelen. Omdat het huidige onderzoek de invoerwaarden met maar drie scenario's varieerde, kan verdere analyse onder diepe onzekerheid van de invoerwaarden verdere kwalitatieve inzichten geven in de mogelijke invloeden van vertrouwen op criminele besluitvorming. Winstmarges en individuele voorkeuren in de variabelen voor afwegingen in de besluitvorming kunnen over een groter bereik van waarden gevarieerd worden voor de huidige criminele logistieke keten.

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Introduction

The port of Rotterdam is an efficient and important gateway to Europe for shipping goods overseas. This attracts smugglers who make use of legal transport routes to transport their illegal goods from South America into the Netherlands or use it as a transit hub to other European ports (Dirksen et al., 2021; Jensen & Dignum, 2019; Zaitch, 2002b). The smuggle of illegal goods is accompanied by other criminal activities harming society (Desroches, 2007; InSight Crime, 2021). Criminals do not shy liquidations (Meeus et al., 2019; Ouhajji, 2021) and draw in the Dutch youth at young ages (Politie, 2022; Unnever, 2019). Besides these issues, the provision of illegal goods on European soil is causing widespread health damage and even death (EMCDDA, 2015, 2020). However, negative impacts are even more far reaching and also take economic form by shipping companies having to abort their activities because of criminal misuse of their transport routes (FD, 2022).

1.1. Problem Statement

To counter these impacts, the Dutch Police tries to disrupt criminal supply chains in the port of Rotterdam by providing intelligence to Dutch customs for intercepting illegal goods, either meant for the domestic market or in transit to other European ports. It is characterized as a ”cat-and-mouse” game between criminals and the police, in which criminals will search for alternative smuggling options and displace activities when authorities get close to catching them (Bagley, 2013; Magliocca et al., 2019; Roks et al., 2021). Although the Dutch Police makes a big effort to increase interceptions, it is estimated that only 10-20% of all illegal goods entering Europe is being intercepted (McDermott et al., 2021). A small percentage which already equaled 40.000 kilograms in 2020 being seized and nearly 73.000 kilograms in 2021 (OM, 2021, 2022), confirming the increasing amount of illegal trafficking (UNODC, 2021). Efforts to disrupt criminal supply chains are hampered by little available information and data on how they operate (Dirksen et al., 2021; Von Lampe, 2009). However, academic research on criminal networks could be an option to provide more insights. Morselli et al. (2007) found that these networks constantly face trade-offs for decision-making. Klaassen (2021) and Zaitch (2002a) found by interviewing Dutch Police officers and respectively Colombian traffickers, that trust between criminals is essential to the trafficking of illegal goods as it strongly reduces risks. However, during conversations with experts, it seemed that there was no consensus on the importance of trust in criminal supply chains. Therefore, this research aims at contributing to the understanding of the importance of trust between criminals in their decision-making in criminal supply chains by a modeling and simulation approach. This helps the Dutch Police in retrieving insights how and to what extent trust within criminal networks affects criminal decision-making.

1.2. Scientific Research Gap

Despite studies showing the effects of trust in legal supply chains, no studies involve trust between criminals in their decision-making and the eventual effects on the criminal supply chain itself. Results from studies on trust in legal supply chains are not simply generalizable to criminal supply chains because trust acts as a substitute for contracts and law for reducing risks (Basu, 2014; Jensen &

Dignum, 2019; New, 1997). Two earlier studies involved trust in criminal supply chains. Klaassen (2021) labeled trust as a possible important factor in criminals their decision-making process, but did not yet study the process of trust and its connection to the criminal decision-making in the supply chain on a deeper level. Jensen and Dignum (2019) studied the relationship of trust within the criminal supply chain, where trust was a decisive factor for the criminals as it reduced risks, but did not yet connect trust to trade-offs criminals make apart from minimizing risks.

This study aims at contributing this knowledge by composing an agent-based model (ABM) of the criminal supply chain and the involved actors. An ABM allows to simulate interactions between autonomous entities according to a set of pre-specified rules for their behavior. All these interactions bundled together will resemble a simplified picture of the criminal supply chain but could provide useful insights in the behavior it has been designed for.

1.3. Research Goal

Aiming to provide insights in the influence of trust on criminal decision-making and the eventual effects on the criminal supply chain from South America to the port of Rotterdam by a modeling and simulation approach as just mentioned, requires preliminary research. To be able to contribute this knowledge, several steps have to be taken to come to a conclusion. The research can be split in two parts: (1) a qualitative part gaining the knowledge for constructing the (2) quantitative model which allows for analysis and conclusions based on the qualitative theories and knowledge gathered.

1.4. Research Scope

To keep the research manageable within the time frame outlined, the research will be demarcated in several aspects. For the first aspect, one conceptualization of the dynamics of trust will be constructed. Next, a total of two decision-making models affected by trust will be incorporated in the model to not only be able to tell whether trust is important in the criminal supply chain, but also to show whether the way criminals shape their decision-making is relevant for the influences of trust. As a third aspect, the criminal supply chain will be spatially and actor wise demarcated. Each demarcation of the three aspects required for this research, will be discussed in the next chapters devoted to this.

1.5. Research Questions

With the research goal and scope in mind and knowing what is required to come to a conclusion for the importance of interpersonal trust between criminals in the criminal supply chain, the research question in the blue box below has been defined.

Main Research Question

How does trust affect decision-making in criminal supply chains, and what is its influence on illegal goods flow?

For answering this research question, trust and criminal decision-making must be conceptualized, and subsequently implemented in a model. A case study for a supply chain of illegal goods from South America to the port of Rotterdam will be used. As trust might be directly or indirectly influenced by the supply chain or Police interventions, the research will also analyze what will happen in this case. Therefore, this main research question can be divided into the following three sub-questions for structuring the research:

In the context of a criminal supply chain...

1. *how can decision-making related to trust be conceptualized?*
2. *how can the impact of trust on decision-making be modeled using agent-based modeling?*
3. *how do interventions affect trust and illegal goods flow?*

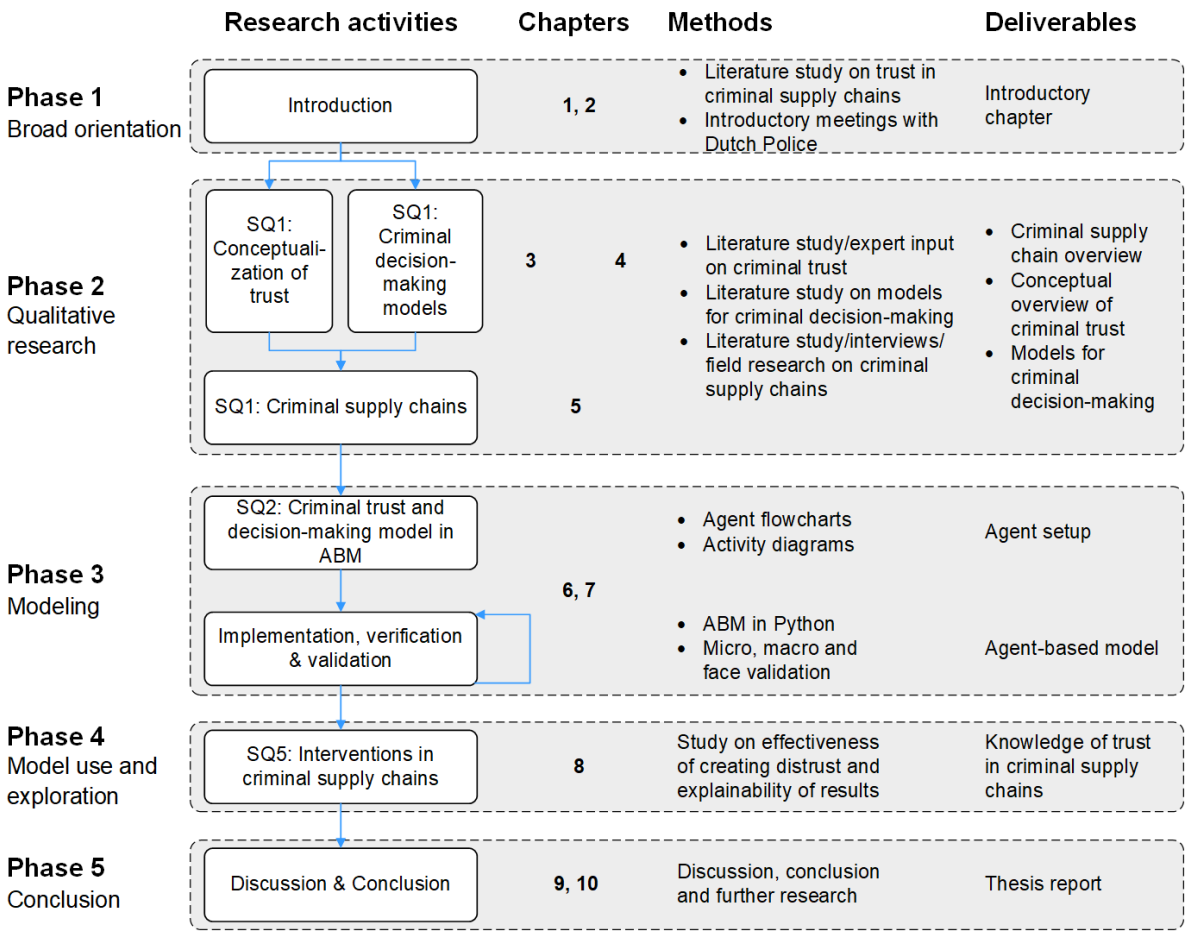

Figure 1.1: *Research design including sub-questions.*

1.6. Research Design

This research is divided into several separate phases. All phases will be briefly discussed and the connection between the phases is shown in Figure 1.1.

Phase 1: Broad orientation The goal of the first phase is gaining an understanding of the criminal supply chain by doing research and talking to experts in the field, as little specific information is actually publicly available. This allows for giving a direction to the research by defining the most relevant area to focus on.

Phase 2: Qualitative research In this phase of the research, the objective is to provide a solid and complete base for the quantitative model to be constructed. A literature study on trust and criminal decision-making will provide the base for interpersonal dynamics in the model. Dynamics which eventually result in the flow of illegal goods in the specific supply chain from South America to the port of Rotterdam. Due to limited and outdated information on criminal activities in the port of Rotterdam, experts in the field are consulted for gathering a clear overview of the criminal supply chain.

Phase 3: Modeling The qualitative findings of the previous phase will be translated into a quantitative model. This model will be able to simulate criminal activities and interpersonal interactions between criminals affected by trust and decision-making models and in turn affecting trust as result of these interactions.

Phase 4: Model use and exploration During this phase the constructed model will be used for testing the effectivity of interventions under uncertainty. Quantifying abstract psychological processes like

trust is intuitively accompanied by uncertainty, as is it unclear to what extent interpersonal interactions may lead to feelings of trust and how these feelings of trust in turn influence the mind in its decision-making.

Phase 5: Conclusion After obtaining results from the model, the study can be concluded by stating whether trust is important within criminal networks that facilitate the smuggling of illegal goods under the set conditions and assumptions with whichthe study has been done. However, this also allows for discussing the consequences of these conditions and assumptions and whether the conclusions are more generally applicable, possibly contributing to a broader field of criminological research.

2

Methods

This research combines qualitative research with quantitative research, where the qualitative research provides the base for composing the quantitative model to perform the analysis with. The qualitative research is split into three parts: (1) retrieving and documenting a clear insight in the criminal supply chain, (2) getting familiar with trust and its workings and (3) how this influences (criminal) decision-making. The modeling research will combine these three qualitative parts into a quantitative model that allows for analysis answering the main goal of the research. This chapter is devoted to giving a clear picture of how this research is performed for creating a first of its kind insight.

2.1. Qualitative Research

During qualitative research a literature study was performed accompanied by unique insights from experts in the field. Per part of the qualitative research will be mentioned how it was performed.

Although the smuggle of illegal goods is a common subject in Dutch newspapers, the available insightful information on criminal supply chains is limited or outdated. The primary information on the criminal supply chain has been gathered during meetings with experts for constructing a framework of the criminal supply chain and its actors, in combination with additional documents that were provided. Their knowledge is based on expertise gathered during doing their job. Furthermore, a field trip into the port of Rotterdam provided a clearer picture by being able to see the problem with own eyes from the side of law enforcement.

Trust seems to be an abstract topic and hard to express for people how and to what extent it plays a role. It is unknown how trust affects criminals in their decision-making and therefore is the goal of this research. For gathering these insights a literature study is performed on trust and how it can be conceptualized

Another literature study is performed on several decision-making models for being able to model criminal decisions. As there are no separate models for criminals' decision-making, models that could be applicable to criminal decision-making are selected. The risk vs. gain trade-off is identified as a relevant decision-making model by Morselli et al. (2007) as criminals have proven to constantly evaluate risks and gains. Additionally, trust could act as a substitute for the absence of contracts and law in criminal networks striving for efficient business relationships. Therefore, transaction-cost economics (TCE) is another decision-making model that will be included as TCE theory tells that individuals tend to establish relationships that are as efficient as possible.

2.2. Quantitative Research

The above three parts of qualitative research, the criminal supply chain, trust, and decision-making, will be bundled into one single computational ABM model.

2.2.1. Model Formalization

ABM is a powerful modeling technique with many implications in social simulation, including supply chains (Macal & North, 2005; Strader et al., 1998). It is best described as a collection of autonomous entities (agents) in a certain space making decisions based on a pre-specified set of rules (micro-behavior), which may result in (un)anticipated emergent patterns (macro-behavior) (Bonabeau, 2002; Polhill et al., 2021). ABM helps in understanding these emergent patterns of social systems by characterizing them by certain micro-behavior and explaining social phenomena (Bankes, 2002; Conte, 2002; Helbing, 2012).

Micro-behavior of agents can be as real as physical laws of nature (Van Dam et al., 2012). Often the perception is that human beings behave rational and always want to maximize efficiency. But actually rationality is just a small part of behavior that is dominated by habits and routines (James & Skrupskelis, 1983). Therefore, integrating habits and routines provides more realistic micro-behavior and is important for better understanding of social systems (Epstein, 2014; Gibson et al., 2021; Jager, 2017; Mercuur, 2021). In the context of a criminal supply chain with trust between agents, this could imply that agents have a 'memory' of good and bad experiences when doing business with other agents. Agents might tend to do business once again with agents with whom they had a good experience, because they associate this with a low risk for a bad experience. For being able to generate a useful ABM, models need to be grounded in social sciences (Boero & Squazzoni, 2005; Edmonds, 2010; Epstein, 2014; Mercuur, 2021; Moss & Edmonds, 2005; Squazzoni et al., 2014). Thus integrating trust and decision-making in the criminal supply chain context, will be a scientifically relevant model in its own context.

The benefit of using the ABM approach is that these 'simple' behaviors of individuals which interact in the criminal supply chain, could generate emergent macro-behavior when distrust is created within the criminal network. These emergent properties may be unexpected, but explainable by these simple behaviors and provide new insights for the scientific community and the Dutch Police of trust and distrust in the criminal supply chain from South America to the Netherlands. However, the usage of ABM also has its limitations. One of the limitations is that ABM is very computationally intensive (Bonabeau, 2002). Especially in a system like this where many things are uncertain, the need for computational power will increase rapidly and has to be taken into account when creating the model and setting up model runs. Another consequence of the wide spectrum of uncertainties is a limited ability to validate the model, because much is simply unknown. However, because much is unknown this exploratory modeling may provide new insights as discussed before.

2.2.2. Model use

As already mentioned, an ABM allows for exploration of a system and generating new knowledge based on a set of implemented theories. In this model use phase, interventions in the supply chain will be implemented and investigated how these influence key performance indicators (KPIs) such as trust in networks and illegal goods interceptions and throughput. To cope with uncertainty in model parameters several scenarios will be composed on which trust influences can be seen with and without interventions. For analyzing results will be made use of independent samples t-tests. T-tests allow analysis of means of two results samples of the same size with a similar variance. This allows for analyzing whether scenarios mutually differ and whether interventions do have effects.

3

Criminal supply chain

As a starting point in retrieving insights in the role of trust in criminal supply chains from South America to Rotterdam, a clear picture of the supply chain, its actors and its dynamics needs to be provided. Although knowledge on criminal activities may be limited, combining available literature, general information and expert knowledge generates a clear overview of the criminal activities for smuggling illegal goods. This chapter will first discuss the criminal supply chain, followed by connecting criminal processes to the criminal actors involved to provide a base for an ABM concerning criminal decision-making in criminal supply chains. Most of the presented knowledge has been gathered during conversations with experts who have checked this chapter for compliance to their views.

3.1. The rip-off smuggling method

As displayed in Figure 3.1, the criminal supply chain starts at the farmland in South America and eventually the produced illegal goods end up at consumers in the Netherlands and further into Europe through the port of Rotterdam and other European ports. This research focuses on the distribution process from South American ports to the point where the illegal goods are extracted from the port of Rotterdam by criminal organizations, thus the transatlantic distribution and retrieval as indicated in Figure 3.2.

For the transatlantic distribution of illegal goods, several smuggling methods are exploited which are briefly described in Table 3.1. This research will focus on the rip-off method for several reasons. During

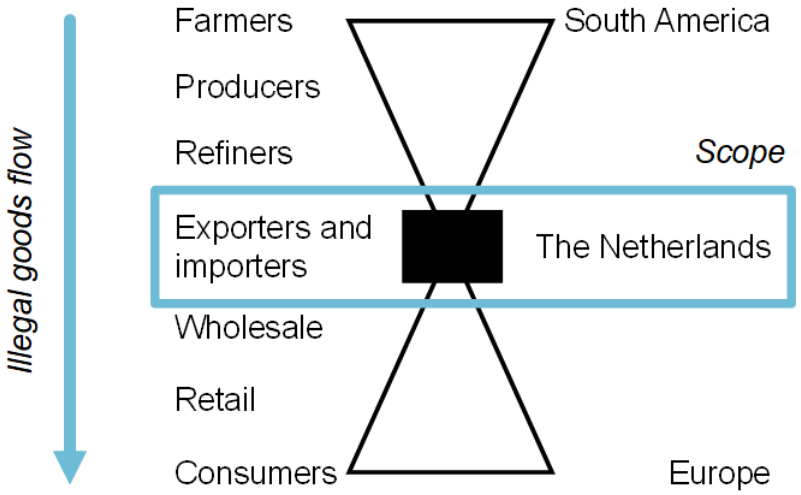

Figure 3.1: *Criminal supply chain from production to consumption (based on Jensen and Dignum (2019) and Zaitch (2002b)). The blue box is the scope of this research.*

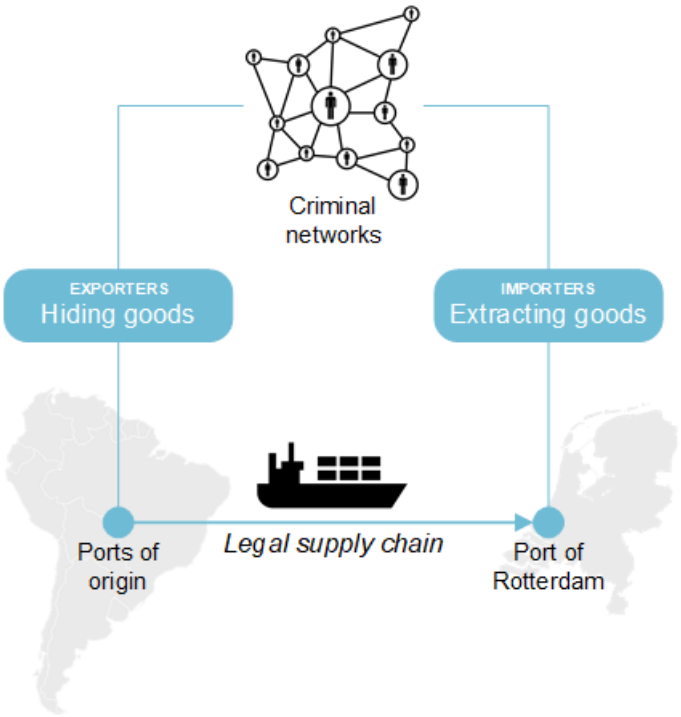

Figure 3.2: *High-level criminal supply chain demarcation.*

conversations with experts, they indicated that the rip-off method is most likely most exploited. This view is confirmed by Gandilhon (2016) who states that there has been a shift from concealment in structures and cargo to the rip-on/rip-off method. Furthermore, although still a common used smuggling method, cover loads involve malicious companies controlled by criminal organizations. This involves less actors in the transatlantic shipping process and therefore doing research on the relevance of trust in the criminal supply chain applies better to the rip-off method. Moreover, criminal organizations smuggling their illegal goods using the rip-off method are not likely to switch on short-term to other forms of trafficking as these require to set up malicious companies. Focusing on the rip-off method where trust most likely has influence in the criminal supply chain keeps the research scope manageable and can provide a first of its kind insight that eventually could be extended to other forms of trafficking.

3.1.1. The legal container route

The smuggle with the rip-off method takes advantage of legal container routes from South America to the port of Rotterdam. Illegal goods are hidden between legal cargo on the other side of the ocean, which is called rip-on. The extraction of the illegal goods in the port of Rotterdam is called rip-off. It is thus useful to have an understanding of the legal supply chain since illegal goods travel along. This process is illustrated in steps in Figure 3.3.

Step 1 After production legal goods are loaded into containers and transported to a port in South America.

Step 2 After arrival of the container at the port of origin, containers are loaded onto a large container ship that transports the containers to the port of Rotterdam. When the container ship arrives, the containers are loaded off and placed in stacks on the terminals awaiting pickup.

Step 3 To pick up a container from the terminal it must be pre-notified at Portbase for a swift flow of goods (Portbase, n.d.). Pre-notifying is the process of declaring the cargo after which the container may be cleared by customs and can be collected. To pre-notify a container, the container number and a specific unique PIN code belonging to the transport should be specified. In case customs want to check the cargo, either a hidden check is performed at arrival or it is communicated, 72 hours before

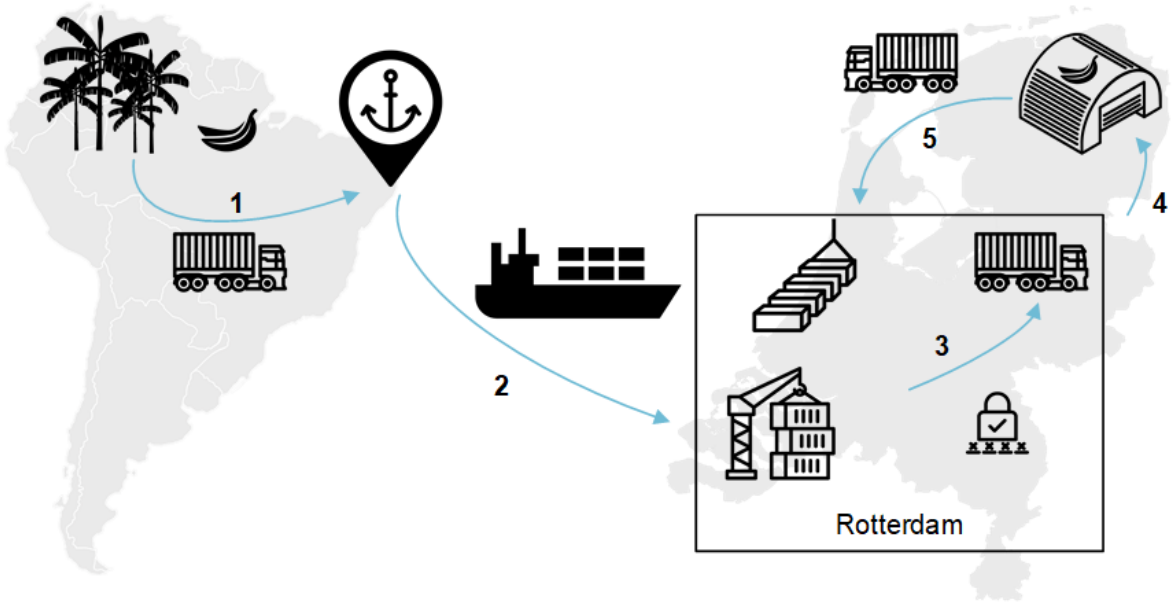

Figure 3.3: *Overview of the legal supply chain from South America to the port of Rotterdam.*

the estimated time of arrival of the ship, to the pre-notifier that the container will be checked at pickup. Then the container is either scanned at the port terminal or scanned at the customs scan facility. In case of no irregularities the truck driver can drive the container to its destination. When irregularities are noticed the container will be manually checked for cargo compliance to the submitted documents. Any undeclared goods will be seized and destroyed or import fees could have to be paid.

Step 4 When the container is successfully pre-notified it can be collected from the port area by a truck driver who transports the container to its destination. This may either be the company that has ordered the goods or a transshipment company that empties the container and transfers the cargo to other trucks or transport modes.

Step 5 After transshipment of cargo, the empty container is usually transported to an empty depot on the port area of Rotterdam. On the empty depot the container may be awaiting another cargo transport, regular inspection, cleaning or repair.

3.1.2. Different types of rip-offs

Rip-off is a broad term covering multiple forms of smuggling where illegal goods are hidden between cargo or in the container structure and interacting differently with the legal supply chain. Early forms of rip-offs where extractors left the port area carrying bags with illegal goods are not occurring anymore. Currently four different rip-off modus operandi (MO), which are briefly described in Table 3.1, are omnipresent in the port of Rotterdam. Each of these will be discussed and visualized in detail in the next sections. However, only separately discussing the different types of rip-offs does not suffice. Even the rip-off method can be dynamic during the trafficking of a load of illegal goods as has become apparent over time. Criminals often have a plan B or even C to secure their loads when plan A fails. Therefore, also the criminal adaptivity between the different rip-off types will be highlighted.

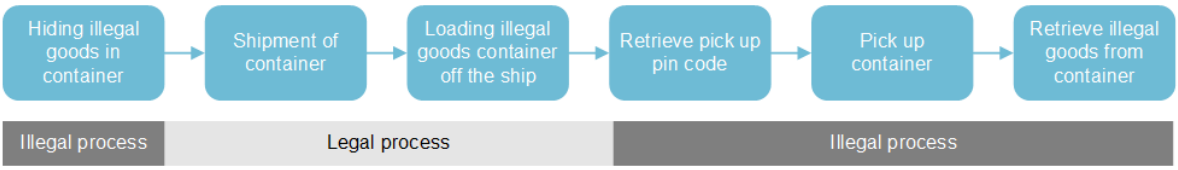

Figure 3.4: *Process overview of PIN code fraud.*

Table 3.1: *Overview of most occurring rip-off methods.*

Rip-off type	Brief description	Size of loads
PIN code fraud	The criminal organization retrieves the PIN code with which to pick up the container in which the illegal goods are hidden in bags or in its structure from the port area, which is passed on to a bribed truck driver who is then able to pick up the container before the regular truck driver arrives.	300-700 kilos
Switch	Bags with illegal goods are hidden in containers and transferred to another container in its proximity. This other container could be owned by the criminal organization, be in transit from one European country to another and bypass customs clearance because of the free movement of goods in the EU. The bags can also be loaded into another container in its proximity. Criminals will subsequently commit PIN code fraud to retrieve the container.	300 - 700 kilos
Extracting	Bribed port employees or customs officers retrieve the bags with illegal goods from the container and/or cooling departments, and transport them out of the port in their vehicles.	20-150 kilos
Empty depot	Illegal goods are hidden in the structure and/or cooling engine of a container. When an empty container is sent to Rotterdam or after transshipment of legal goods, the container is sent to an empty depot where the illegal goods are removed from the container by extractors or bribed repairmen.	100-400 kilos

PIN code fraud Criminals make use of bona fide companies when trafficking by committing PIN code fraud. These companies are unaware of the rip-on of illegal goods between their cargo in the container in South America. After arrival the shipping companies in the port of Rotterdam make use of PIN codes for picking up containers on older terminals and terminal appointment reference codes (TAR codes) on newer terminals (RST, 2021). A TAR code is a unique code retrieved after pre-notifying a container only visible for the legal company, whereas a PIN code is the same code which is used for pre-notifying. Criminals thus need a bribed contact within the legal company to be able to commit PIN code fraud, in case the legal company pre-notified the container. Another difference between old and new terminals is the pick-up process. For terminals where a TAR code is used, a container must be retrieved in a certain time slot whereas any time suffices on old terminals.

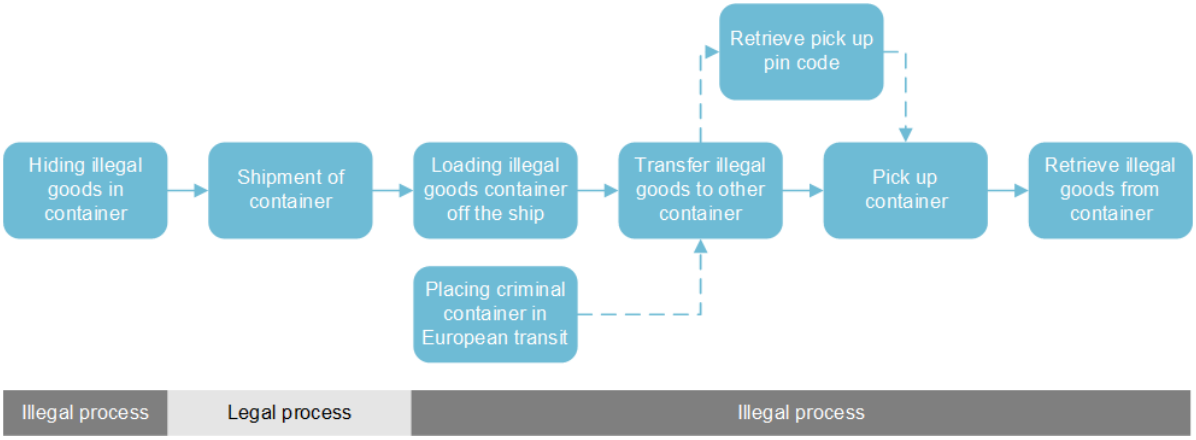

Figure 3.5: *Process overview of switch rip-off.*

Switch Bags with illegal goods are hidden between the cargo of bona fide companies and cooling compartments. When the container with illegal goods arrives in the port of Rotterdam and is taken off the boat, it is placed strategically by a bribed planner in such way that it is well accessible (EMCDDA, 2016). This enables extractors or bribed port workers to transfer the illegal goods from one container to another container in its proximity and seal both again to avoid detection. This may either be a container owned by the criminal organization in transit from one European country to another that

avoids customs control because of the free movement of goods in the EU or simply a container with goods having a low risk of inspection, or a container of another bona fide company that has already been cleared by customs or is also subject to the free movement of goods. An important aspect is that this other container to which the load is transferred is also well accessible and close to the container in which the illegal goods are hidden. Considering the container owned by the criminal organization, this smuggling method entails corruption even before the container with illegal goods arrived for the strategical placement. This is not the case when transferring the load to another container of a bona fide company. However, in that case the criminal organization will instead have to commit PIN code fraud for securing their load.

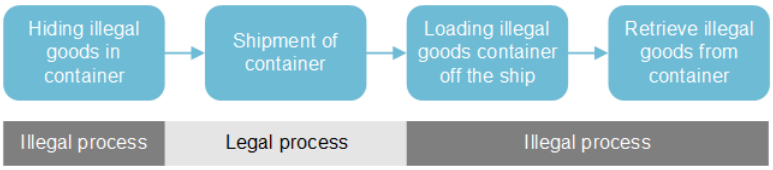

Figure 3.6: *Process overview of extracting rip-off.*

Extracting Bribed shipping company employees or bribed customs will retrieve the illegal goods from the container in which they are hidden and seal the container door again or from the cooling compartments. They load these illegal goods in their vehicles and drive them out of the port to secure the load.

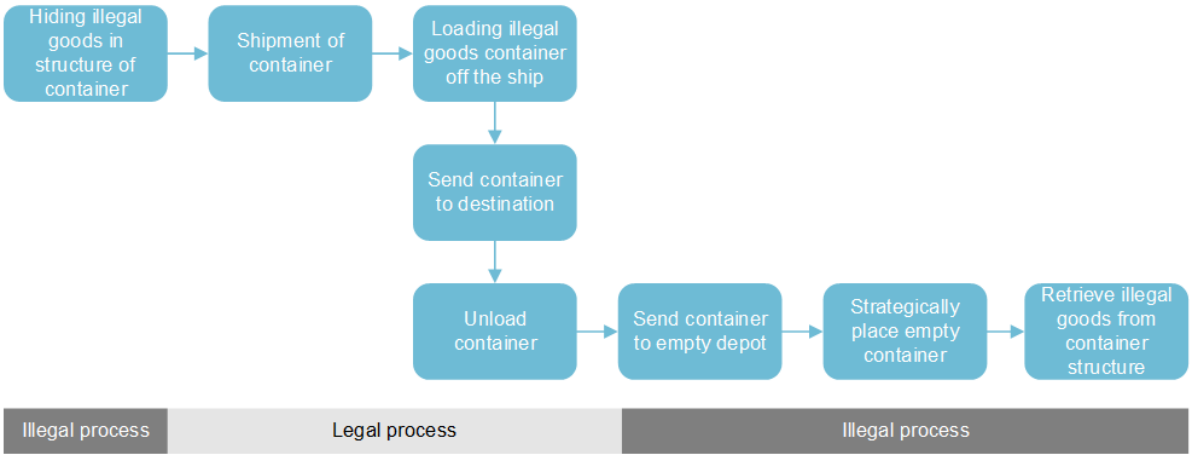

Figure 3.7: *Process overview of empty depot rip-off.*

Empty depot When criminal organizations plan on extracting the illegal goods from the container at the empty depot, these are hidden in the structure and cooling compartments of the container without the knowledge of the bona fide company. The container follows it legal transport route to the transfer point where the legal goods are transferred or to the company itself which unloads the legal goods. A bribed shipping company employee makes sure the empty container is sent to a certain empty depot and passes on this information to the criminal organization, or criminals know where containers of a certain shipping company end up in general. When the container has arrived at the empty depot, bribed repairmen or extractors will search for the container, weld open the structure and retrieve the illegal goods.

Criminal adaptivity When criminals ship their illegal goods, they are often well prepared. However, their plan A may fail because of unforeseen customs checks, failing to retrieve pick up PIN or TAR codes on time or extractors being caught. Reacting to these events, criminals might switch to plan B or even C in an attempt to secure their illegal goods. This is illustrated in Figure 3.8. When shipping and anticipating on committing PIN code fraud to retrieve the load, aforementioned hurdles may occur.

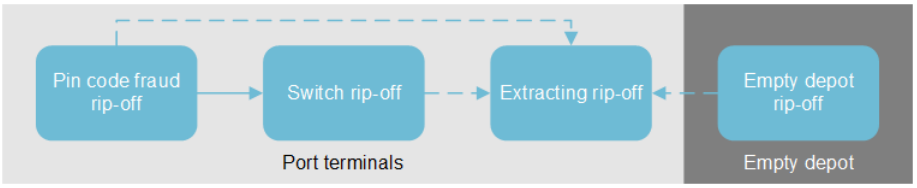

Figure 3.8: *Criminal adaptivity with the rip-off method.*

A criminal organization might mobilize port workers to quickly extract smaller loads from the container and transport out of the port using their vehicles. For bigger loads of illegal goods criminal organizations could try to mobilize extractors to perform a so-called 'kamikaze' rip-off. These extractors will transfer the illegal goods to another container in the proximity and the criminal organization will try to recover the load by committing PIN code fraud on that specific container. When planning to perform a switch rip-off extractors may be caught when on their way to the container. Port workers could be mobilized to secure a small load.

As becomes apparent from the discussed smuggling methods, an empty depot rip-off is most often a one opportunity shot. Illegal goods hidden in the container structure are impossible to retrieve when there is still cargo in the container. However, still some illegal goods may be retrieved from the cooling departments of a container on the terminal as these are accessible.

3.2. Criminal rip-off networks

In facilitating this smuggling process using the rip-off method, multiple criminal actors are included which are briefly described in Table 3.2. These actors are connected in a network structure as visualized in Figure 3.9 to be able to order illegal goods, ship them and eventually retrieve them from the port. Not all of these actors are involved in all smuggling methods and their roles may differ. The area of interest of this research lies in the port of Rotterdam and is therefore focused on the Netherlands. In all cases it is assumed that a Dutch principal orders illegal goods via a broker at a principal who facilitates the export. In case illegal goods are ordered, the principal responsible for export will ensure that the transport is placed onboard and that the container number ends up at the Dutch principal.

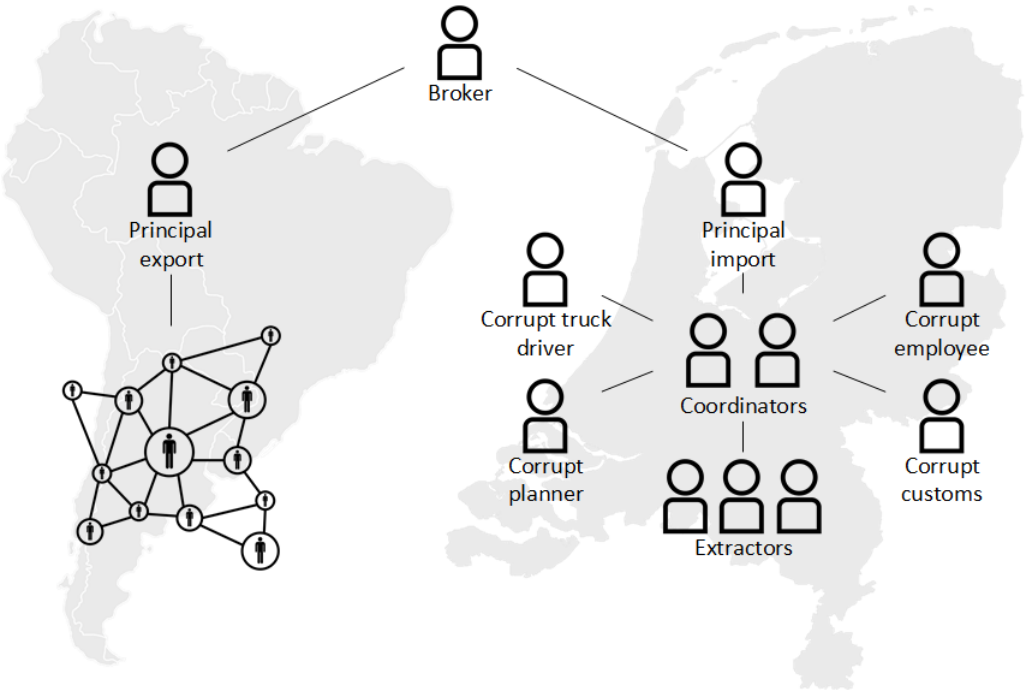

Figure 3.9: *A general overview of a criminal network shipping illegal goods.*

Table 3.2: *Actors involved in the criminal supply chain.*

Actor	Brief description
Broker	Brokers play a central role in the communication between Europe and South America. They facilitate transactions between South American gangs and Dutch importers (Kenney, 2007).
Principal export	Arranges the shipments of illegal goods. It ensures that a certain ordered amount is placed in containers between legal goods of bona fide companies. Containers of a certain shipping company may be targeted, because of preferences of Dutch importing networks that have bribed contacts at a certain shipping company.
Principal import	Imports illegal goods by placing orders in South America and choosing coordinators for planning to retrieve the shipments from the Rotterdam port area.
Coordinator	Coordinates the smuggling process. Recruits actors that can carry out the jobs needed to retrieve the illegal goods from the port area and provides them with the necessary information. In general there seem to be two coordinators for a shipment.
Extractor	Switches illegal goods from one container to another in its proximity. Extractors act in groups as it is impossible for one single person to carry all bags within a reasonable time frame from one container to another.
Bribed truck driver	Collects a container from the terminal with a PIN or TAR code and drives this container to a location where criminals retrieve the bags of illegal goods. Consequently, the truck driver gets rid of the container by transporting the container to the bona fide company.
Bribed planner	Bribed planners can strategically place containers with illegal goods next to containers owned by criminals that are already on the port area or pass on information to criminals. Information that is passed on may consist of PIN codes and/or container locations.
Bribed shipping company employee	Can pass on container pick-up PIN and TAR codes to criminals.
Bribed port employee	Can pass on container locations to criminals and is also able to extract illegal goods from containers and transport it out of the port in a van.
Bribed customs officer	Is able to extract illegal goods from containers and transport it out of the port in a van.

3.2.1. Criminal actors and rip-off processes

Since not all actors are involved in all rip-off processes, a clear picture will be provided here on how each of these works. Note that for all modus operandi the process of ordering illegal goods and the rip-on is considered the same and takes place as discussed previously.

PIN code fraud When committing PIN code fraud usually two coordinators are involved overseeing the process. They are in contact with a bribed employee for retrieving the PIN with which to pick up or pre-notify the container and a bribed truck driver for the container pickup. In case a TAR code is required for picking up a container, criminals must pre-notify the container themselves with the PIN code as they are otherwise not able to retrieve the TAR code (this code is only visible to the pre-notifier). A shipping company employee must provide the PIN code of the container to the criminals because only this certain employee has access to it. When just the PIN code is required for picking up a container, the process is simplified for criminals. They can either receive the PIN code from a bribed planner or shipping company employee and use it to immediately drive the container off the port area independent of the fact whether they or the legal party pre-notified the container.

Switch A switch rip-off also requires two coordinators to oversee the smuggle. A bribed planner must ensure the correct placement of the container in which the illegal goods are hidden, next to the container of the criminals on the port area. The planner must then pass on the exact location of the container to the coordinators who pass this information on to a group of extractors who switch the illegal goods from the container from South America to the container owned by criminals. When this has been done and communicated to the coordinators, they will ensure that a bribed truck driver drives their own container off the port area to secure their load of illegal goods.

Extracting The extracting rip-off requires a small network. Therefore, only one coordinator is required in general who is in contact with a bribed customs officer, or bribed port employee. When the coordinator passes on the container number to this bribed accomplice, the accomplice is able to locate the container himself because of its access to port systems with which it is possible to see container locations. The accomplice will subsequently switch the load of illegal goods from the container of interest to its van and drive it off the port area.

Empty depot Besides passing on the container number, the export principal also passes on the location of the illegal goods inside the container to the Dutch principal. This allows for a directed search for the illegal goods when extracting them from the container. This happens in general by bribed repairmen of containers or extractors who slice open e.g. the floor of the container, retrieve the illegal goods and drive them off the port area. For coordinating this process one coordinator in general satisfies to successfully oversee an empty depot rip-off.

4

Trust between criminals

Little research has been done on trust between criminals and also a clear framework of the dynamics of criminal trust is missing. Therefore, this chapter discusses the available literature on trust between criminals, complement lacking elements with general literature on trust and combine this with expert views on the topic to create such a framework of the dynamics of criminal trust. However, first will be discussed what trust is and how it can be defined.

4.1. Interpersonal trust

Continuing on earlier research that made distinctions between cognitive and affective trust, Mayer et al. (1995) clearly differentiated amongst factors contributing to trust, what trust itself is and its outcomes (Heyns & Rothmann, 2015). They defined trust as ”the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control that other party.” (Mayer et al., 1995, p.712). Rousseau et al. (1998, p.395) slightly reformulated this by stating that trust is ”a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another”. Another similar definition of trust has been given by Werbel and Henriques (2009, p.781) who define it as ”the willingness to make oneself vulnerable to another person despite uncertainty regarding motive and prospective actions”. What all of these definitions have in common are three components: (1) accepting to be vulnerable, (2) positive expectations about the actions of the of the trustee and (3) risk-taking. Risk-taking is the real action that results from the decision based on trust of willing to become vulnerable, to really becoming vulnerable (Mayer et al., 1995).

Mayer et al. (1995) formulated such a first of its kind clear definition of trust by also clearly separating from what trust is not. They stated the importance of separating trust from trustworthiness. Trustworthiness is composed of three characteristics of the trustee: (1) ability, (2) integrity and (3) benevolence which capture the trustee’s competence and character (Colquitt et al., 2007). These are briefly described in Table 4.1. Trust is the result of the trustor its intention to trust (which is based on the trustee its trustworthiness) and its propensity to trust, which is defined as an individual characteristic affecting

Table 4.1: *Different components of trustworthiness as described by Gabarro (1978) and Mayer et al. (1995).*

Component	Description
Ability	The perception of the trustee its required knowledge and skills to successfully perform a specific job in combination with the general wisdom and interpersonal skills to do well in an organization. Also called competence.
Integrity	The perception of the trustee its extent to which it adheres to moral and ethical principles. Relevant synonyms are promise fulfillment, consistency and fairness.
Benevolence	The perception of the extent to which a trustee has the trustor its best interests at heart, independent of any profit motives. Loyalty, caring and openness are relevant synonyms.

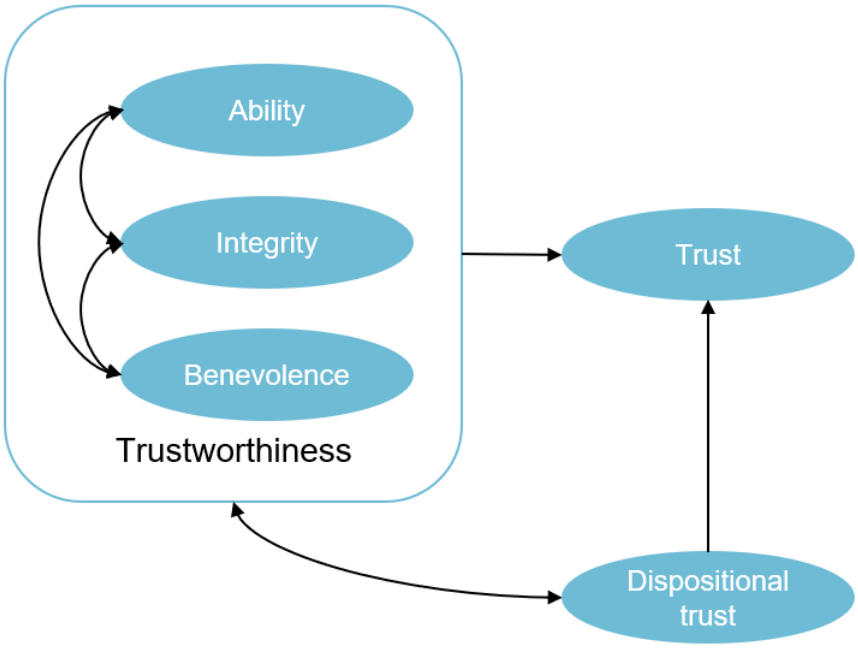

Figure 4.1: *Simplified (inter)factoral correlations to trust.*

the likelihood that a person will trust (Colquitt et al., 2007; Mayer et al., 1995; Rotter, 1967; Stack, 1978).

4.2. Trust, trustworthiness and propensity to trust

Although the relevance of trustworthiness factors and the propensity to trust are intuitive for the creation of interpersonal trust, it is unclear to what extent these factors foster trust in this criminal context. Hurdles for determining the influence of a factor on trust are possible mutual correlations in trustworthiness components, correlations between trustworthiness and propensity to trust (these correlations are visualized in Figure 4.1) and dependency on perspectives and contexts (Colquitt et al., 2007). To complicate the process even more, Gill et al. (2005) showed that correlations may be dynamic based on the situation.

4.2.1. Trustworthiness correlations

According to Colquitt et al. (2007), all of the trustworthiness factors ability, integrity and benevolence have a significant impact on trust levels. However, this impact is not unique since the factors are mutually correlating. Moreover, the correlations are even context dependent as others found that integrity and benevolence were redundant with each other (i.e., they did not both have unique impacts) (Boies & Corbett, 2005; Knoll, 2007; Schoorman et al., 1996). Possible influences of perceived trustworthiness components on trust are thus ambiguous because of different contexts in which the analyses took place. The absence of research on criminal trust and especially with this framework, makes these influences at the moment highly uncertain.

4.2.2. Propensity to trust and trustworthiness correlations

Propensity to trust has been found to contribute to eventual trust not only theoretically, but also in practice (Colquitt et al., 2007; Gill et al., 2005; Mayer et al., 1995). However, the propensity to trust also correlates to the perceived trustworthiness. In general, a higher perceived trustworthiness also seems to increase the trustor its propensity to trust and vice versa in repeated actions (Colquitt et al., 2007). Additionally, according to Gill et al. (2005) the trust propensity and perceived trustworthiness do not correlate when available trustworthiness information is unambiguous (e.g., non-contrasting views of a person its reputation). Then merely the rational perception of trustworthiness seemed to dominate the creation of trust. This is called the affective decision-making related to trust. Vice versa, when information is ambiguous, the propensity to trust does play a role. This phenomenon is explained as

selecting information congruent to people their trust in humanity and a ”suspicion” bias when information is ambiguous (Ferrin & Dirks, 2003; Fiske & Taylor, 1991; Kahneman & Tversky, 1973). Furthermore when placing this in criminal context, Shover and Hochstetler (2005) point out that white-collar criminals (i.e., criminals with a higher social status) always seem to be more rational than other criminals. So even in situations where trustworthiness information is ambiguous, the bigger players in the criminal organizations will act more rational than those with lower ranks.

4.2.3. Perspectives

In regular organizational context also perspectives matter for the importance of factors of trustworthiness on trust. Ferrin and Dirks (2003) indicate a significant difference in the importance of trustworthiness factors on trust for a leader trusting a coworker and vice versa. However, when strictly applying the framework of Mayer et al. (1995), Colquitt et al. (2007) do not find a similar result. Instead, they emphasize that only the relationship between integrity and trust is significantly stronger for the development of trust in a leader as coworker as result of the power differential. These findings show the importance to separate leader-subordinate and subordinate-leader correlations from trustworthiness factors to trust.

Table 4.2: *Overview of sources for trust and their direct influences on trustworthiness components.*

Source	Mechanisms for building trust	Ability	Integrity	Benevolence
1	Inclination and willingness (propensity) to trust.			
2	Routinized behavior (i.e., repeated transactions) between individuals.	x	x	
3	Own experiences, vouching, reputation and membership of certain groups.	x	x	
4	Loyalty, friendship and kinship.			x

4.3. Building trust

Trust is a dynamic process that needs to develop over time. According to Woolthuis et al. (2002), there are four sources for the development of trust, which are briefly described in Table 4.2. The first source is the propensity to trust which has been discussed earlier. Without any propensity to trust, a relationship of trust will never develop. When at the very beginning of the creation of trust, people tend to interpret new information congruent with their propensity to trust (McKnight et al., 1998). Meaning that building a relationship of high trust takes longer to establish for someone with a low propensity to trust, than someone with a high propensity to trust. Second, trust as a result of routinized behavior (i.e., repeated transactions) between individuals. One may gain both trust in competence and intention as the trusted party becomes more familiar (Nooteboom, 2008). A third source of trust is knowledge about a partner. Important factors for this source are: own experiences, vouching, reputation and membership of certain groups (Kamphausen & Werse, 2019; Monsted, 1998; Zucker, 1986). Lewicki, Bunker, et al. (1996) point out that this source of trust is mainly quite important if there is no prior trust. Aligning with this view, Basheer et al. (2015), Dubois et al. (2012), and Tzvetkova et al. (2016) found that reputation is important in criminal organizations for building trust and that being a member of a trustworthy organization serves as a ’brand’ for one’s own trustworthiness. In criminal supply chain context, traffickers may gain a trustworthy reputation in case they deliver a good, constant quality product and deliver it fast (Tzvetkova et al., 2016). Basheer et al. (2015) points out that this source of trust is very complex in case of conflicting opinions of criminals’ trustworthiness within one’s own network or if his/her own opinion and/or experience deviates. However, as discussed before it seems plausible that dispositional trust will dominate the imaging. The fourth source of trust is characterized by loyalty, friendship and kinship (Luhmann, 2018; Nooteboom, 1996; Organ & Konovsky, 1989; Ouchi, 1980). Loyalty may develop as a result of long-term trust in criminal networks (Moeller & Sandberg, 2015) and friendship may develop over time, but kinship is static and predetermined. Connecting these four sources of trust to the different kinds of trust, Woolthuis et al. (2002) emphasizes that the fourth source of trust only applies to the character component of trustworthiness (i.e., loyalty, friendship or

kinship does not mean the trustee is competent for the job).

4.4. Distrust

Just as trust can develop over time, it can decline. It is easier to see trust decline than to increase (Suzuki et al., 2013). A result of declining trust may either be low trust or even distrust, which is an opposite construct of trust and can also be high or low (McKnight & Chervany, 2001). The differences between low trust and distrust are the opposites of confidence and doubt. With a low level of trust, there is still some level of confidence that the trustee is expected to handle in the trustor its interests. On the contrary, distrust resembles a feeling of (strong) doubt whether the trustee has the trustor its interests at heart. Once distrust arises, it is difficult to restore the relationship and obtain trust again (Schweitzer et al., 2006). Something which could be explained by the feeling of doubt: it might be unlikely to engage once again in an interaction with someone you distrust.

Additionally to distrust being a perception of trust in others, distrust is also a personal mental state which is the consequence of the threat of being deceived (Schul et al., 2008). This represents not the distrust in another, but a general disposition to distrust caused by past interactions with untrustworthy individuals and it makes others behave differently towards others (Kramer, 1999). This definition of distrust as a disposition to distrust others, aligns with the model of Mayer et al. (1995) and the correlations shown by Colquitt et al. (2007). They showed correlations between interactions with untrustworthy individuals and someones disposition to trust, which in turn contributes to the trust in an individual. Interactions with untrustworthy individuals will thus increase the disposition to distrust others, separate from the perception of trustworthiness.

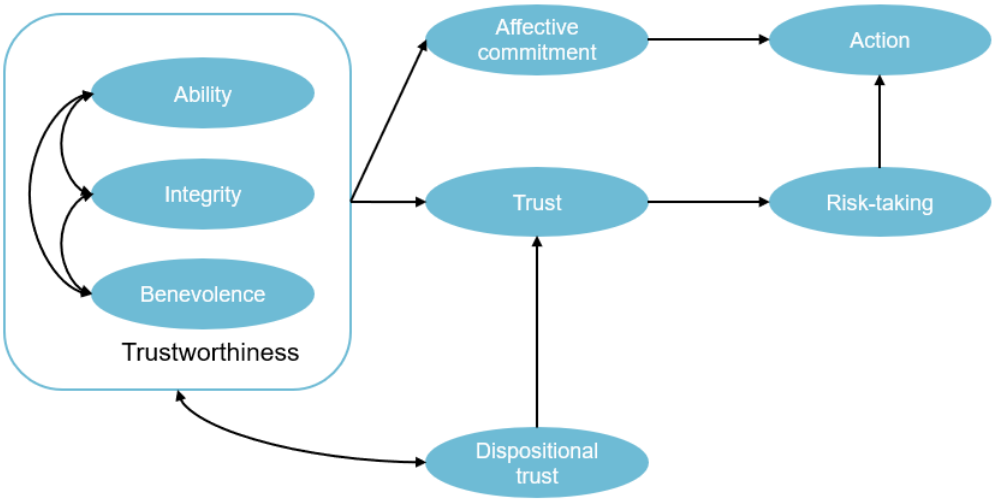

Figure 4.2: *Simplified (inter)factoral correlations to trust and affective commitment.*

4.5. Affective commitment

Besides the trustworthiness factors influencing trust, trustworthiness also creates affective commitment (Colquitt et al., 2007; Lewicki, Bunker, et al., 1996; McAllister, 1995; Rousseau et al., 1998). Affective commitment is another construct serving a similar function as trust as basis for social exchange relationships (Mowday et al., 2013; Shore et al., 2006). Besides a cognitive trustworthiness calculation, affect covers the mutual concern in the relationship of trust (Colquitt et al., 2007). The affective commitment does not relate to eventual risk-taking, but simply to the resulting action itself as is illustrated in Figure 4.2. In the study of (Colquitt et al., 2007) are all trustworthiness factors correlated to affective commitment. The correlation of benevolence can simply be explained by the fact that benevolence reflects personal affect. Additionally, people value leadership integrity in regular organizational context creating affective commitment to the leader (Chalistya et al., 2019; Leroy et al., 2012; Yang et al., 2014). No research has been done on integrity of subordinates and affective commitment of the leader to the subordinate. However, during meetings with experts it became clear that there is no such thing as affect to criminals that are easily 'replaceable'. Thus, the same holds for ability. Continuing with

the case of ability, it seems unlikely that ability plays a role in affective commitment to leaders, since leaders delegate to subordinates. A leader its ability for its own tasks, is unlikely to create affective commitment of its subordinates that are not affected by that task. To illustrate this argument in criminal context, simply receiving your promised payments is a form of integrity. A criminal leader can not pay a certain amount better than the other.

Although affective commitment seems a relevant factor related to trust, it will be left out-of-scope of this research. It covers the mutual concern in a trust relationship, is not related to cognitive decision-making models and thus extends beyond the scope. Moreover, it is a reasonable assumption not to include affective commitment as it has been estimated to have a weak relation with risk-taking (Colquitt et al., 2007).

5

Criminal decision-making

This chapter elaborates on the decisions criminals make in the criminal supply chain and two decision-making models: (1) the risk vs. gain trade-off and (2) transaction-cost economics. These decision-making models are influenced by trust and seem relevant for analysis.

5.1. Criminal decisions in trafficking

The eventual trafficking process is a convergence of multiple decisions by criminals where trust is involved. Recall Figure 3.9, where the Dutch criminal network consists of a principal, coordinators and executive actors physically involved in the smuggling process. These three different types of criminals represent three distinct layers as displayed in Figure 5.1: the upper level calling the shots, the coordination level coordinating the trafficking process and the executive level responsible for executing the job. These layers are interconnected by top-down and bottom-up decisions and additionally individual decisions occur. Next, these different decision categories will be discussed and subsequently applied to the three distinct layers of the criminal network.

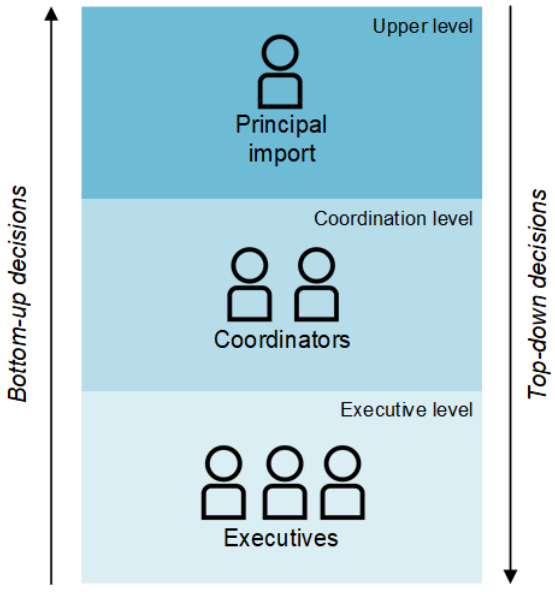

Figure 5.1: *Three different layers of criminals invovled in smuggling illegal goods.*

Top-down decisions cover the question with whom to collaborate for the job (i.e., who to select for getting the job done). Bottom-up decisions in turn are an answer to top-down decisions by deciding whether the agent of interest wants to execute the job it is prompted to do. At last, individual decisions

cover agents their decisions which do not contain any form of interaction with others but may possibly impact others (e.g., deciding whether to order illegal goods overseas).

5.2. Rationality and affect

The component of affect in criminal decision-making as described by Van Gelder (2013) distinguishes itself from rationality because it considers feelings and explains criminal behavior better. However, there seems to be variation in the extent to which affect and rationality play a role in the decision-making process. Shover and Hochstetler (2005) mention that white-collar criminals (i.e., criminals with a higher social status) are more rational than other criminals. Considering the component of affect could thus provide better understanding of the system, but care needs to be taken in how to value this component for different actors in the criminal supply chain.

The affective component of criminal decision-making takes into account several factors: (1) ”a cognitive and affective appraisal of risk” (Van Gelder, 2013, p.748), (2) ”emotions, moods and visceral drive states” (Van Gelder, 2013, p.748) (Van Gelder, 2013, p.750) and (3) ”anticipated versus immediate affect” (Van Gelder, 2013, p.750). Each of these could apply in some way to trust or to criminal supply chains. For the first factor, criminals might become blind to risks because of trust. Furthermore this factor applies to criminal supply chains in general, as criminals tend to underestimate risks for higher prison sentences (Mastrobuoni & Rivers, 2016; Nagin et al., 2009). The second factor raises the question what happens in the case of distrust to criminals their emotions and how they react. And at last, the third factor complements the rational decision-making processes which consider anticipated effect in the form of efficiency, by also considering the value of trust. Although the rational decision-making process tells to defect from the relationship of trust, their feelings may tell they do not want to do this. Especially as the fourth source of trust in Table 4.2: loyalty, friendship and kinship, is described as affect-based trust (McAllister, 1995). Furthermore, in criminal supply chain context, one most likely considers the consequences of betraying certain people’s trust as these do not directly affect their expected outcomes but will eventually hurt when acting accordingly.

5.3. Risk vs. gain

A crucial criminal trade-off is risk vs. gain (Klaassen, 2021; Morselli et al., 2007). Risk is the criminal’s perception of the shipment with illegal goods being intercepted, whereas gain is the profit associated with the shipment or e.g., bribes. It is a relevant trade-off as Kenney (2007) and Morselli et al. (2007) argue, because actors in criminal supply chains are mainly driven by financial motives. Criminals want to maximize their profits and when seizures increase, criminal organizations adapt quickly and find new methods or routes for smuggling illegal goods to increase their profit (Colman, 2018; Staring et al., 2019). Additionally, Jensen and Dignum (2019) argue that when traffickers of illegal goods run out of stock because of increased interceptions, tend to order larger quantities to replenish stock and meet demand of criminals further in the supply chain like in regular supply-demand theory. On the other hand, large shipments may also be caused by excessive transatlantic stocks of illegal products which have to get rid of in profitable manner.

The other side of the trade-off, the risk part, is constantly being evaluated by criminals as indicated by Zaitch (2002a) in a study conducting interviews with Colombian traffickers. Smuggling routes, methods and time planning are based on this risk evaluation and thus shift when seizures increase or gains decrease. However, this risk evaluation is not the same for all actors in a criminal supply chain and may differ in definition. Traffickers arranging shipments perceive risk as the probability of a shipment being intercepted, whereas risk for criminals physically involved is perceived as the risk of being caught by the Police. Therefore, it is vital to distinct different valuations of risks by actors, as the origins of these risk perceptions may be different. For example, in the latter perception a criminal might heavily rely on its own ability in evaluating the risk, whereas in the former perception of risk the criminal might rely on others executing the job. Relying on others (i.e., relationships of trust) is a crucial component in criminal supply chains for reducing risks of interceptions (Bright et al., 2019; Dirksen et al., 2021; Klaassen, 2021; Moeller & Sandberg, 2015; Neumann & van Putten, 2018; Tzanetakis et al., 2016; Tzvetkova et al., 2016).

5.4. Transaction-cost economics

Supply chains exist because of supply and demand. Economic transactions will arise where the supply and demand meet, also in criminal form. Hence, an economic decision-making model could be well-applicable to criminal supply chains. One of such economic decision-making models is transaction-cost economics (TCE). According to TCE, decisions between alternatives are made based on minimizing the total of production and organization costs for reaching efficient outcomes (Klos & Nooteboom, 2001; Williamson, 1975, 2007). From a TCE point of view, trust could be seen as a substitute of legal contracts for minimizing the organizational costs in criminal supply chains (Woolthuis et al., 2002). Where in the process of building trust, it serves as a complement to control factors induced by criminals for checking each other. As Nooteboom (2011, p.172) puts it: ”Trust, one might say loosely, begins where contract necessarily ends.” However, since in criminal supply chains no contracts exist, we can interpret this where the control factors end. The Dutch Police mentioned during meetings that they discovered such control factors in criminals their messages, in the form of sending photos and videos as proof that the illegal goods have been placed in a certain container. Trust is thus a substitute for legal contracts in TCE as well as a complement to control factors for when there is no strong relationship of trust.

For establishing business relationships in TCE, finding the most trustworthy partner for a transaction is a search with bounded rationality. Trust is characterized as whether to be able to rely on someone and that this someone does not behave opportunistic because of higher profits elsewhere and lets you down, but also values the relationship of trust (Nooteboom, 1992). Opportunism thus corresponds to intentional trust. Risk for opportunistic behavior is characterized by two components according to Nooteboom (2008), the room for and the inclination towards opportunism. To trust someone doing business with, evaluating these risks is subjective and prone to bounded rationality. There is no certainty that the evaluation is correct, information about trustworthiness is imperfect especially in the beginning (Nooteboom et al., 2001). If the evaluation turns out to be wrong and the counter party does show opportunistic behavior, distrust may arise. However, repeated transactions without opportunism, may result in more efficient relationships. Both parties will be less likely to be opportunistic, because efficiency will be lost. Opportunism will yield switching costs for both parties creating dependence (Nooteboom et al., 2001).

6

Model formalization

The description of the criminal supply chain in combination with trust and decision-making is converted to a quantitative model using the Mesa library for agent-based modeling in Python (Masad & Kazil, 2015). This chapter elaborates on the structural implementation of qualitative descriptions into the quantitative model. The formalized model can be found on GitHub (click for link) and can be accessed with authorization.

6.1. Criminal supply chain implementation

To model the criminal supply chain in an ABM three aspects are relevant: (1) the legal supply chain from South America to the port of Rotterdam, (2) the smuggling methods taking advantage of this legal supply chain and (3) the legal and criminal actors involved in the process. For formalizing these aspects, the model makes use of classes which are blueprints for objects that can be instantiated from that type. For discussing the implementation, distinctions are being made between classes representing (physical) objects, actors and categories.

Furthermore for modeling the criminal smuggling process in an ABM, the time step needs to be chosen adequately (i.e., the time interval the model is updated and agents perform an action). This issue brings forth a trade-off between computational power and accuracy. The time frame in which the model will be simulated also plays a role as computational power can increase a lot with smaller time steps. As timing is essential for smuggling illegal goods with the rip-off method a time step of one hour is chosen, because this allows for simulating behavior where criminals are just on time with retrieving their illegal goods. This provides enough detail to simulate criminal smuggling and legal processes as well as reasonable required computational power for model runs of 180 days. A time frame of 180 days allows for analysis of changes in the model as in such time frame many shipments with illegal goods are smuggled, as it is a developing shipping network.

6.1.1. The legal supply chain

To implement the legal supply chain in the model, physical objects as well as actors and categories have been implemented as described in Table 6.1. Ships of a certain shipping company are sent according to a specified shipping frequency of that company from South America to a terminal at the port of Rotterdam. These ships carry containers containing legal and illegal goods. For computational purposes and since the area of interest merely consists of the illegal goods, only containers containing illegal goods are simulated. From three days on before the container ship arrives, containers can be pre-notified after which customs declares the container or puts a block on the container in case of inspection, either announced or a hidden check. At arrival of the container ship, hidden checks on containers are performed by customs. Containers that are declared or where the customs check is visible to others, are placed in stacks on the terminal. When pre-notified, a container can be retrieved from the port area and driven to a customs check when applicable.

Table 6.1: *Classes used for the operationalization of the legal supply chain.*

Class type	Class	Description
(Physical) objects	Ship	A container ship transporting shipping containers overseas.
	Container	A shipping container in which goods are stored for transport.
	RotterdamPort	The port of Rotterdam where container ships arrive, containers are placed in stacks and subsequently retrieved from the port area.
Actors	ShippingAgent	The shipping agent class is a simplification of the legal supply chain taking care of the legal shipping process by managing container ships, pre-notifying containers, unloading containers from container ships, performing hidden customs checks and eventually transporting the containers from the port area to their destination and performing an announced check if applicable.
	Customs	The customs agent class merely puts the customs checks on containers when these are pre-notified. The executive task of the customs is given to the shipping agent.
Categories	CustomsCheck	Defining whether a container is declared at pre-notification, a customs check is announced or that customs will perform a hidden check on the container.
	ShipStatus	Indicates whether the ship is in a South American port, in transit from South America to Rotterdam or arrived at the port of Rotterdam.
	Terminal	Different terminals of the port of Rotterdam where container ships from South America arrive and where a lot of illegal goods are smuggled.
	ShippingCompany	Several shipping companies that ship containers from South America to Rotterdam.

6.1.2. Smuggling methods

The smuggle of illegal goods has been modeled as a shipment of illegal goods that has been placed in a container onboard a container ship of the legal supply chain. This is done by South American exporters that place the goods according to the order preferences in certain containers of a shipping company or ending up at a certain terminal as depicted in Figure 6.1. These order preferences are determined by the importers according to the logic shown in Figure 6.2 and depends on the modus operandi, as well as the order weight as shown in Table 3.1. The smuggle is divided into four categories of modus operandi. A brief overview of these classes is given in Table 6.2. The smuggling methods exploited by criminals

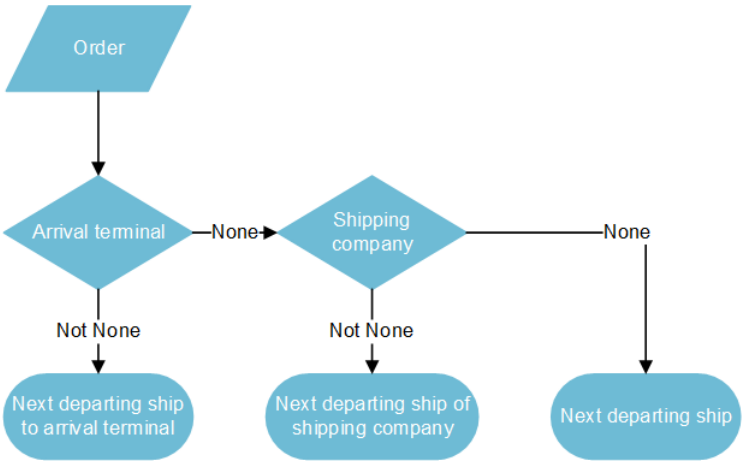

Figure 6.1: *Flowchart of South American exporters placing goods in container. None means no preference of the party placing the order.*

Table 6.2: *Classes used for the operationalization of smuggling methods.*

Class type	Class	Description
(Physical) objects	Order	An order placed by importers with their preferences at the exporting party.
	Shipment	A shipment of illegal goods according to the order preferences.
Categories	ModusOperandi	A category of the different modus operandi used for smuggling with the rip-off method. This includes (1) PIN code fraud, (2) Switch, (3) Switch and PIN code fraud and (4) extraction.

are dynamic as shown in Figure 3.8 in Chapter 3 if a customs check is announced on a container or the container has been pre-notified by the legal party on the APM1, APM2 or RWG terminal.

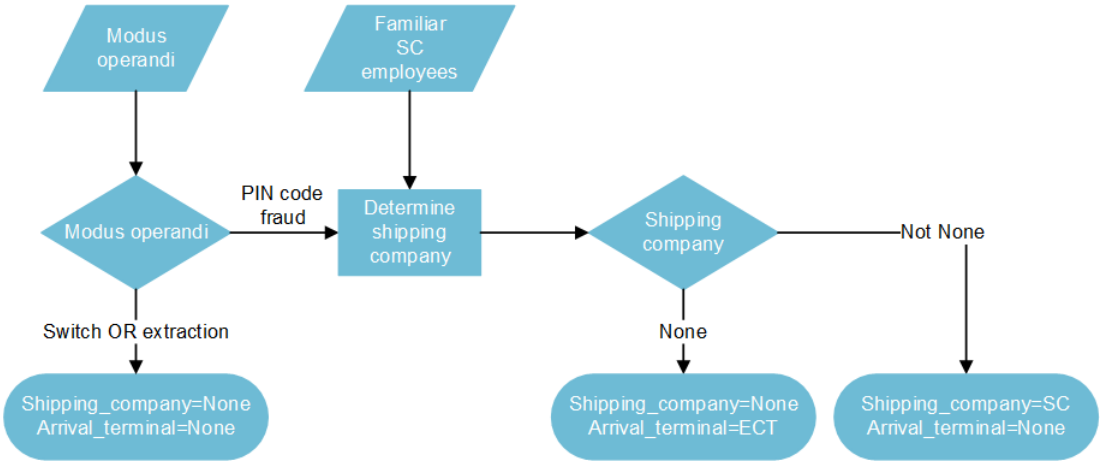

Figure 6.2: *Flowchart of Dutch principal placing order for illegal goods. For some terminals a bribed shipping company employee is required for successfully smuggling illegal goods with the PIN code fraud method.*

The temporal element is another important aspect of the smuggle of illegal goods. The model implementation assumes criminals try to retrieve their illegal goods as soon as possible from the port area accompanied by some time randomness. Coordinators try to arrange to get hold of PIN codes as soon as possible, switch goods immediately after arrival or immediately pick up a container.

When a 'criminal job' is performed, agents have a certain chance to fail the job and a risk to get caught if it failed the job, that have been determined by reason as no information was available. If the agent is caught, coordinators also have a risk getting caught as authorities could trace it back to them. The model implementation does not support principals getting caught, because that extends beyond the scope of the research as it focuses on the port of Rotterdam. When a job is completed successfully, the competence of executive agents for the job is raised and their risk of failing a job becomes smaller.

the competence of executive agents for the job is raised

6.1.3. (Criminal) actors

The agents in Table 6.3 have been implemented in the model in combination with their actions they can perform for smuggling illegal goods. The roles of Dutch principals and coordinators in the smuggle are more complicated than those of the executive agents (those directly taking part in the smuggling process) and will be discussed further.

Dutch principals Dutch principals search for coordinators to manage a shipment they want to order overseas. They weigh off the different modus operandi based on the decision-making models, and consider the coordinators that would be involved. For extraction rip-offs one coordinator suffices and for the other rip-off methods two coordinators are required. For each modus operandi the most trusted

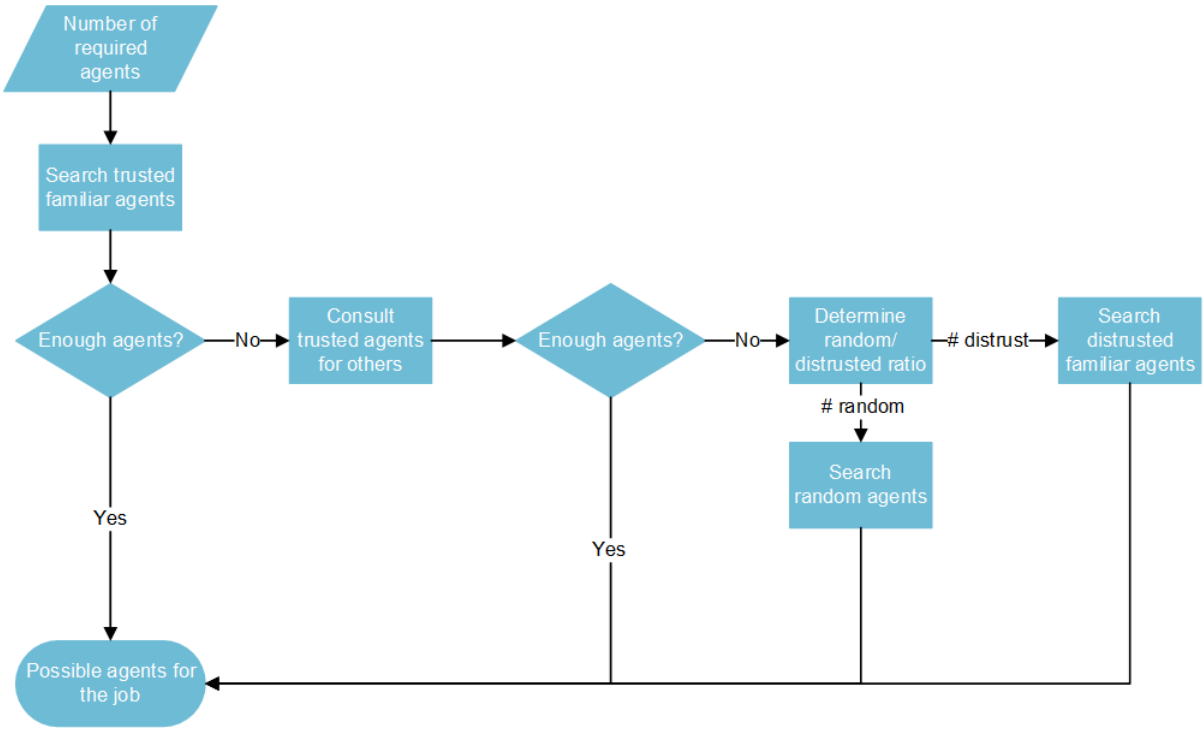

Figure 6.3: *Flowchart of selecting agents.*

familiar coordinators willing to cooperate are selected.

Coordinators Coordinators compose networks dependent on the modus operandi and shipment details. Coordinators check every step how many agents are still required for the job. The implementation of checking this every step allows for (1) replacing agents that are caught while doing a criminal job before the shipment the coordinator is monitoring and (2) reaching out to other agents when the coordinator did not yet succeed in completing the team in previous steps. The logic of reaching out to agents is implemented as shown in Figure 6.3. First trusted familiar agents are reached out to for doing a job, second trusted familiar agents are consulted for other trustworthy agents and thirdly untrustworthy and random agents are reached out to.

6.2. Trust implementation

The model starts with neutral propensities to trust (i.e., zero), perceptions of trustworthiness, and trust of individuals and thus represents beginning smuggling networks instead of the existing criminal networks active in the port of Rotterdam. The model entails four different possibilities where trust, trustworthiness and possibly propensity to trust are updated which are briefly described in Table 6.4. An agent its own propensity is also updated in case of an own experience with another. The extent to which these factors are updated is dependent on a model parameter that defines how many successful interpersonal interactions establish full trust. The trustworthiness increase as result of a successful or unsuccessful action affects ability as its main factor as this proves the competence of an individual and correlates to integrity and benevolence. As ability is modus operandi specific, a successful shipment will only update the ability of that certain modus operandi for coordinators and principals.

Besides the implementation of trust, trustworthiness and propensity to trust multiple functionalities from Chapter 4 have been included. These functionalities are included in Table 6.5 accompanied by an elaboration on how these are implemented.

Table 6.3: *Classes used for the operationalization of (criminal) actors.*

Actor type	Class	Description
Criminal	DutchPrincipal	The Dutch principal imports illegal goods to supply its clients. It delegates the coordination of the smuggling to coordinators.
	SaPrincipal	The South American principal acts as the head of South American exporters and ensures shipments are placed onto container ships according to the order specifications.
	Broker	The broker is an intermediary party facilitating the communication between the Netherlands and South America.
	Coordinator	Coordinators oversee the smuggling process according to the preferences of the Dutch principal and control the executive actors physically involved.
	BuyerAgent	The buyer agent buys stock of illegal goods from Dutch principals.
	Extractor	Extractors switch illegal goods from one container to another in case of a switch rip-off.
Legal	Planner	In case planners have been bribed they can pass on container locations and PIN codes to criminals.
	ScEmployee	Bribed shipping company employees can pass on container locations and PIN codes to criminals.
	TruckDriver	Criminal truck drivers pick up containers with PIN or TAR codes provided to them by the coordinator.
	CustomsOfficer	A bribed customs officer may pass on container locations or retrieve illegal goods from a container and drive them out of the port in its van.
	PortEmployee	A corrupt port employee may pass on container locations or retrieve illegal goods from a container and drive them out of the port in its van.

6.3. Decision-making models implementation

The risk vs gain trade-off and transaction-cost theory from Chapter 5 have been implemented in the model as separate decision-making models. In the model setup can be defined which decision-making model to choose. The specified decision-making model is used for all decisions involving a trade-off in the model run. These decisions are: whether to place an order, the order details, who to select for a job, and whether to accept a job.

6.3.1. Risk vs gain

The risk vs gain trade-off has been split into three components: gain, the interception risk of a shipment and the risk of capture. Gain has a monetary unity whilst both risks are percentages. For solving this unit issue and quantify the risk vs gain trade-off there were three options, all with their limitations which are described in Table 6.6.

The percentages and monetary options seem to be most likely equal. For the current operationalization the percentages approach has been chosen as for this implementation only one factor has to be con-

Table 6.4: *Possibilities for updating trust, trustworthiness and possibly propensity to trust.*

When	How
During shipment	Agents can finish their task while the shipment is not completed yet. After finishing their task, whether successfully or not, the trustworthiness, trust and propensity to trust are mutually updated.
After shipment	When a shipment is finished, all agents still involved in the shipment mutually update perceived trustworthiness, trust relations and their own propensity to trust.
Consulting others	Trust and trustworthiness of an agent are updated of an agent recommended by others.

Table 6.5: *Trust functionalities from trust theory in the model.*

Functionality	Implementation
Distrust arises faster	The model contains a parameter that multiplies a negative trustworthiness increase.
Difficult to restore distrust	Once an agent reached out to all its trusted familiar agents and consulted familiar agents for trustworthy individuals, there is a certain chance the agent starts recruiting distrusted agents. Otherwise it starts reaching out to random agents it encounters.
Loyalty	Trust is calculated based on the perceived trustworthiness and is capped between minus one and plus one. However, trustworthiness is not capped and may result in high levels. As a result could a negative interaction not decrease the trust between the agents.
Affective trust	In case an agent reaches out to its familiar agents to find trustworthy individuals it may find conflicting opinions of the trustworthiness of an agent. In that case the trust in that agent is defined by the recruiter its propensity to trust.

verted. The main drawback of this method however, does not align with reality. A maximum satisfiable gain does not explain why criminals keep shipping illegal goods. Still it is considered a viable approach to quantifying the risk vs gain trade-off as no perfect options exist. It allows making decisions based on risks and gains and leads to Equation 6.1. The important feature of this equation is the ratio between α, β and γ for applying weights to respectively gain, interception risks and risks of getting caught.

$$utility = \alpha \times \frac{gain}{gain_{max}} - \beta \times risk_{interception} - \gamma \times risk_{arrest} \tag{6.1}$$

Trust reduces the perceived risks of interception of the shipment. It allows one agent to trust the other agent in successfully executing the job. The correlation between trust and risk defines to what extent trust is able to reduce the risks of interception as Equation 6.2 shows. Trust is a variable with a range from -1 to 1. Minus one represents distrust, whereas one represents full trust.

$$risk_{interception} = risk_{interception,regular} \times r_{trust,risk} \times trust \tag{6.2}$$

Criminals may escape authorities even when they are caught in the act. When an agent fails its job in the model there is a certain chance of getting captured. Equation 6.3 shows this relation mathematically.

$$risk_{arrest} = risk_{interception} \times risk_{capture} \tag{6.3}$$

Table 6.6: *Risk vs gain operationalization options.*

Option	Disadvantage
Percentages	Converting gain to a percentage requires to divide the gain by a monetary value that indicates a gain after which an agent does not receive more utility anymore if gain increases. This value is highly uncertain as no information is available.
Monetary	Converting the interception risk to a monetary value is very well possible. However, converting the risk of arrest to a monetary value seems to introduce more uncertainty. First and foremost
Categorical	Converting all parameters to categorical parameters requires the most adaptation and probably results in the most uncertainty. Compared to the percentages approach this operationalization actually has the same main drawback. The last category indicates a gain with which the agent does not gain extra utility. Furthermore, if a few categories are defined the chances of creating a deterministic model is larger than for the other options.

Table 6.7: *Explanation of KPI's.*

Type	KPI	Description
Supply chain performance	Interception_rate	A The rate of shipments containing illegal goods being intercepted by customs.
	Total_throughput	The total amount of illegal goods that is successfully imported.
	Total_intercepted_goods	The total amount of illegal goods that is intercepted catching criminals red-handed or during hidden checks.
	Total_expired_intercepted_goods	The total amount of illegal goods being intercepted, when containers having a visible customs block, are inspected at legal pickup.
Trust	Coordinator_trust_TD	The trust of principals in coordinators.
	Coordinator_trust_BU	The trust of executive agents in coordinators.
	DP_trust	The trust of coordinators in principals.
	Executive_trust	The trust of coordinators in executive agents.

6.3.2. Transaction-cost economics

Three components have been included in the model to simulate a transaction-cost economics trade-off, (1) gain, (2) operational costs and (3) organizational costs as indicated in Equation 6.4.

$$utility = gain - costs_{operational} - costs_{organizational} \tag{6.4}$$

Gain is defined as the gain associated with the shipment. Operational costs are the physical costs an agent has for completing a job. Organizational costs are the coordination costs of monitoring, controlling and managing interactions (Williamson, 1979). Trust reduces these costs in the model as shown in Equation 6.5 to a certain height, the correlation between trust and organizational costs.

$$costs_{organizational} = costs_{organizational,regular} \times r_{trust,costs} \times trust \tag{6.5}$$

Eventually these three components result in a monetary utility. Rational agents will only perform the action according to the decision-making model if the monetary utility is bigger than the gain associated with the job times the risks of interception as Equation 6.6 tells.

$$utility_{min} = gain \times risk_{interception} \tag{6.6}$$

6.4. Measuring model output

For measuring the model behavior and retrieving insights out of the model, several key performance indicators (KPI's) have been implemented. These KPI's are calculated during, and at the end of model runs. In Table 6.7 an overview of the KPI's is presented in combination with an explanation of their relevance, and thereafter this section goes on to elaborate on their calculation. They are split up in two kinds of KPI's: (1) supply chain performance and (2) trust. This allows for analyzing changes in trust within criminal networks and eventual influences on the criminal supply chain from South America to the port of Rotterdam. After

Although Table 6.7 reflects on the meaning of the KPI's, additional explanation of the calculation provides deeper understanding of what the model output really reflects. Table 6.8 describes the KPI calculation in words. Measuring the model output in combination with the way the model is implemented also introduces some limitations. As the model represents a beginning criminal shipping network, shipments that are already sent and to some extent included in trust calculations, are not included in the supply chain performance as these shipments did not yet arrive.

Calculating the mean trust over all active shipments every model step, makes shipments that take long to complete weigh heavy in the trust calculation and vice versa. However, as trust between criminals in

Table 6.8: *Explanation of KPI calculation.*

KPI	Calculation description
Interception_rate	Divides all completed shipments (successful and failed) by the number of failed shipments.
Total_throughput	Every time a shipment is successfully completed, the weight of the shipment is added to the total throughput.
Total_intercepted_goods	Every time a shipment is successfully intercepted with a hidden customs check or criminals being caught red-handed, the weight of the shipment is added to the total intercepted goods.
Total_expired_intercepted_goods	Every time a shipment is successfully intercepted with a regular announced customs check at legal pickup, the weight of the shipment is added to the total expired intercepted goods.
Coordinator_trust_TD	The average trust in coordinators by principals calculated over all currently active shipments.
Coordinator_trust_BU	The average trust in coordinators by executives calculated over all currently active shipments.
DP_trust	The average trust in principals by coordinators calculated over all currently active shipments.
Executive_trust	The average trust in executives by coordinators calculated over all currently active shipments.

a shipment already resembles that a criminal accepted a job, this limitation will have a small impact on the KPI's as there is no correlation between low trust and the delay of a task not being carried out due to no-one willing to do the job. The calculation mostly introduces randomness into the KPI's as shipments on board of shipments that take a long time to cross the ocean weigh heavy. However, the degree to which this happens is dependent on the spread of trust between criminals within these shipments. If the trust between criminals in all shipments is more or less equal, this effect will be very small. An alternative and more accurate way would be to accumulate the levels of trust when reaching out to others and accepting a job and dividing these by the number of interactions. However, the difference is expected to be small and the current implementation also support timeseries analysis. The alternative approach will generate oscillating behavior that will be hard interpret as every step the trust in the approached agents and the trustor may vary significantly.

Table 6.9: *Intervention explanation.*

Type	Intervention	Description
Trust	Creating distrust	When a hidden check is performed on a container and illegal goods are intercepted, the Police publishes a press release that the goods have been detected because of an anonymous tip. Criminals start distrusting each other of leaking information.
Supply chain	Preventing MO switches	Containers that are announced to be checked by customs are placed together in stacks, that are secured from individuals entering the area. This prevents extractors from switching illegal goods to another container from containers that are blocked by customs.
	Reducing time interval before ETA of announcement customs checks	Reducing the time interval that customs checks are announced to pre-notifiers, gives criminals less time to reorganize and plan an alternative MO for retrieving the illegal goods from the container.

6.5. Interventions

To allow for experimenting with intervening in trust within criminal networks and the criminal supply chain, several interventions have been selected and implemented in the model. Currently, a total of three interventions have been implemented that can be divided into two categories: (1) trust interventions, and (2) supply chain interventions. These interventions are described in Table 6.9. The intervention of reducing the time interval that customs checks are announced before ETA of a ship, from 72 to 24 hours, has its limitations for the implementation. Due to a misunderstanding of the legal supply chain process, the legal party is able to pre-notify the shipment when customs checks should be announced. This decreases the chances that criminals are too late with retrieving their illegal goods from the container.

7

Results

This chapter introduces an experimental setup for the described quantitative model and elaborates on the results. The results will be presented first for the base scenarios, followed by the interventions for both decision-making models simultaneously. The most relevant results are included either in this chapter or in Appendix B, as many tables and figures have been generated but did not necessarily provide additional insights. All these files can however be found on the GitHub of this Msc. thesis project in case of curiosity.

Table 7.1: *Parameter ranges for the scenarios.*

Rationality	Parameter	Range	Sources
Universal	ia_{trust}	4-10	-
	$M_{distrust}$	2-3	-
Risk vs gain	α	1	(Baumeister et al., 2001; Yechiam, 2015)
	β	1-5	
	γ	1-5	
	$r_{trust,risk}$	0.2-0.6	(Colquitt et al., 2007)
TCE	$costs_{organizational,regular}$	10000-20000	-
	$r_{trust,costs}$	0.5-1	-

7.1. Experimental design

To experiment with the model and retrieve results, an experimental design has been composed. This experimental design consists of three parts: (1) composing scenarios to run the model for, (2) determining the required number of model replications for retrieving reliable results to deal with model stochastics and (3) analyzing the model output.

Three trust scenarios per decision-making model have been composed: (1) the base case scenario, (2) a high trust scenario, and (3) a low trust scenario. As trust and trade-off preferences are abstract mental processes, the quantification of these scenarios is uncertain and a well-estimated guess. Table 7.1 shows the scenario parameters in combination with their ranges and sources, if applicable. Only non-criminological sources have been used, as criminological sources did not quantify these artifacts. The absence of a source for a parameter range, means that the range is based on a well-estimated guess within bounds of reason. The (successful) interactions until full trust arises, ia_{trust}, is a well-estimated guess as not any literature provided information on the quantification how fast trust develops. Two parameter ranges are based on deeper theories. The distrust multiplier, $M_{distrust}$, starts at a value of two since trust theory suggests distrust arising faster than trust. The ratios between gains and risks, α, β and γ, are based on the economic loss aversion model of Kahneman and Tversky (1973) that individuals value risks higher than gains in general. However, also an equal valuation of risks has been taken as plausible range to resemble findings of Yechiam (2015) who did not find any significant difference. The influence of trust on these risks is based on a study estimating the relation between

Table 7.2: *Scenarios for the experiments.*

Rationality	Parameter	Base case	High trust	Low trust
Universal	ia_{trust}	7	4	10
	$M_{distrust}$	2.5	2	3
Risk vs gain	α	1	1	1
	β	3	5	1
	γ	3	5	1
	$r_{trust,risk}$	0.4	0.6	0.2
TCE	$costs_{organizational,regular}$	10000	20000	5000
	$r_{trust,costs}$	0.75	1	0.5

trust and risk taking by Colquitt et al. (2007). They estimate this influence in the middle of the parameter range, and for scenario composition the value slightly deviates within a reasonable range, as trust is not able to eliminate all risks nor is expected to have no influence. The TCE cost parameter is not based on theoretical sources but have been purely estimated looking at the costs to come to a reasonable range. As organizational costs contain the costs of managing a relationship, the range of trust being able to reduce these costs has been chosen in such way, that it could eliminate all costs but also a part of it.

Converting the parameters of Table 7.1 to scenarios, leads to six scenarios in total that are depicted in Table 7.2 as for both decision-making models three scenarios are designed. The base case scenario is an average of the high and low trust scenarios. The high trust scenario is characterized by fast trust development and a slow occurrence of distrust. Furthermore, in making decisions according to the risk vs, gain trade-off, risks weigh heavy and trust strongly reduces these perceived risks. In the case of transaction-cost theory, organizational costs are high and trust strongly reduces these costs. Strong risk aversion or high organizational costs in combination with a high influence of trust on these risks or costs, makes trust potentially important in the decision-making process. On the contrary, trust develops slowly in the low trust scenario and distrust arises quickly. Risk have a low weight in the decision-making process or organizational costs are low. Trust reduces risks and costs to a lesser extent.

To test whether including affective decision-making related to trust in the model as suggested by Van Gelder (2013), all three scenarios per decision-making model will be run with a boolean stating whether affective decision-making is turned on or off. This yields six scenarios per decision-making model: (1

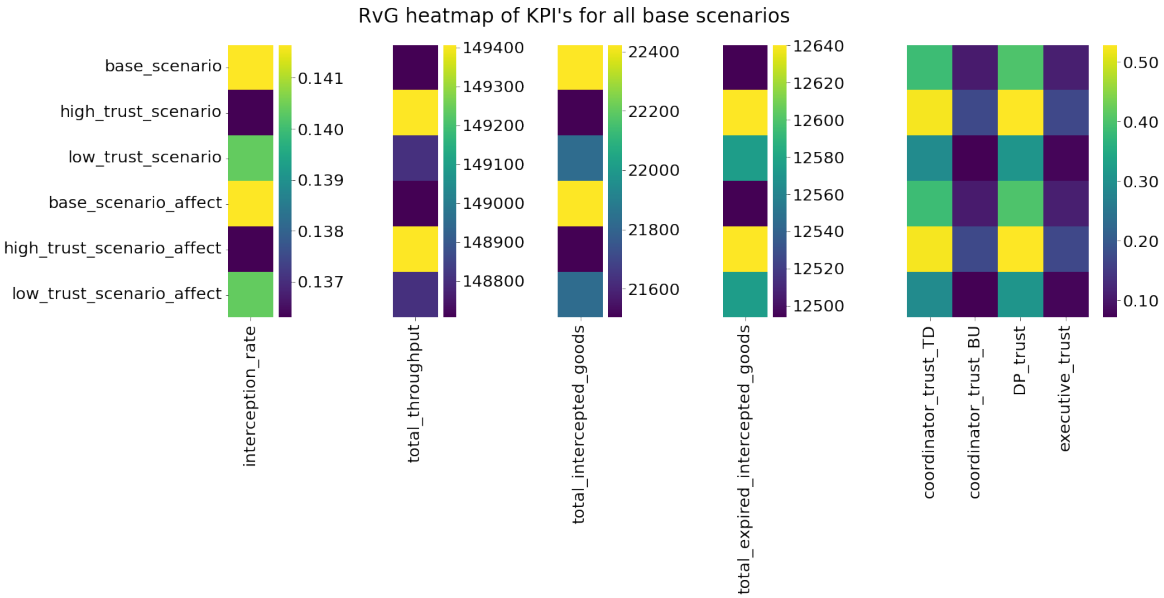

Figure 7.1: *Heatmap of the base scenarios for the risk vs. gain trade-off including affect.*

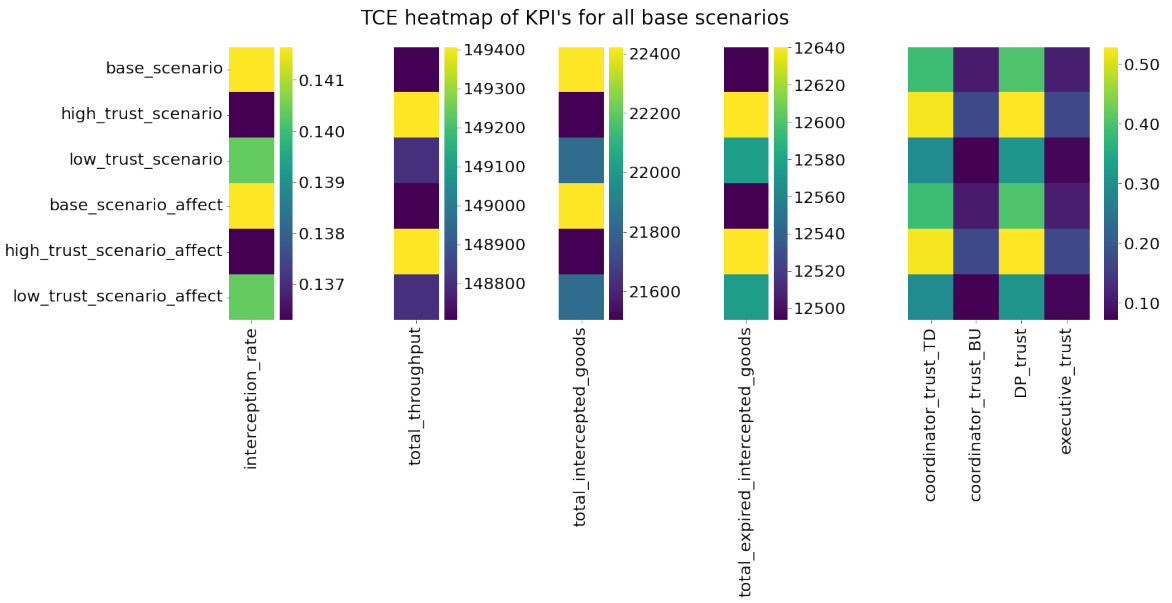

Figure 7.2: *Heatmap of the base scenarios for the TCE decision-making model including affect.*

and 2) a base case scenario with and without affect, (3 and 4) a high trust scenario with and without affect, and (5 and 6) a low trust scenario with and without affect. In total this results in twelve scenarios.

The second part of the experimental design requires to determine the number of model runs that gives reliable results. This has been done by taking a set of 100 random seeds for which the base scenarios for both decision-making models have been run. For each multiple of ten up until 100, this number of model runs has been plotted for each KPI in a boxplot as shown in Figures A.1, A.2, A.3, A.4. At a number of 70 replications and more it seemed that the boxes converged to a more or less solid shape and approached a reliable number of model runs. Therefore, each experiment will be run for a total of 70 replications.

The experimental setup is implemented by making use of the EMA workbench for exploratory modeling (Kwakkel, 2017). Analyzing the model output will be done visually as well as statistically. The visual approach consists of heatmaps of KPI's. A heatmap presents the values of KPI's in colors and makes differences and high and low values easy observable. Interesting results will also be statistically tested to support the visually observed results by performing t-tests. T-tests are able to measure whether two populations of results are significantly different for a confidence interval. Prerequisite is that these populations are normally distributed or consist of more than 30 observations. With the determined number of 70 replications this prerequisite is satisfied.

7.2. Base scenarios

Figure 7.1 shows a heatmap for all six scenarios for the risk vs. gain trade-off. The figure shows two patterns requiring further investigation: (1) relatively small spreads in the supply chain performance KPI's, and (2) similar patterns for the upper three scenarios without affect and the lower three scenarios with affect. Therefore, these two elements will be further investigated with t-tests.

Tables B.1 compares the high and low trust scenarios to the base scenario as reference scenario for the risk vs. gain trade-off. The supply chain performance does not differ between scenarios, however the trust within the criminal shipping networks changes as expected. In the high trust scenario the trust is significantly higher for all different trust KPI's and in the low trust scenario trust is significantly lower. The observed small spreads in the supply chain performance KPI's are thus non-significant changes between the base and the low and high trust scenarios. Additionally, the changes in supply chain performance does not differ significantly between the low and high trust scenario as Table B.2 shows. A remarkable result, as this would be the situation where intuitively the biggest difference would be expected. To come to the second element that requires further investigation, Tables B.3 show no

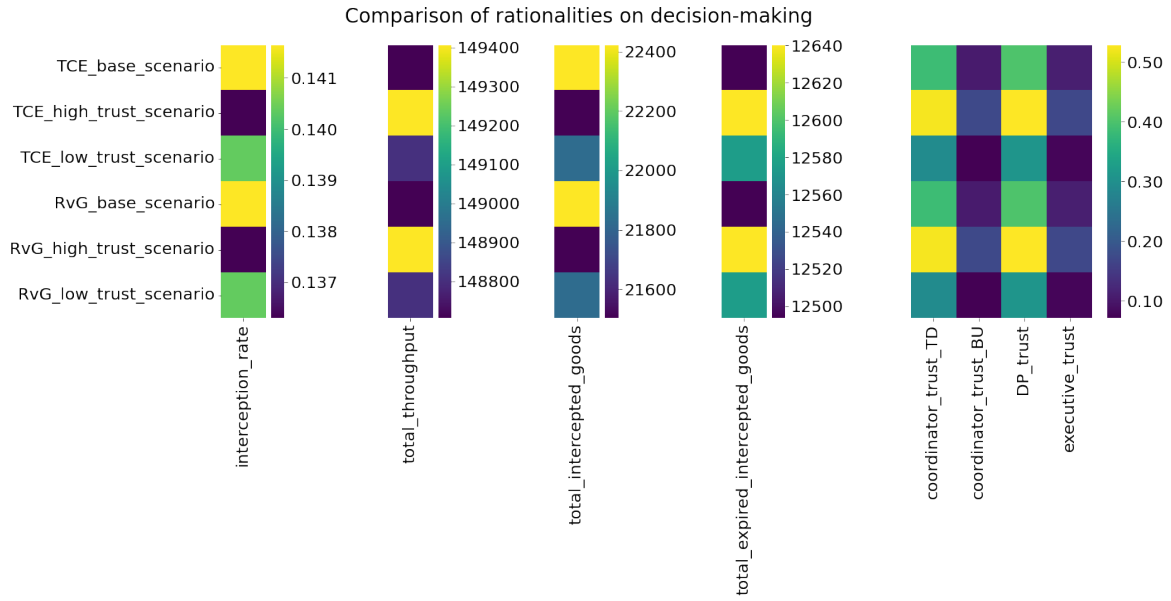

Figure 7.3: *Comparison of the high trust scenarios for both rationalities without affect.*

differences between the high trust scenarios with and without affect, as the p-value of the t-test is 1.0. This value indicates that both compared samples are identical and that the implemented affective decision-making with the current used set of random seeds, does not occur.

Figure 7.2 displays the heatmap of all KPI's for the base scenarios with the TCE decision-making model. This figure looks similar to Figure 7.1 of the risk vs. gain trade-off. Therefore, this heatmap raises the following three patterns for further investigation: (1) the relatively small spreads in supply chain performance are also not significantly different between the base scenarios, (2) affective decision-making related to trust does not occur with the current set of seeds, and (3) TCE produces the same results as the risk vs. gain trade-off.

Table B.4 shows that supply chain performance KPI's do not significantly differ from each other when the low and high trust scenarios are compared to the base scenarios, as well as when the low and high trust scenarios are mutually compared. Additionally, also for the TCE decision-making model, affective decision-making does not occur in the model runs as Tables B.3 and B.6 show p-values of 1.0 for all KPI's. For the third pattern, Figure 7.3 shows indeed no visual differences between the risk vs. gain trade-off and TCE. Table B.7 statistically support this observation by showing p-values of 1.0 when comparing the high trust scenarios of the two decision-making models, where the difference between the two decision-making models would be best observable.

7.3. Interventions

Besides running the model for different scenarios, also model runs have been performed for the interventions as described in Chapter 6 in the different scenarios. As previous section showed the insignificance of affective decision-making based on trust, scenarios including affect will not be analyzed in this results section to keep things organized. Furthermore, previous section also indicated differences in trust between the scenarios but no significant changes in supply chain performance. As this research focuses on the influence of trust, first the high trust scenario will be analyzed as the influences of trust will be best visible. In case these high trust scenarios generate new insights to also analyze scenarios where trust is less relevant, these will be reviewed too.

7.3.1. Creating distrust

Figure 7.4 shows for both decision-making models the base high trust scenario and the high trust scenario where distrust is created. The spreads in the supply chain performance KPI's are small and the trust values seem almost similar for the two cases of each decision-making model. Tables B.8 and

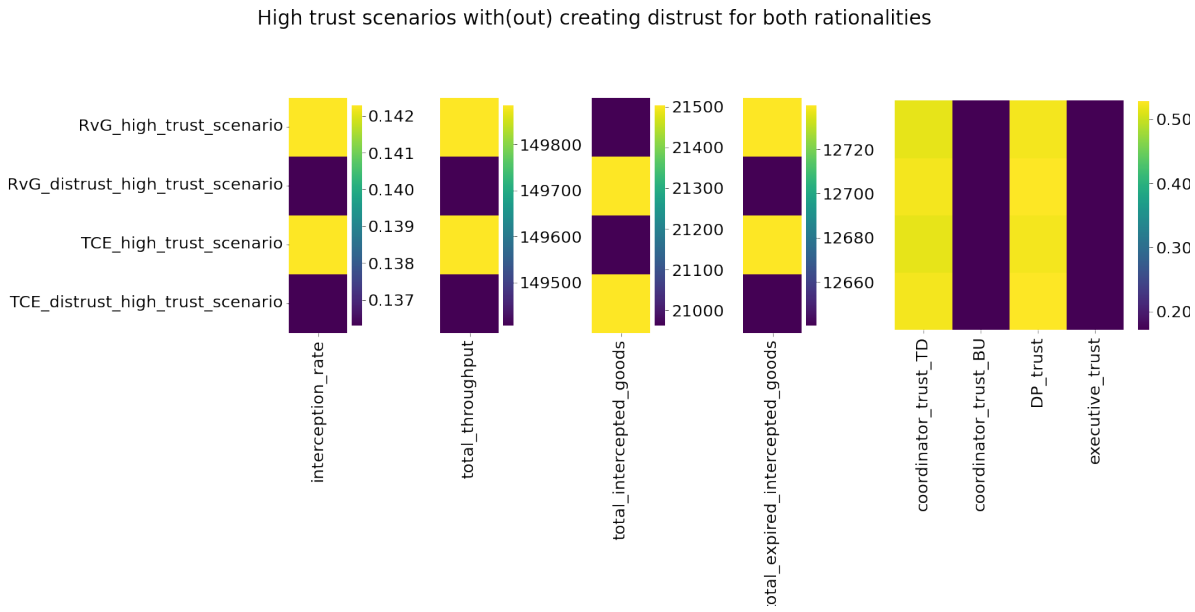

Figure 7.4: *Comparison of the high trust scenarios for both rationalities when distrust is created and between the base scenario.*

B.9 confirm that for all KPI's the results are not significantly different for both the risk vs. gain trade-off and TCE. They do differ in some sense as the p-value is smaller than 1.0, however the intervention does not seem to have any effect even in the high trust scenario. Another observation is that the scenarios where distrust is created for both decision-making models look identical, just like the base high trust scenarios that did not differ between the decision-making models. T-tests in Table B.10 again show p-values of 1.0, indicating that also when distrust is created, both the risk vs. gain trade-off and TCE yield the exact same result.

7.3.2. Preventing MO switches

Preventing criminals from being able to switch MO does seem to have its impact. Figure 7.5 shows declining levels of trust that are statistically significant as Tables B.11 and B.12 show. As expected the

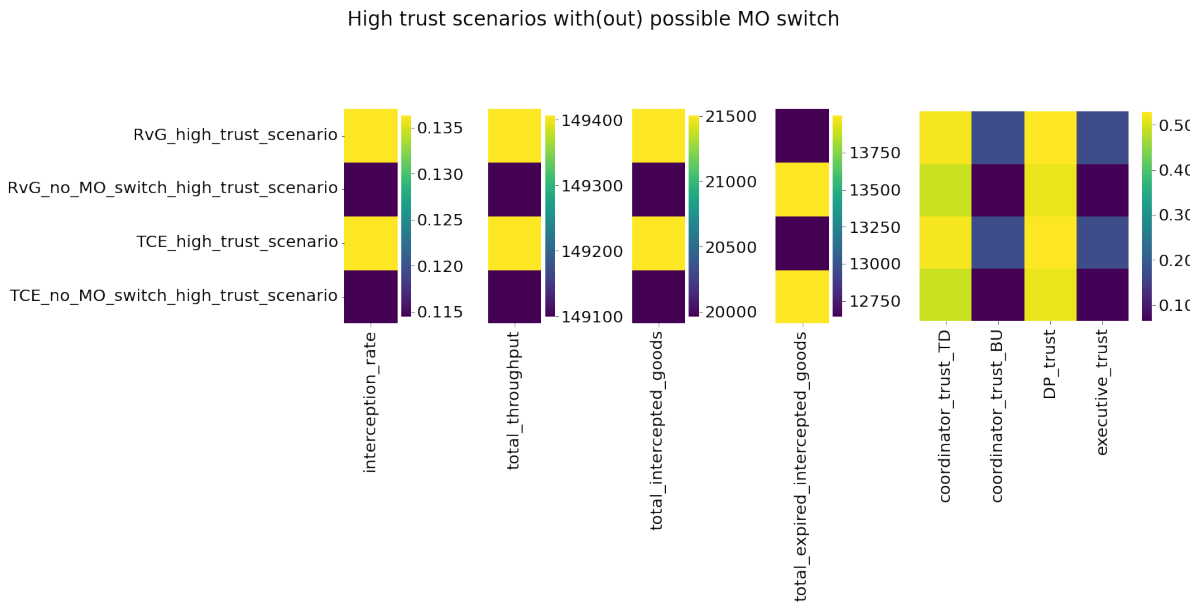

Figure 7.5: *Comparison of the high trust scenarios for both rationalities when MO switches are prevented and between the base scenario.*

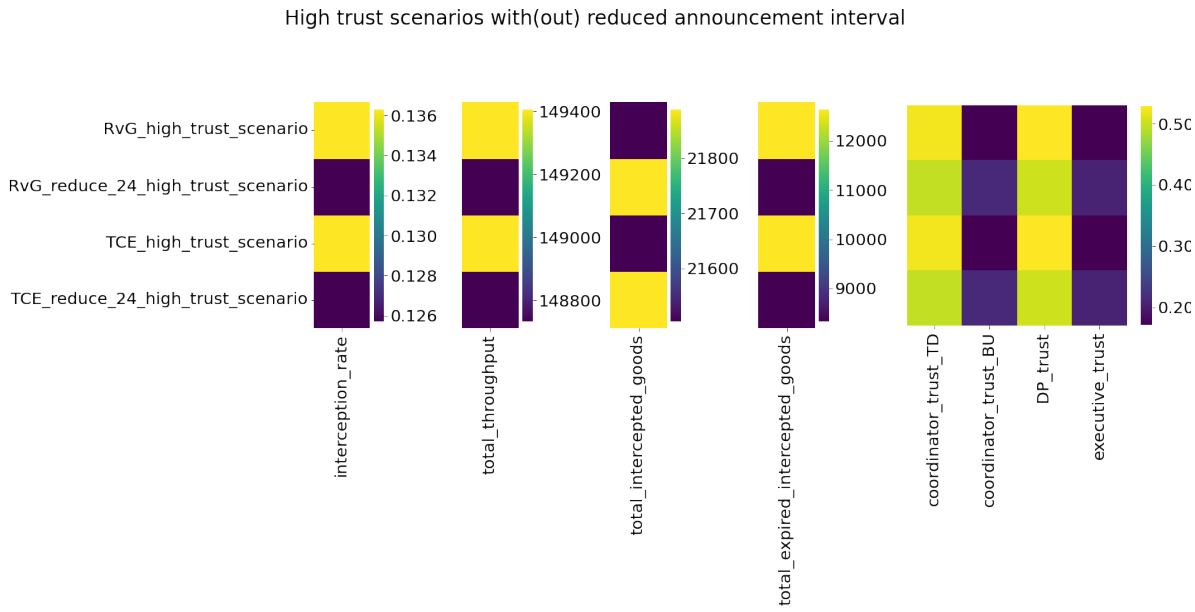

Figure 7.6: *Comparison of the high trust scenarios for both rationalities when customs checks are announced later before arrival, and between the base scenario.*

expired intercepted illegal goods rises and the intercepted illegal goods declines. This reflects a shift from catching criminals while retrieving the illegal goods from the port area to discovering illegal goods at legal pickup of the container when the customs check is performed. Remarkably the interception rate decreases significantly in contrast to what would be expected. However, this observation leads back to the model structure. As many shipments are sent overseas and the legal pickup of containers has been modeled as a probability, the shipments to be checked by customs accumulate on the terminals because of this probability being too small. As a consequence the expired intercepted illegal goods is too small compared to what it should be. Again, another visual observation is the similarity between the two decision-making models. Also in the case of preventing criminals to switch between MO's in high trust scenarios the results are exactly identical. Table B.13 shows p-values of 1.0.

7.3.3. Reducing interval of announced customs checks

Figure 7.6 shows a declining interception rate when the interval that customs announces checks before the estimated time of arrival (ETA) of a ship is reduced. This declining interception rate is significant as Tables B.14 and B.15 show and is caused by a significantly lower amount of illegal goods caught at legal pickup. Because of less shipments being caught, trust levels also rise significantly. Both decision-making models again generate identical results as Table B.16 shows with p-values of 1.0. Although the declining interception rates are counter intuitive, this finding can be lead back to the model structure. Since legal parties can only pre-notify containers 24 hours instead of 72 hours before the ETA of a ship, it takes longer for legal parties to pick up containers and the container may already be gone or have its illegal goods switched to another container. This behavior is caused by the legal pickup of a container being modeled as a probability.

8

Discussion

This chapter will reflect on the model validity, results from Chapter 7 of the relation between trust and criminal decision-making, and generalization of the results to other sorts of criminal supply chains. The chapter will be concluded by discussing the limitations related to the research approach, and a lack of information and data.

8.1. Model validity

Model validity expresses if the model is able to reproduce real system behavior. Since this research is analyzing a criminal supply chain, comparison to real world values is impossible as criminals do not share information about their operations. The model has instead been built on insights gathered from experts who have a clear picture of the way illegal goods are smuggled. However, as they indicated, they do not have hard facts about how much is smuggled. Literature does however provide some rough estimations as mentioned in the introduction. Some estimates about interceptions indicate interception percentages between 10 and 20 percent. The model ranges lay within these percentages, however since these estimates are highly uncertain and cover multiple smuggling methods besides rip-offs, the model only proves validity in the order of magnitude. Furthermore, when looking at the total amount of intercepted goods, thus the amount of goods being confiscated with hidden and announced checks, and when criminals are caught red-handed, also aligns in order of magnitude in comparison to 2021. Back in 2021 73.000 kilos were intercepted and the model estimates lay around 65.000 kilos a year. Since only rip-offs are considered, the model most likely overestimates the total amount of intercepted goods. However, during conversations with experts, it became clear that there is an imbalance between the way illegal goods are intercepted in reality and in the model, and thus may cause the difference. The model overestimates the amount of illegal goods that is being confiscated at announced customs checks. This implies that in reality criminals are better able to anticipate on announced customs checks by switching to other MO's or that criminals successfully avoid hiding the illegal goods in containers that will be checked by customs. An additional point of model validity flows from the analysis of the interventions that have counter intuitive effects that are theoretically impossible. Legal companies wait too long in the model with pre-notifying containers and picking them up from the terminal causing accumulation of containers to be picked up on the terminal.

Although accurate validation of the model is first of all impossible for a criminal supply chain and knowledge is limited, the model is able to simulate the criminal supply chain dynamics and trust between criminals shipping illegal goods. Therefore, the model suffices for gathering insights in the role of trust in criminal decision-making in criminal supply chains. However, the implemented dynamics also have its limitations as has become clear from analyzing the results and may impede drawing conclusions of the effects of interventions.

8.2. Results interpretation

The results in Chapter 7 led to some expected and unexpected results. These results have to be interpreted under the set of inputs passed on to the model. These inputs consisted of three scenarios: (1) a base scenario that was the average of a (2) high and (3) low trust scenario. All these scenarios were combined with affective decision-making related to trust turned on and off, leading to a total of six scenarios. The model was run for two decision-making models each with these six scenarios. Additionally three interventions were explored in the model: (1) creating distrust, (2) preventing criminals from switching MO, and (3) reducing the interval before ETA that customs checks are announced. This experimental setup allows for several analyses under the current quantification of the model: (1) determining the influence of trust on the criminal supply chain for each decision-making model, (2) determining the influence of affect, (3) analyzing the effects of interventions, and (4) analyzing the influence of the selected decision-making models on trust, affect and interventions.

The three trust scenarios showed significant differences in the trust between criminals as would be expected. In the high trust scenario trust levels between criminals were relatively high, and in the low trust scenario trust levels were relatively low. However, none of the supply chain performance KPI's (i.e., the interception rate, total throughput and intercepted goods) did differ significantly between the scenarios both for the risk vs. gain trade-off and TCE. Under the current set of scenario input parameters, the levels of trust in the criminal network do not seem to influence the overall supply chain performance. Meaning that criminals will keep ordering illegal goods from South America and that there are criminals willing to participate in the smuggling process to secure the shipments from the port area.

The scenarios with affective decision-making turned on, yielded the exact same results as the scenarios without affective decision-making. This was possible as the model used the same set of seeds for the number of replications the model was run. The way affective decision-making related to trust is currently implemented in the model also clarifies to some extent why this could be. An agent only reaches out to a few others to consult for trustworthy individuals, if the agent runs out of familiar agents that want to do the job. If the few others by accident recommend the same agent, but provide ambiguous perceptions of trustworthiness, only then the propensity to trust of the agent reaching out will determine the level of trust in the trustee. Chances of this happening are very small, but may not be intuitively unrealistic.

All interventions have been run for the high trust scenario without affect, since affect did not seem to have any influence on the trust between criminals nor supply chain performance. And since the goal of this research is to find the influence of trust on criminal decision-making, possible changes would be best observable in a scenario where trust is most relevant. One intervention is directly aimed at influencing trust: creating distrust. The creation of distrust does not lead to any significant changes in trust levels or supply chain performance. This intervention is only possible when illegal goods are found when performing a hidden check, because criminals could start suspecting each other of talking to the Police. Criminals will notice regular checks and consider it part of the process. Since on only one percent of all containers arriving from South America hidden checks are performed, the influence is seemingly very small.

The other two interventions are supply chain interventions targeting trust indirectly. The goal of these interventions is to increase interceptions and create distrust as result. Placing containers to be checked in one secured location together, avoids criminals being able to switch from one MO to another. Containers that will be checked will stay unchanged and hidden goods will be detected. The model results shows a significantly lower interception rate for this intervention in combination with significantly more illegal goods being discovered during announced checks, and significantly lower levels of trust. The lower interception rate is counter intuitive, however explainable by model structure. Due to choices in model structure and parameter values, containers to be checked accumulate on the port terminals. Illegal goods from containers being declared by customs are still retrieved by criminals and thus the interception rate goes down. This is a distorted picture of what is happening. However, since illegal goods being discovered rises significantly while containers to be checked are accumulating on the port terminal, it can be expected that the interception rate will become significantly higher when this issue is fixed. In combination with the lower levels of trust and if the interception rate would be dynamically integrated into the model, this intervention has the potential to change the decision-making of criminals.

Reducing the interval before the ETA of a ship that customs announces the checks from 72 to 24 hours

also shows a significantly lower interception rate. This result is unexpected as the intervention was aimed at allowing criminals less time to reorganize in case of a customs check. However, due to how the intervention is modeled the result is explainable. Legal companies can only pre-notify a container when customs checks are announced and have a probability of doing so every hour. This leads to less containers being pre-notified by legal companies and often actually removing the need to switch to another MO if the ship is destined for the APM1, APM2 or RWG terminal.

Further analysis that also compared the results between the decision-making models showed totally identical numerical results. Again, this is possible because of the specified set of seeds to be used for every scenario. However, two different decision-making models yielding the exact same results generates additional insights for the relation between trust and decision-making under the current set of input parameters. Since both decision-making models are quantified in a different way, it is impossible for the two different rationalities to have the exact same tipping points for all the decisions made in a model run of half a year. This result means that every time the exact same decision was made when a decision had to be made by an agent, and trust thus did not influence this decision. Since illegal goods keep flowing through the port of Rotterdam in the model, it shows that this decision was always 'positive'. The gains always outweighed the risks and/or costs associated with participating in the smuggling process and ordering illegal goods. The changes in trust for the different trust scenarios are thus not caused by the decision-making model parameters, but purely by the speed with which trust develops and how much faster distrust arises.

8.3. Generalization of results: appliance to other supply chains

The discussed results apply to the specific case study used in this research: the criminal supply chain from South American ports to the port of Rotterdam. Quantitatively generalizing these results is not possible for two reasons: (1) the quantification is highly uncertain, and (2) quantification is specific to the case study. However, the study did generate some insights that can be generalized.

The model results show that in criminal supply chains where gains are relatively high compared to risks and/or costs associated with performing the criminal act, trust is potentially not relevant for the decision-making of the criminal. This result is also dependent on the risk or cost aversion of individuals. It means that if criminals perceive an imbalance in the gains, risks and/or costs taking part in criminal activities is tempting. Quantifying the individual preferences has however turned out to be uncertain as these are abstract mental processes. Nonetheless, lower gains in combination with higher risks and/or costs, and higher risk or cost aversion could provide insights in the role of trust in criminal decision-making when trust is able to tilt the tipping point. This could provide additional insights in the role of trust on criminal decision-making when the tipping point is reached. However, knowing when the tipping point will be reached in reality is impossible. Only a best effort to push the criminal decision-making to the tipping point may be effective instead of aiming to increase interception risks to certain heights.

Another finding of the model is that regular supply chain interventions can also affect the trust between criminals, besides having direct effects on the supply chain. Although a decreased trust as result of an intervention did not significantly affect the supply chain performance, interventions could shift the criminal decision-making to the tipping point in two ways simultaneously: (1) increasing the interception risks and (2) decreasing the levels of trust and thus increasing perceived risks or costs. Interventions do possibly have the potential to have a reinforcing factor on criminal supply chain performance through trust as side effect.

8.4. Limitations

The limitations of this research are split up into two parts: (1) limitations of the research approach and (2) data and knowledge limitations.

8.4.1. Research approach limitations

The study comes with several limitations of the research approach. First and foremost, the use of a simulation model is a simplification of reality (Kleijnen, 1995). A simulation model fails to capture all elements of reality and may also be inaccurate. Therefore, the results should be interpreted on a purely qualitative basis instead of accepting quantitative results as the truth (Bonabeau, 2002). The values

of abstract mental processes presented in this study are uncertain and thus most likely inaccurate. However, the qualitative results do provide insights for when the balance of input parameters resembles a real-world situation. Since models are very sensitive to input parameters (Kilkenny & Robinson, 2018), different sets of input parameters could broaden the scope of the qualitative results for possible influences of trust on criminal decision-making.

Secondly, most information gathered during the literature review is based on non-criminological sources. The main reason why this has been done is because of the limited research on trust and decision-making between criminals. As a best effort, the criminological literature has been supplemented with non-criminological literature. However, it is unclear to what extent this literature is applicable to criminal supply chains.

8.4.2. Data and knowledge limitations

The research contains three main aspects in data and knowledge limitations: (1) the criminal supply chain structure and quantification, (2) the quantification of trust, and (3) the quantification of the decision-making models. On each of these aspects will be reflected in the paragraphs hereafter.

As already mentioned several times before, little data and knowledge on criminal supply chains is available as criminals tend to hide their operations from authorities. Therefore, the structural implementation of the criminal supply chain has been based on general available knowledge combined with views of experts who are relatively well-informed of criminal operations. However, still the exact operations may deviate from what has been put in the model. The quantification of this supply chain introduces more uncertainty. Experts stated that they have no knowledge about the real interception rates, how much is being shipped and in what manner. As a consequence, results may be unrealistic but still provide qualitative insights in the topic.

The quantification of trust is another limitation within the scope of this research. Most studies on trust that have also been used for this research describe the process of trust, trustworthiness and propensity to trust in a qualitative manner which allows for the composition of a quantitative trust system with dynamics according to the qualitative descriptions. However, quantifying each of these parameters stacks uncertainty on uncertainties. To avoid a estimation of all trust parameters, the study by Colquitt et al. (2007) has been used for quantifying part of these parameters. This study analyzed the correlations between propensity to trust, trustworthiness, trust and risk-taking. This study seems a reasonable substitute for non-existing criminological sources as risk-taking is omnipresent in the smuggling of illegal goods. However, still parameters such as how fast trust establishes, how fast it deteriorates, and the extent to which it influences organizational costs in TCE, have all been estimated. This emphasizes the fact that only qualitative conclusions from the model should be drawn and no attention should be given to quantitative results for generalizing obtained knowledge.

The third limitation concerns the quantification of the decision-making models. Some studies provided estimates of preferences between gains and risks for the risk vs. gain trade-off (Baumeister et al., 2001; Kahneman & Tversky, 1973; Yechiam, 2015). These estimates were inconclusive and seemed context dependent. Furthermore, none of the contexts was criminal. However, since no literature could be found that provided preferences between risks and gains in criminal context, scenarios were constructed containing the ranges of these estimates. TCE is most often qualitatively described in literature and moreover, not applied to criminal problems. The organizational costs are a best guess based on the costs an individual associates with managing relationships with others and coordinating processes.

9

Conclusion

The smuggle of illegal goods through the port of Rotterdam causes public health issues, violence, youth crime and economic damages. Dutch customs in collaboration with the Dutch police only manages to intercept a small percentage of all illegal goods entering Europe via the port of Rotterdam. Earlier studies found that mutual trust between criminals was essential for smuggling illegal goods, whereas within the Dutch police there was no consensus whether trust is of crucial importance. Instead of increasing the detection, influencing trust could possibly reduce the smuggle of illegal goods. Therefore, this study was performed to simulate the role of trust in criminal decision-making for smuggling illegal goods via the port of Rotterdam. This chapter will give an answer to the research question below, which had been formulated at the beginning of this research.

Main Research Question

How does trust affect decision-making in criminal supply chains, and what is its influence on illegal goods flow?

This main research question was divided into the following three sub-questions for structuring the research:

In the context of a criminal supply chain...

1. *how can decision-making related to trust be conceptualized?*
2. *how can the impact of trust on decision-making be modeled using agent-based modeling?*
3. *how do interventions affect trust and illegal goods flow?*

9.1. New insights

The first sub-question covers the criminal supply chain from South America to Rotterdam, how criminals make their decisions in this criminal supply chain and how these decisions are influenced by trust. The research focused on the rip-off method where illegal goods are hidden between legal cargo in containers in South America and retrieved from the port area in Rotterdam. Criminals made use of different types of rip-offs and were able to easily shift from one smuggling method to another to avoid detection by customs. In this smuggling process actors make decisions how, where, when and with whom to ship the illegal goods, whether to collaborate in managing the shipment and whether to retrieve the goods from the port area. These decisions were based on two decision-making models: (1) the risk vs gain trade-off and (2) the transaction-cost economics theory. The risk vs gain trade-off is influenced by trust as it decreases perceived risks and transaction-costs economics is influenced by trust as it increases efficiency.

The second sub-question defines several aspects of a computational model. At first how to include trust in a criminal supply chain and second how to include this in the decision-making of criminals. Trust was defined as a combination of perceived trustworthiness and one's own propensity to trust. A successful interaction in the criminal supply chain with another would increase the perceived trustworthiness of the other person and its own propensity to trust, a factor that would be universal for all trust interactions. On the other hand, unsuccessful interactions created distrust faster than trust could be created. Trust reduced perceived risks of shipments in the risk vs gain trade-off and reduced costs for monitoring and controlling others in transaction-cost economics theory.

Answering the third sub-question has its limitations, however the study does provide insights. Actively creating distrust between criminals by spreading information that a shipment on which a hidden customs check has been performed has been caught because of an anonymous tip, does not have significant impacts on trust between criminals and supply chain performance. This is the case because of the relatively little fraction of shipments that is being checked during hidden checks, only one percent. Intervening in the supply chain directly does not affect supply chain performance because of the imbalance between gains and risks and/or costs. It does however influence the trust levels between criminals, indicating interventions could be effective in two ways: (1) directly increasing interception risks and (2) reducing trust between criminals and possibly making individuals stop participating in smuggling illegal goods.

The main research question can be answered in context of the current parameterization of the criminal supply chain model. The model results show that for certain risk or cost aversions of individuals trust does not influence criminal decision-making in criminal supply chains, if gains are relatively high compared to the risks and/or costs associated with shipping illegal goods or taking part in smuggling activities. The high gains make illegal activities tempting for individuals and only very risk-averse criminals would not engage in those activities. Smaller profit margins and/or higher risk aversion or costs could shift the decision-making to a tipping point, where trust could be of pivotal influence in the decision-making of the criminal.

9.2. Further research

As modeling trust and decision-making within an itself uncertain criminal supply chain is highly uncertain, further research could focus on deep uncertainty analysis where many model runs are performed for a lot of uncertain parameters. Smaller profit margins, higher risks, and higher risk aversion or organizational costs would provide insights in the relevance of trust at the tipping point in the criminal decision-making where trust could potentially be of pivotal influence. As all these parameters are uncertain, this analysis would provide qualitative insights on system behavior influenced by trust. This would also allow for a broader generalization of results in criminal supply chains.

Future research in the behavioral aspect of the model dynamics would also be interesting. The current model bases its decision-making and trust on general literature on decision-making and trust. Interviewing (ex) criminals could provide more insights in the relevance of trust in criminals their decision-making, however the question is whether this is feasible, and whether these results are reliable. An additional behavioral aspect that could be added is a reputation system that would enlarge the possibilities of affective decision-making related to trust to better analyze the role of an affective component besides rational models.

A final recommendation for further research is the scope. In interviews with the Dutch police it became clear that smuggling networks overseas often have a share in the load of illegal goods. Successful or unsuccessful shipments could have its reciprocity on overseas trust relations. In combination with a geographical scope extension also shifts from one port to other ports could be simulated. If trust in criminals operating in the port of Rotterdam is low, illegal goods might enter Europe via different routes. The throughput of illegal goods in the port of Rotterdam could decline because of displaced activities.

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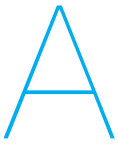

Model stochastics

Four pairplots of boxplots are shown for determining the number of replications of the model. Two for each decision-making model, one scaled and one not scaled. With increasing replications the spread of the boxplot converges to a solid form that represents the spread of the randomized model runs.

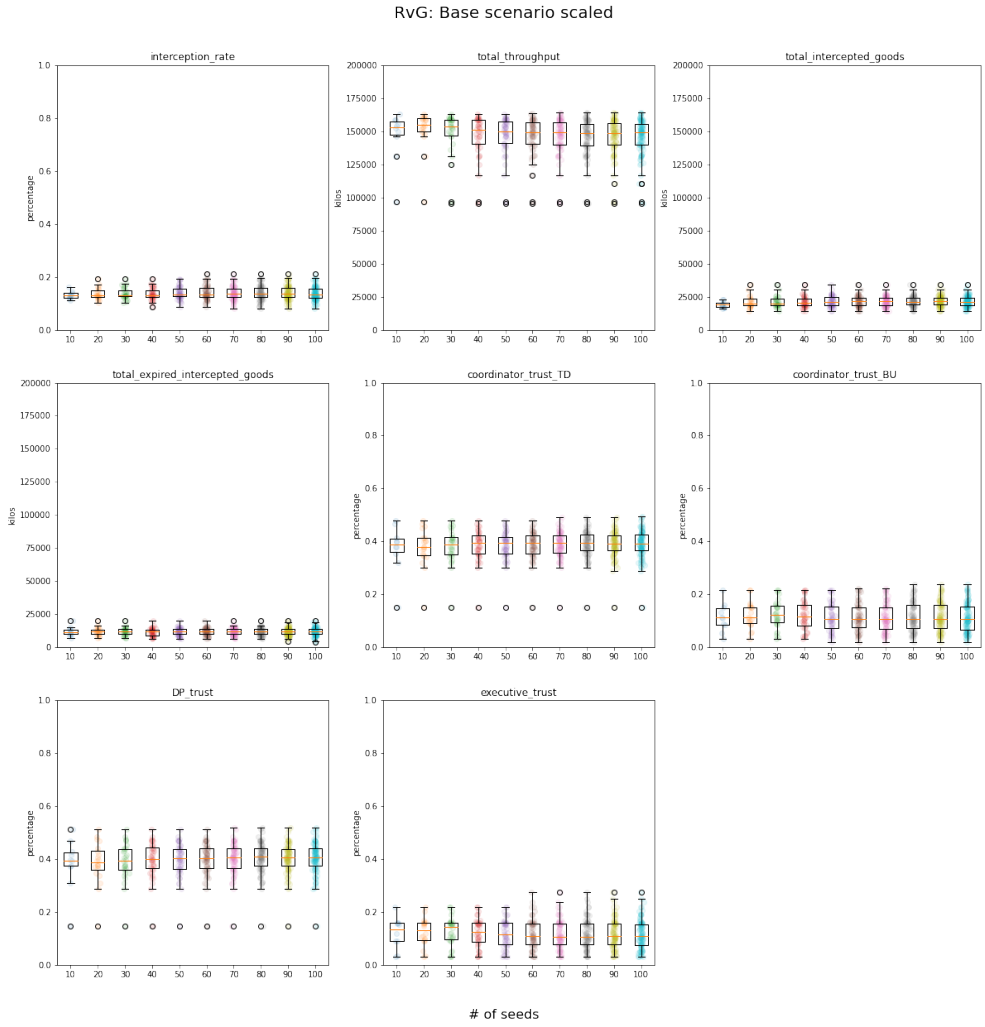

Figure A.1: *Scaled base scenario boxplot for the risk vs gain trade-off for different number of seeds.*

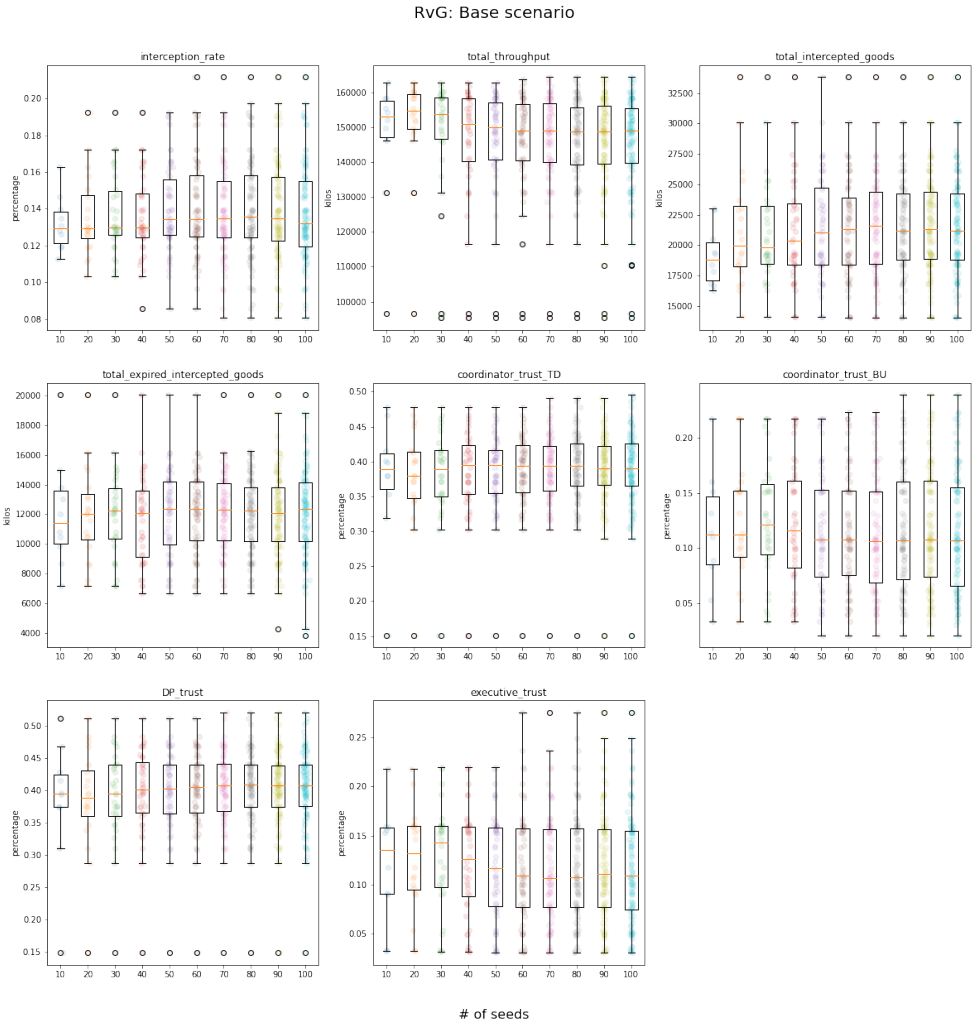

Figure A.2: *Base scenario boxplot for the risk vs gain trade-off for different number of seeds.*

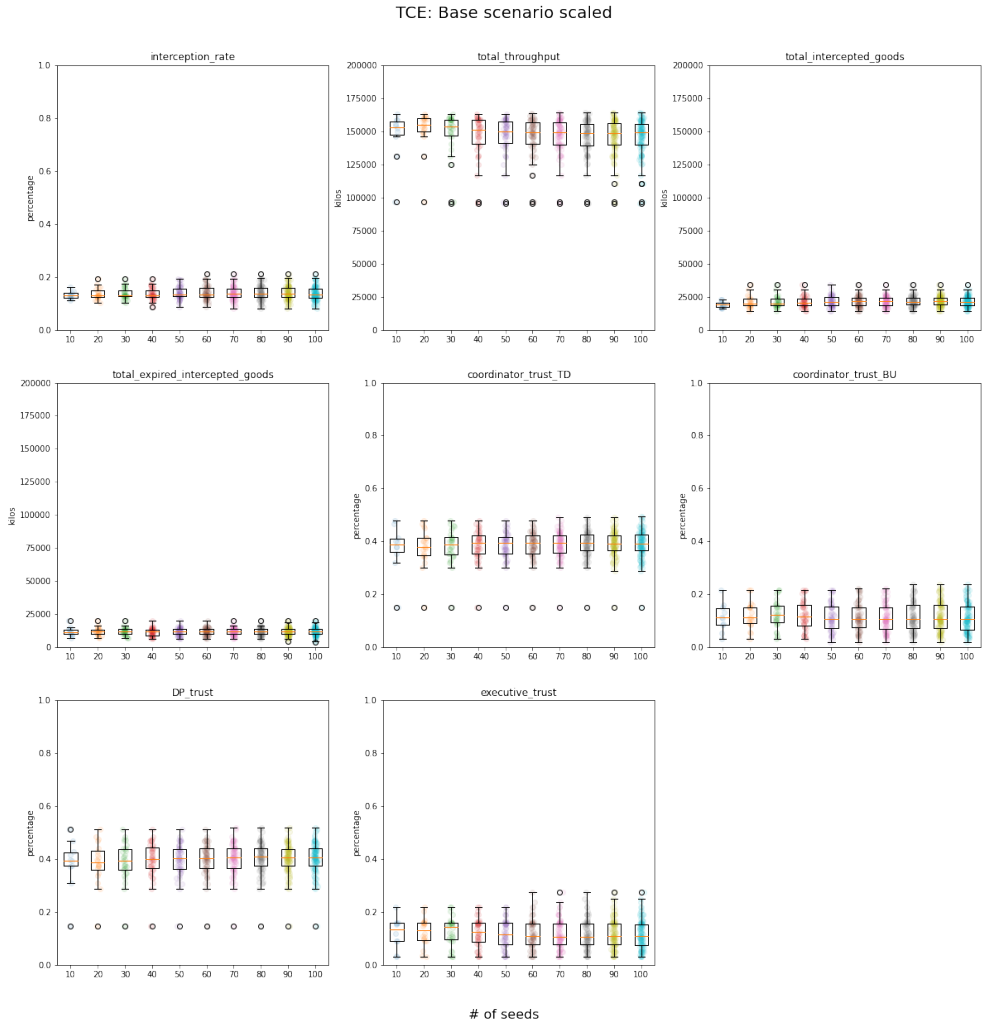

Figure A.3: *Scaled base scenario boxplot for transaction-cost economics for different number of seeds.*

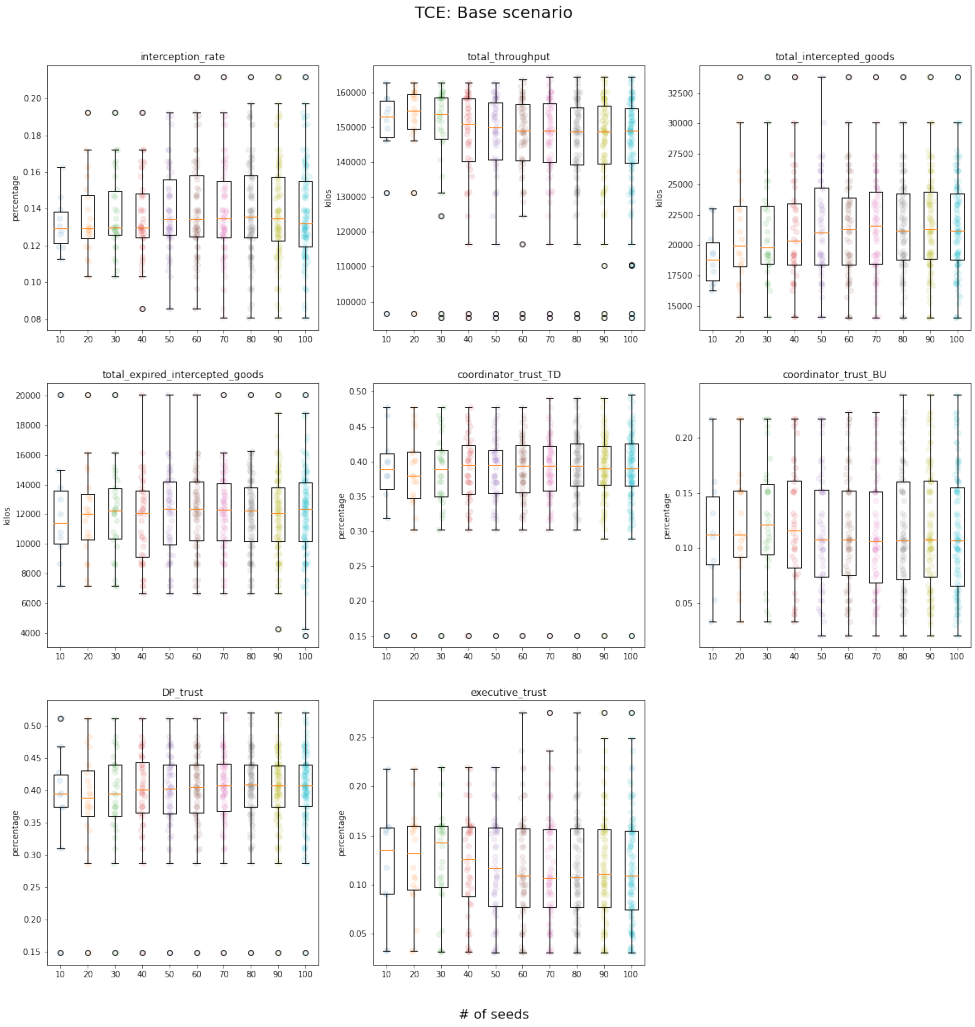

Figure A.4: *Base scenario boxplot for transaction-cost economics for different number of seeds.*

B

Results

This appendix provides additional figures that are referred to in the results section accompanied by explanation. Not all data that has been gathered during model runs has been visualized due to a lack of relevance. However, all data is available on the GitHub of this project.

B.1. Base scenarios

B.1.1. Risk vs. gain trade-off

Table B.1: *The means and standard deviations of 70 replications of each scenario accompanied by p-values of t-tests. The base scenario is the reference case. Italic p-values are significant for a 99% confidence interval.*

	Base		**High**		**Low**		**T-test**	
KPI	**Mean**	**Std**	**Mean**	**Std**	**Mean**	**Std**	$p_{Base,High}$	$p_{Base,Low}$
Interception rate	0.1416	0.0250	0.1363	0.0239	0.1404	0.0255	2.020e-01	7.647e-01
Total throughput	148705	11769	149406	11188	148803	11679	7.205e-01	9.610e-01
Total intercepted goods	22422	3596	21503	3841	21823	3446	1.495e-01	3.201e-01
Total expired intercepted goods	12494	2968	12640	3367	12575	2938	7.865e-01	8.725e-01
Coordinator trust top-down	0.3846	0.0506	0.5232	0.0598	0.2907	0.0453	*4.775e-30*	*7.795e-22*
Coordinator trust bottom-up	0.1046	0.0468	0.1722	0.0722	0.0713	0.0374	*1.161e-09*	*8.973e-06*
Dutch principal trust	0.4016	0.0554	0.5289	0.0636	0.3102	0.0520	*1.557e-24*	*5.072e-18*
Executive trust	0.1095	0.0498	0.1714	0.0717	0.0774	0.0384	*2.807e-08*	*4.224e-05*

Table B.2: *The means and standard deviations of 70 replications of the high and low trust scenarios accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		**Low**		**T-test**
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Low}$
Interception rate	0.1363	0.0239	0.1404	0.0255	3.3729e-01
Total throughput	149406	11188	148803	11679	7.5720e-01
Total intercepted goods	21503	3841	21823	3446	6.0748e-01
Total expired intercepted goods	12640	3367	12575	2938	9.0284e-01
Coordinator trust top-down	0.5232	0.0598	0.2907	0.0453	*1.4672e-54*
Coordinator trust bottom-up	0.1722	0.0722	0.0713	0.0374	*7.9748e-19*
Dutch principal trust	0.5289	0.0636	0.3102	0.0520	*3.6250e-47*
Executive trust	0.1714	0.0717	0.0774	0.0384	*5.1766e-17*

Table B.3: *The means and standard deviations of 70 replications for the high trust scenario with and without affect. Also the p-values of t-tests are included.*

	High		Affect		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{H,Affect}$
Interception rate	0.1363	0.0239	0.1363	0.0239	1.0
Total throughput	149406	11188	149406	11188	1.0
Total intercepted goods	21504	3841	21504	3841	1.0
Total expired intercepted goods	12640	3367	12640	3367	1.0
Coordinator trust top-down	0.5232	0.0598	0.5232	0.0598	1.0
Coordinator trust bottom-up	0.1722	0.0722	0.1722	0.0722	1.0
Dutch principal trust	0.5289	0.0636	0.5289	0.0636	1.0
Executive trust	0.1714	0.0717	0.1714	0.0717	1.0

B.1.2. TCE

Table B.4: *The means and standard deviations of 70 replications of each scenario accompanied by p-values of t-tests. The base scenario is the reference case. Italic p-values are significant for a 99% confidence interval.*

	Base		High		Low		T-test	
KPI	**Mean**	**Std**	**Mean**	**Std**	**Mean**	**Std**	$p_{Base,High}$	$p_{Base,Low}$
Interception rate	0.1416	0.0250	0.1363	0.0239	0.1404	0.0255	2.020e-01	7.647e-01
Total throughput	148705	11769	149406	11188	148803	11679	7.205e-01	9.610e-01
Total intercepted goods	22422	3596	21503	3841	21823	3446	1.495e-01	3.201e-01
Total expired intercepted goods	12494	2968	12640	3367	12575	2938	7.865e-01	8.725e-01
Coordinator trust top-down	0.3846	0.0506	0.5232	0.0598	0.2907	0.0453	*4.775e-30*	*7.795e-22*
Coordinator trust bottom-up	0.1046	0.0468	0.1722	0.0722	0.0713	0.0374	*1.161e-09*	*8.973e-06*
Dutch principal trust	0.4016	0.0554	0.5289	0.0636	0.3102	0.0520	*1.557e-24*	*5.072e-18*
Executive trust	0.1095	0.0498	0.1714	0.0717	0.0774	0.0384	*2.807e-08*	*4.224e-05*

Table B.5: *The means and standard deviations of 70 replications of the high and low trust scenarios accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		Low		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Low}$
Interception rate	0.1363	0.0239	0.1404	0.0255	3.3729e-01
Total throughput	149406	11188	148803	11679	7.5720e-01
Total intercepted goods	21503	3841	21823	3446	6.0748e-01
Total expired intercepted goods	12640	3367	12575	2938	9.0284e-01
Coordinator trust top-down	0.5232	0.0598	0.2907	0.0453	*1.4672e-54*
Coordinator trust bottom-up	0.1722	0.0722	0.0713	0.0374	*7.9748e-19*
Dutch principal trust	0.5289	0.0636	0.3102	0.0520	*3.6250e-47*
Executive trust	0.1714	0.0717	0.0774	0.0384	*5.1766e-17*

Table B.6: *The means and standard deviations of 70 replications for the high trust scenario with and without affect. Also the p-values of t-tests are included.*

	High		Affect		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{H,Affect}$
Interception rate	0.1363	0.0239	0.1363	0.0239	1.0
Total throughput	149406	11188	149406	11188	1.0
Total intercepted goods	21504	3841	21504	3841	1.0
Total expired intercepted goods	12640	3367	12640	3367	1.0
Coordinator trust top-down	0.5232	0.0598	0.5232	0.0598	1.0
Coordinator trust bottom-up	0.1722	0.0722	0.1722	0.0722	1.0
Dutch principal trust	0.5289	0.0636	0.5289	0.0636	1.0
Executive trust	0.1714	0.0717	0.1714	0.0717	1.0

B.1.3. Decision-making model comparison

Table B.7: *The means and standard deviations of 70 replications for the high trust scenario for the risk vs. gain trade-off and TCE. Also the p-values of t-tests are included.*

	RvG		TCE		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{RvG,TCE}$
Interception rate	0.1363	0.0239	0.1363	0.0239	1.0
Total throughput	149406	11188	149406	11188	1.0
Total intercepted goods	21504	3841	21504	3841	1.0
Total expired intercepted goods	12640	3367	12640	3367	1.0
Coordinator trust top-down	0.5232	0.0598	0.5232	0.0598	1.0
Coordinator trust bottom-up	0.1722	0.0722	0.1722	0.0722	1.0
Dutch principal trust	0.5289	0.0636	0.5289	0.0636	1.0
Executive trust	0.1714	0.0717	0.1714	0.0717	1.0

B.2. Interventions

B.2.1. Creating distrust

Table B.8: *The means and standard deviations of 70 replications of high trust scenarios with(out) creating distrust for the risk vs. gain trade-off, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		Distrust		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Distrust}$
Interception rate	0.1363	0.0239	0.1423	0.0227	0.1341
Total throughput	149406	11188	149885	11990	0.8088
Total intercepted goods	21503	3841	20962	3396	0.3818
Total expired intercepted goods	12640	3367	12740	3465	0.8643
Coordinator trust top-down	0.5232	0.0598	0.5153	0.0602	0.4419
Coordinator trust bottom-up	0.1722	0.0722	0.1720	0.0725	0.9888
Dutch principal trust	0.5289	0.0636	0.5222	0.0645	0.5428
Executive trust	0.1714	0.0717	0.1710	0.0723	0.9753

Table B.9: *The means and standard deviations of 70 replications of high trust scenarios with(out) creating distrust for TCE, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		Distrust		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Distrust}$
Interception rate	0.1363	0.0239	0.1423	0.0227	0.1341
Total throughput	149406	11188	149885	11990	0.8088
Total intercepted goods	21503	3841	20962	3396	0.3818
Total expired intercepted goods	12640	3367	12740	3465	0.8643
Coordinator trust top-down	0.5232	0.0598	0.5153	0.0602	0.4419
Coordinator trust bottom-up	0.1722	0.0722	0.1720	0.0725	0.9888
Dutch principal trust	0.5289	0.0636	0.5222	0.0645	0.5428
Executive trust	0.1714	0.0717	0.1710	0.0723	0.9753

Table B.10: *The means and standard deviations of 70 replications of high trust scenarios with creating distrust for both decision-making models, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	RvG		Distrust		TCE
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{RvG,TCE}$
Interception rate	0.1423	0.0227	0.1423	0.0227	1.0
Total throughput	149885	11990	149885	11990	1.0
Total intercepted goods	20962	3396	20962	3396	1.0
Total expired intercepted goods	12740	3465	12740	3465	1.0
Coordinator trust top-down	0.5153	0.0602	0.5153	0.0602	1.0
Coordinator trust bottom-up	0.1720	0.0725	0.1720	0.0725	1.0
Dutch principal trust	0.5222	0.0645	0.5222	0.0645	1.0
Executive trust	0.1710	0.0723	0.1710	0.0723	1.0

B.2.2. Preventing MO switches

Table B.11: *The means and standard deviations of 70 replications of high trust scenarios with(out) preventing MO switches for the risk vs. gain trade-off, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		Prevent		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Prevent}$
Interception rate	0.1363	0.0239	0.1144	0.0203	*4.5058e-08*
Total throughput	149406	11188	149099	12664	8.8010e-01
Total intercepted goods	21503	3841	19958	3560	1.5433e-02
Total expired intercepted goods	12640	3367	13999	2780	1.0772e-02
Coordinator trust top-down	0.5232	0.0598	0.4921	0.0605	*2.8394e-03*
Coordinator trust bottom-up	0.1722	0.0722	0.0646	0.0106	*8.3607e-24*
Dutch principal trust	0.5289	0.0636	0.5138	0.0658	1.7322e-01
Executive trust	0.1714	0.0717	0.1710	0.0095	*6.4522e-23*

Table B.12: *The means and standard deviations of 70 replications of high trust scenarios with(out) preventing MO switches for TCE, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		Prevent		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Prevent}$
Interception rate	0.1363	0.0239	0.1144	0.0203	*4.5058e-08*
Total throughput	149406	11188	149099	12664	8.8010e-01
Total intercepted goods	21503	3841	19958	3560	1.5433e-02
Total expired intercepted goods	12640	3367	13999	2780	1.0772e-02
Coordinator trust top-down	0.5232	0.0598	0.4921	0.0605	*2.8394e-03*
Coordinator trust bottom-up	0.1722	0.0722	0.0646	0.0106	*8.3607e-24*
Dutch principal trust	0.5289	0.0636	0.5138	0.0658	1.7322e-01
Executive trust	0.1714	0.0717	0.1710	0.0095	*6.4522e-23*

Table B.13: *The means and standard deviations of 70 replications of high trust scenarios with preventing MO switches for both decision-making models, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		Prevent		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Prevent}$
Interception rate	0.1363	0.0239	0.1144	0.0203	1.0
Total throughput	149406	11188	149099	12664	1.0
Total intercepted goods	21503	3841	19958	3560	1.0
Total expired intercepted goods	12640	3367	13999	2780	1.0
Coordinator trust top-down	0.5232	0.0598	0.4921	0.0605	1.0
Coordinator trust bottom-up	0.1722	0.0722	0.0646	0.0106	1.0
Dutch principal trust	0.5289	0.0636	0.5138	0.0658	1.0
Executive trust	0.1714	0.0717	0.1710	0.0095	1.0

B.2.3. Reducing interval of announced customs checks

Table B.14: *The means and standard deviations of 70 replications of high trust scenarios with(out) reducing interval for the risk vs. gain trade-off, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		Reduce		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Reduce}$
Interception rate	0.1363	0.0239	0.1257	0.0231	*9.1410e-03*
Total throughput	149406	11188	148733	12108	7.3485e-01
Total intercepted goods	21503	3841	21889	3523	5.4059e-01
Total expired intercepted goods	12640	3367	8330	2167	*2.2547e-15*
Coordinator trust top-down	0.5232	0.0598	0.4961	0.0546	*6.0415-03*
Coordinator trust bottom-up	0.1722	0.0722	0.2111	0.0634	*9.9850e-04*
Dutch principal trust	0.5289	0.0636	0.5012	0.0601	*9.6267e-03*
Executive trust	0.1714	0.0717	0.2061	0.0632	*3.0470e-03*

Table B.15: *The means and standard deviations of 70 replications of high trust scenarios with(out) reducing interval for TCE, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	High		Reduce		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{High,Reduce}$
Interception rate	0.1363	0.0239	0.1257	0.0231	*9.1410e-03*
Total throughput	149406	11188	148733	12108	7.3485e-01
Total intercepted goods	21503	3841	21889	3523	5.4059e-01
Total expired intercepted goods	12640	3367	8330	2167	*2.2547e-15*
Coordinator trust top-down	0.5232	0.0598	0.4961	0.0546	*6.0415-03*
Coordinator trust bottom-up	0.1722	0.0722	0.2111	0.0634	*9.9850e-04*
Dutch principal trust	0.5289	0.0636	0.5012	0.0601	*9.6267e-03*
Executive trust	0.1714	0.0717	0.2061	0.0632	*3.0470e-03*

Table B.16: *The means and standard deviations of 70 replications of high trust scenarios with(out) reducing interval for both decision-making models, accompanied by p-values of t-tests. Italic p-values are significant for a 99% confidence interval.*

	RvG		TCE		T-test
KPI	**Mean**	**Std**	**Mean**	**Std**	$p_{RvG,TCE}$
Interception rate	0.1257	0.0231	0.1257	0.0231	1.0
Total throughput	148733	12108	148733	12108	1.0
Total intercepted goods	21889	3523	21889	3523	1.0
Total expired intercepted goods	8330	2167	8330	2167	1.0
Coordinator trust top-down	0.4961	0.0546	0.4961	0.0546	1.0
Coordinator trust bottom-up	0.2111	0.0634	0.2111	0.0634	1.0
Dutch principal trust	0.5012	0.0601	0.5012	0.0601	1.0
Executive trust	0.2061	0.0632	0.2061	0.0632	1.0