



# Information-sharing in humanitarian operations in complex disasters

Using Agent-Based modelling to identify policies for improved performance

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*This thesis is dedicated to my mother,  
without whom I would have never gotten to the point where I am now*



# Information-sharing in humanitarian operations in complex disasters

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# I. PREFACE

Welcome to my thesis. What is lying in front of you is the conclusion of eight months of research, a little over two year of the Master of Science in Engineering and Policy Analysis and seven years of Delft University of technology. This preface gives me the opportunity to thank a number of people:

First of all I would like to thank Tina. Starting with Skype meetings while I was still on exchange in the USA, Tina managed to guide me through the dive in the deep which is took with this thesis, but also with the iTrack project we worked on together. A special thanks for the sharp eye for a scientific contribution, which I sometimes lost out of sight.

Secondly, I want to thank Martijn. Rumors among students are that Martijn is one of the best supervisors at TPM and I am indeed not disappointed. Martijn's door was always open for a brainstorm session on whichever topic. A special thanks for Martijn for the ability to look at my thesis from a student perspective, which was very valuable to me.

As a final member of the committee I would like to thank Bartel. Bartel has always kept an eye out for the practical usability of the thesis. Along with Martijn and Tina, it made a very balanced and pleasant committee to work with.

Also I want to thank Nico. Not only for the great feedback she gave throughout the thesis, but also for the much-needed mental support.

Last but definitely not least, I want to thank my family. Not only for the last period of studies, but also for the earlier years in Delft. Without the guidance and support of my parents and Vera, I probably would not have even started in Delft.

Enjoy reading this thesis!

## *Intermezzo*

Throughout the thesis, a timeline of Syria's modern history is made by means of eight defining pictures. Every chapter starts with a picture, which describes a period of time in Syria's history.

The moments that are chosen are not directly related to the stylized case study which is used in this thesis. It shows the historical run-up towards modern-day Syria.



## II. EXECUTIVE SUMMARY

This research has aimed at identifying critical factors in decision-making for humanitarian operation in slow-onset man-made conflict situations. This has been done by developing an Agent-Based model on the basis of the humanitarian program cycle. Working with the model, four policies and four scenarios have been developed. Analyzing the model behavior of those policies and scenarios a number of key factors for decision making are derived.

The research has been based on the following sub questions and main question:

**Which policies are able to improve the performance of a humanitarian operation in a complex disaster through information sharing?**

1. How is information sharing in a humanitarian operation in a complex disaster organized; what are the characteristics of IM policies, and what are criteria to evaluate the impact of information sharing?
2. How can information sharing of a humanitarian operation be simulated in an Agent-Based model?
3. What are potential alternative policies and scenarios?
4. What is the impact of policies on the performance of a humanitarian operation for the identified scenarios?

### *Methodology*

The approach that has been chosen is Agent-Based modelling, with an exploratory character. This approach has been chosen because Agent-Based modelling is suitable to capture bottom-up behavior. Emergent patterns can arise from predefined algorithms per agent in the model. This is a suitable approach as information sharing in complex disaster is largely defined by trust and social connections and therefore hard to capture in macro models.

The exploratory nature of the methodology derives from the different policies and scenarios that are projected on the model. The policies represent different accents that policy makers can exercise in their policy. The scenarios are chosen based on a stylized case-study of the Syrian civil war and represent various phases and instances of the war.

### *Model development*

Based on seven core processes and eight initialization steps the model is implemented. The model logic is inspired by the program cycle by UNOCHA (figure 1.1). A needs assessment is done by NGOs (needs assessment), after which other NGOs move to the camp where most aid is needed (strategic planning). Based on experience and size, a certain number of days is needed to move to the camp (resource mobilization). The NGO stays and provides aid until a certain threshold is met (implementation & monitoring). Its achievements with respect to safety and security and effectiveness of aid are monitored and used for evaluation of the budget. If it is positive, more money will be received, if negative, less money will be received (operational peer review & evaluation). After that, the cycle starts again. Internally in the model, the information management cycle by UNOCHA is implemented. This provided guidance for how NGO-agents deal with information. This is elaborated on in chapter 3.

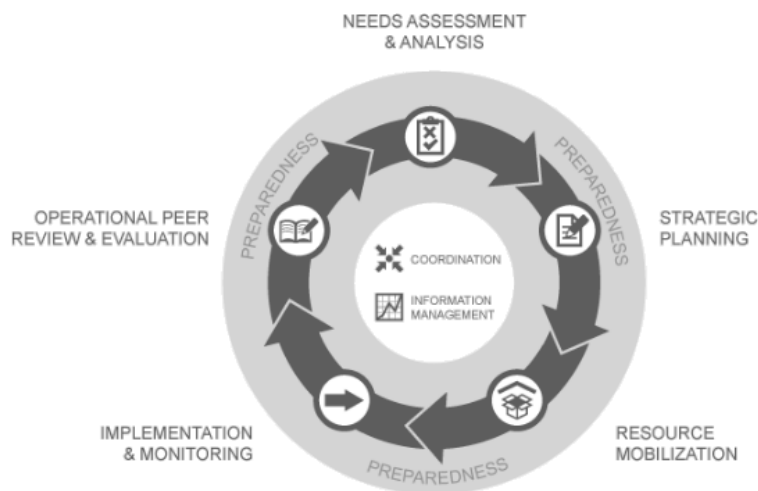


Figure 1.1 Humanitarian program cycle (UNOCHA, 2017)

Complete validation of the model is out of scope for this thesis. This is because there is a limited amount of empirical data available and because the thesis is of a high abstraction level. Based on limited face validation, literature validation and historical validation there can however be concluded that the model is usable for analyses. This does imply that numerical outcomes are to be reasoned well before deriving conclusions.

### *Policies and scenarios*

Policies with regard to information sharing in complex disaster have a qualitative nature and cannot be expressed sufficiently numerically within the given range of variables defined in this thesis. The policies are therefore defined aiming to cover the full range of policy variable values as defined for this model, while being internally coherent.

With regards to the scenarios, a stylized case-study of the Syrian civil war is used. The scenarios are based on different episodes in the Syrian civil war, but do not exactly represent one of those episodes.

The model is run with four policies and four scenarios, leading to a sum of 16 experiments.

### *Model results*

To research the influence of the policies on the scenarios, the model results have been visualized using R. The conclusion that can be drawn is that the hypothetical policies have a clear influence on the range of possible outcomes of KPIs. There is however not a single policy which scores well on all KPIs. The results differ given the scenario the humanitarian operation is set in. A number of trade-offs have been identified which can be taken into account in policy-making.

### *Conclusions*

The conclusions from this thesis can be summarized in five lessons for policy makers of a humanitarian operation:

1. *A policy needs to be tailor fit for the situation in which it operates.*
2. *A policy maker will always deal with trade-offs when making policy-decisions.*
3. *The duration of a project is a crucial factor for many KPIs.*
4. *The more spread-out POCs are, the shorter the reporting cycle has to be.*
5. *Risk approach needs to be tailored to the situation.*

# III. TABLE OF CONTENTS

I.	Preface .....	8
II.	Executive Summary .....	9
III.	Table of contents .....	11
IV.	List of figures .....	14
V.	List of tables .....	16
VI.	List of equations .....	17
1.	Introduction.....	20
1.1	Scope of research .....	21
1.2	Information and its role in a humanitarian operation.....	21
1.3	Current use of information in complex disasters .....	22
1.4	Research questions .....	27
1.5	Research approach .....	28
1.6	Research methodology .....	28
1.7	Research flow.....	31
1.8	Terminology .....	32
2.	Conceptualization .....	34
2.1	Understanding a humanitarian operation .....	34
2.1.1	Who are the players that are involved in a humanitarian operation and how are they organized?.....	35
2.1.2	What is information and why is it so important? .....	39
2.1.3	What are indicators of performance of a humanitarian operation?.....	41
2.2	Implications for modelling.....	42
2.2.1	Implications for actors in the model.....	42
2.2.2	Implication for information in modelling .....	43
2.2.3	Implications for modelling KPIs .....	43
2.3	System decomposition using the XLRM-framework.....	43
2.4	Preliminary conclusion .....	46

3. Model specification.....	48
3.1 Agents in the model.....	48
3.2 High level model narrative (sequence diagram).....	50
3.3 Detailed model narrative .....	52
3.3.1 Initialization .....	53
3.3.2 Processes .....	58
3.3.3 List of assumptions.....	67
3.4 Verification.....	69
3.5 Validation .....	69
3.5.1 Face validation through expert consultation.....	69
3.5.2 Literature validation.....	69
3.5.3 Validation conclusion .....	70
3.6 Preliminary conclusion .....	70
4. Experiment design.....	72
4.1 Scenario variables .....	73
4.2 Scenarios.....	74
4.2.1 Scenario 1: ISIS/ISIL/Daesh taking over.....	74
4.2.2 Scenario 2: Advanced in conflict of ISIS/ISIL/Daesh taking over.....	74
4.2.3 Scenario 3: Aleppo.....	74
4.2.4 Scenario 4: North of Damascus.....	75
4.3 Policy variables .....	75
4.4 Policies .....	77
4.4.1 Policy 1: Low trust, high control .....	77
4.4.2 Policy 2: High trust, low control.....	78
4.4.3 Policy 3: Organic development.....	78
4.4.4 Policy 4: Combination.....	79
4.5 Overview of experiments to run.....	79
4.6 Preliminary conclusions.....	80
5. Analysis of results .....	82
5.1 High aggregation results of policies per scenario .....	82
5.1.1 Steps towards high aggregation result table .....	82
5.1.2 Lessons from high aggregation result table.....	84
5.2 Analysis per KPI of first scenario.....	85
5.2.1 Total funding available for NGO-agents .....	85
5.2.2 Total percentage of POC-agents helped .....	87
5.2.3 Percentage of funding converted.....	89

5.2.4	Total time to move to camp.....	91
5.2.5	Total incidents .....	93
5.2.6	Fake news reactions.....	95
5.2.7	Percentage of reported incidents .....	97
5.2.8	Preliminary conclusion.....	99
5.3	Functionality of policies in different scenarios.....	99
5.3.1	Differences in maximum funding.....	100
5.3.2	Different processing times.....	101
5.3.3	Third policy changing from good to bad for incidents .....	101
5.3.4	Different fake news levels.....	102
5.4	Preliminary conclusion .....	102
6.	Evaluation & Limitations .....	104
6.1	Conceptualization.....	104
6.2	Model data.....	105
6.3	Model verification .....	105
6.4	Model validation.....	105
6.5	Model output .....	106
6.6	Scenario and policy choice.....	106
6.7	Scientific contribution .....	106
6.8	Societal contribution.....	107
7.	Conclusions .....	110
7.1	Sub question 1: Information structure, policies and barriers.....	112
7.2	Sub question 2: Simulation in an Agent-Based Model.....	113
7.3	Sub question 3: Policies and criteria to evaluate those policies .....	113
7.4	Sub question 4: Impact of IM policy on safety and coordination.....	114
7.5	Main question: How can this research contribute? .....	116
8.	Reflection and recommendation for further research.....	118
8.1	Reflection on Agent-Based modelling methodology .....	118
8.2	Reflection on the usability for practice .....	119
8.3	Recommendation for further research.....	119
VII.	References.....	121
VIII.	Appendix A .....	127
IX.	Appendix B.....	132
X.	Appendix C.....	140
XI.	Appendix D.....	141
XII.	Appendix E .....	158

# IV. LIST OF FIGURES

Figure 1.1 Humanitarian program cycle .....	10
Figure 1.1 Categorization of disasters .....	21
Figure 1.2 Humanitarian program cycle .....	22
Figure 1.3: Information Management Cycle .....	23
Figure 1.4 Research flow diagram .....	31
Figure 1.5 Beneficiaries terminology.....	32
Figure 2.1 Simplified actor depiction.....	35
Figure 2.2 Cluster approach visualization (UN, 2005a).....	35
Figure 2.3 HCT Coordination and Interface with Government.....	36
Figure 2.4 IASC Humanitarian Coordination Architecture.....	37
Figure 3.1 Sequence diagram.....	51
Figure 3.2 Definition of trust .....	54
Figure 3.3 Beta distribution risk avoiding .....	55
Figure 3.4 Beta distribution risk taking.....	55
Figure 3.5 Build-up of employee turnover rate .....	56
Figure 3.6 Decision tree reporting status .....	59
Figure 3.7 Decision POC movement.....	60
Figure 3.8 Movement decision NGO-agent .....	61
Figure 3.9 Camp assessment NGO.....	62
Figure 3.10 Variables influencing aid distribution.....	63
Figure 3.11 Decision region type.....	64
Figure 3.12 Trust build-up and incidents .....	65
Figure 3.13 Graphical depiction of chance distribution of NGO incidents .....	65
Figure 3.14 Average daily incidents single model run .....	66
Figure 3.15 Reported percentage of incidents single model run.....	66
Figure 3.16 Monthly NGO incidents start 2018 .....	66
Figure 4.1 (Who does What, Where, and When), 2015) .....	76
Figure 5.1 Funding available to NGOs, single run .....	86
Figure 5.2 Funding available to NGOs, all runs,.....	86

Figure 5.3 Smoothed percentage covered POC-agents. Single run.....	88
Figure 5.4 Smoothed percentage covered POC-agents. All runs. ....	88
Figure 5.5 Density plot covered POC-agents. All runs.....	88
Figure 5.6 Smoothed graph percentage funding converted pver time. Single run.....	90
Figure 5.7 Smoothed graph percentage funding converted pver time. All runs.....	90
Figure 5.8 Total time to move to camp of all NGO-agents over time. Single run. ....	92
Figure 5.9 Total time to move to camp of all NGO-agents over time. All runs.....	92
Figure 5.10 Total incidents over time. Single run. ....	94
Figure 5.11 Total incidents over time. All runs. ....	94
Figure 5.12 Total fake news reactions over time. Single run.....	96
Figure 5.13 Total fake news reactions over time. All runs.....	96
Figure 5.14 Smoothed percentage incidents reported. Single run. ....	98
Figure 5.15 Smoothed percentage incidents reported. All runs.....	98
Figure 5.16 Density plot percentage reported incidents. All runs. ....	98
Figure 7.1 Thesis structure .....	111
Figure 7.2 Humanitarian program cycle .....	113

# V. LIST OF TABLES

Table 1.1: Decision-Makers' Information Needs .....	23
Table 2.1 Factors influence information sharing in a natural disaster .....	41
Table 2.2 XLRM -Framework.....	45
Table 3.1 UML depiction of POC attributes .....	49
Table 3.2 UML depiction of NGO-agent attributes.....	50
Table 3.3 Initialization steps.....	52
Table 3.4 Model processes.....	53
Table 3.5 Basic parameterization POC.....	55
Table 3.6 Delay days of turnover rate.....	57
Table 3.7 Basic parametrization NGO-agent .....	57
Table 3.8 Percentages aid distribution .....	63
Table 3.9 Assumptions overview.....	68
Table 4.1 Scenario variables .....	73
Table 4.2 Scenario variables scenario 1.....	74
Table 4.3 Scenario variables scenario 2.....	74
Table 4.4 Scenario variables scenario 3.....	75
Table 4.5 Scenario variables scenario 4.....	75
Table 4.6 Policy variables.....	76
Table 4.7 Policy 1 overview.....	78
Table 4.8 Policy 2 overview.....	78
Table 4.9 Policy 3 overview.....	79
Table 4.10 Policy 4 overview.....	79
Table 4.11 Overview experiment combinations.....	79
Table 5.1 Overall performance of policies.....	84
Table 5.2 Legend for overall performance table .....	84
Table 5.3 Surfaces under the graphs .....	86
Table 5.4 Surfaces under lines of time to move to camp.....	92
Table 5.5 Surfaces under lines of total incidents .....	94
Table 5.6 Surfaces under lines of fake news reactions .....	96
Table 5.7 Results overview table scenario 1.....	99
Table 5.8 Legend overview table .....	99



Table 5.9 Results overview table scenario 2.....	99
Table 5.10 Results overview table scenario 3.....	100
Table 5.11 Results overview table scenario 4.....	100

## VI. LIST OF EQUATIONS

Equation 3.1 Specification needs of POCs.....	54
Equation 3.2 Specification initial funding.....	56
Equation 3.3 Specify aid needs .....	58
Equation 3.4 Daily money availability.....	64
Equation 8.1 Needs of POCs.....	134
Equation 8.2 Exemplary needs equation.....	135
Equation 8.3 Funding of NGO example .....	136





- 1920

Syria as a country did not yet exist. The land that is currently known as Syria was part of the Ottoman empire. The picture shows Palais Azim and was home of Ottoman gouvernor Assad Pacha al-Azim.

# 1.

## Introduction

Disasters have always been a crucial part of world history and as of today that has not changed. Disasters of all kinds take place and are followed by responses in all sorts and forms. The organizations helping after a disaster have also turned into a billion-dollar industry containing many of the aspects every other industry has. Think about competition, increasing efficiency, staffing problems and incidents affecting every day work.

Can we then state that the humanitarian sector functions as every other sector does? No; humanitarian aid has always had a status quo as their mandate is helping people and money is not made, but only funded through charity and public instances. These characteristics make it a very interesting field, but at the same time hard to fathom.

This thesis will contribute to achieving a greater understanding of the functioning of the humanitarian sector by researching a specific aspect of the sector: information. Information is a vital part of a humanitarian operation, as it tells aid workers where to go, what to bring and whether it is safe or not. Information is however not as freely available as one would desire. But what is the effect of the unavailability of information to a humanitarian operation? And what should be changed to increase information sharing? These are questions that this thesis will answer through an Agent-Based model of a stylized case study of Syria.

This introduction firstly shows in which specific field of research this thesis can be positioned. Secondly it presents an overview of literature relevant to the subject of information in a humanitarian operation. It concludes with a knowledge gap and the research questions derived from the knowledge gap.

### *Quick read guide:*

- Read chapter 1 Introduction
- Skip chapter 2 Conceptualization, but read 2.2
- Skip chapter 3 Model Specification, but read 3.1 and 3.6
- Read 4.1 and 4.3 Scenario and policy design
- Skip chapter 5 Analysis
- Read chapter 6.7 and 6.8
- Read chapter 7 Conclusions
- Read chapter 8.3 Recommendation



## 1.1 Scope of research

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This thesis focuses on a specific type of disaster. Disasters come in different sizes and shapes, and the most common definition of disaster categories is given by van Wassenhove (2006). He describes four different categories of disaster as follows:

	Natural	Man-made
Sudden-onset	Earthquake Hurricane Tornadoes	Terrorist Attack Coup d'Etat Chemical leak
Slow-onset	Famine Drought Poverty	Political Crisis Refugee Crisis




Figure 1.1 Categorization of disasters

The category that this thesis is focusing on is the slow-onset man-made disasters, because this category of disaster is associated with the most complexity: “*More than anywhere else, information is power*” (Van De Walle & Comes, 2015). This implies that particular interests of different groups spark strategic behavior and therefore a more complex information practice.

Now that it has been concluded that information is so important in this context, it is time to look at what ‘information’ entails precisely. Starting with *information technology*: Information technology (IT) is the use of any computers, storage, networking and other physical devices, infrastructure and processes to create, process, store, secure and exchange all forms of electronic data (Rouse & Bigelow, 2015). The use of the terms ICT (Information & Communication Technology) and IT (Information Technology) differ between users in a US environment and a European environment, but the meaning nonetheless stays the same. *Information management* (IM) is the overarching term referring to the collection of information systems and information technology. The term that is used for the description of technology in a human system is the *work system*. This is described as “*human participants and/or machines use information technologies, and other resources to perform processes for producing products and/or services for internal or external customers*” (Alter, 2002). When information is a product in the human system, there is referred to an *information system* (Van De Walle, Eede, & Muhren, 2009). This thesis focuses on *information systems*, as it aims to scrutinize information as a commodity in a man-made slow-onset crisis.

## 1.2 Information and its role in a humanitarian operation

---

This section aims to define what information systems are used for: coordination of a humanitarian operation. Coordination of a humanitarian operation is to get the right goods and services on the right place on the right time. Coordination of information flows is a sub-category of this and makes sure that the right information is available to the right people at the right time. In the current setup at complex disasters there is an inter-organizational agency from the UN, which aims to “*bring together humanitarian actors to ensure a coherent response to emergencies*” (OCHA, 2014) called the “United Nations Office for the Coordination of Humanitarian Affairs”. A granulation has been implemented with the humanitarian reform

agenda in 2015, where the cluster-approach has been introduced. This provided a framework for information sharing among different groups of humanitarian organizations active in the same discipline (Comes, Meesters, & Torjesen, 2017a).

Summarizing, we can conclude that information is a vital aspect of a humanitarian operation, but what does information exactly entail? Based on personal interviews with humanitarian information specialists, a decision is made to define two categories of information: *Operational & Planning information* and *Safety & security information*. Operational & Planning information is information which is used to plan the humanitarian mission and to define tasks of different NGOs. It is information of the needs and activities of POCs and it entails the “where and what” of NGOs. Safety & security information is information regarding the safety of the personnel. This information contains details on incidents and areas of possible future incidents. It is important to make a distinction as such, because different standards regarding transparency are used. This is elaborated on further in chapter 2.1.2.

### 1.3 Current use of information in complex disasters

The exact elaboration of information will be given through UNOCHA’s information management cycle (IM cycle), but first it is important to see information management in the larger perspective. The Humanitarian Program Cycle provides a good overview of the general actions that need to be undertaken in a humanitarian operation:

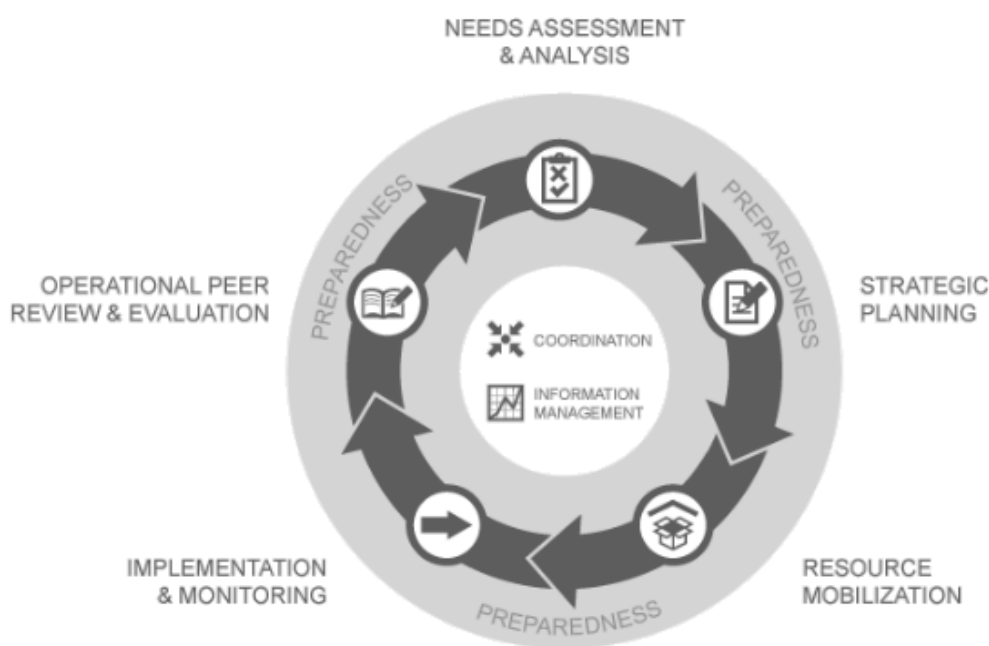


Figure 1.2 Humanitarian program cycle (UNOCHA, 2017)

This cycle contains the main building blocks of a humanitarian operation, but what deserves specific attention in the context of this thesis is the middle part: information management. This research aims at improving the entire cycle through information management. Information management itself also has a cycle. The general IM process adopted by

UNOCHA<sup>1</sup> consists of four elements: (1) planning, (2) collection, (3) processing & analyzing, (4) dissemination & feedback (see figure 2.6). In the following chapters there will be an analysis of the information management practices by UNOCHA that is currently in place.



Figure 1.3: Information Management Cycle (UNOCHA, n.d.)

### Plan

When planning information management, it is important to firstly have an overview of *what* information is needed and *by whom*. Relief efforts involve a wide range of humanitarian organizations and other actors that make decisions and need information to do so. The involved actors have been mentioned in previous sections.

In addition to the question of who is making the decisions, data preparedness and planning also include planning what data will be needed, in what context and how the data should be collected, analyzed, stored and shared (Raymond and Al Achkar 2016). Some generic guidelines and questions have been developed as a part of the working group on decision-makers' information needs (Gralla, Goentzel, & Van De Walle, 2013). This grid has, for instance been used to analyze information needs in the response to Haiyan (Comes, Vybornova, & Van de Walle, 2015), see table 1.1 below. The highlighted rows are information needs that are being addressed through this research.

Table 1.1: Decision-Makers' Information Needs – Taxonomy of Questions from Comes et al., 2015

<b>Emergency Situation</b>	What is the impact and scope of the disaster
	Is assistance needed? Has the government appealed for international assistance?
	What geographical areas are affected?
	What has been damaged: infrastructure? Housing? Existing humanitarian efforts? Resilience?
	What was the baseline situation (before the response), and what has changed (worsened) and where?
<b>Affected Population</b>	How many people have been affected, and how?
	Where (geographically) are the affected people?
	What is the status of the affected people? Are they displaced, vulnerable, etc.?

<sup>1</sup> See <https://www.humanitarianresponse.info/en/applications/tools/toolbox-item/policy-and-guidance> for an overview of available guidance documents

	What are the characteristics of the affected: ethnicity, socio/economic, gender, etc.?
<b>Information Availability</b>	What information is available, both baseline (pre-emergency) data and updates on the current situation?
	What are the existing sources of information?
	How accurate is the information?
<b>Context</b>	What is the local socio-political context: political situation, cultural norms, etc.?
	What is the expected response of the government? Are there restrictions or sensitivities?
	What natural resources are available? What are the harvest/crop cycles? Seasonal changes?
	What is the skillset of the community, and its cohesion?
	What were the previous responses to disasters, coping mechanisms?
<b>Publication and media</b>	What are the public perception, awareness, and attention?
	What are the media and donor perceptions?
<b>Perception</b>	What is the general political will for the response, including local and international?
	How do we balance capacity against expectation? With beneficiaries, donors, media?
<b>Needs</b>	How many people are there in need?
	What are the types of needs (e.g. food, water, health, shelter, protection...)?
	What are the lifesaving needs, and other needs?
	What are the gaps in the response?
<b>Priorities</b>	Which geographic areas are the most critical?
	What are the priority sectors, such as health, shelter, ...?
<b>Information sources and gaps</b>	Does response community agree on number of people in each type of need?
	What are the sources of our information, and the extend of assessments?

Given the wide range of possible needs and the limitation of modelling, the decision has been made to use a proxy for all humanitarian needs for simplification purposes. The proxy that will be used in this modelling study will be Dollars.

The humanitarian response to the Haitian earthquake in 2010 is generally seen as a turning point in humanitarian operations (Comes et al., 2017a). The ‘digital humanitarians’ made their entrance (Crowley & Chan, 2010; Meier, 2015): through crowdsourcing almost real-time maps were made using satellite images, social media feeds and information gathered by ‘conventional’ humanitarians. This crowd-sourced information has gained more prominence ever since. These new developments need to be taken into account when planning information management. Crowd sourcing approaches have opened up a plethora of data collection techniques and new data sources (Meesters & Van de Walle, 2014). However humanitarian organizations struggle with these new types and the large volumes of data, as it is often of unclear origin and validity (Whipkey & Verity, 2015). At the same time,



often time for verification is short since the humanitarian organizations are under pressure to act. In the conflict areas, specifically the issues of rumors, propaganda and misleading information need to be addressed. In this study verification of information is taken into account. A higher priority for verification will also lead to a longer time needed to get to the location.

### *Collect*

Collection of humanitarian data is a rapidly changing field. The use of monitoring technology to track response efforts, resources and needs has received much attention for its potential to reduce cost and errors associated with repetitive tasks and real-time data analysis and sharing (Ergun, Gui, Heier Stamm, Keskinocak, & Swann, 2014).

Before diving deeper in the newest collection methods, it is worthwhile looking at the way data is stored. Since this is no explicit part of the IM cycle this will be discussed in this section. We focus here on the storage of digital data; we do not consider storage of physical documents. Storage of data most basically needs a working telecommunication infrastructure and a functioning electricity network.

Secure storage of data is an aspect of information management in the humanitarian sector which is often not adequately practiced. Sandvik (2016) states that involuntary sharing of information is an increasingly big problem. Humanitarian aid organizations are targeted for their information involuntarily by governments, armed non-state actors and hackers. To counter this, many humanitarian organizations lack robust guidelines for their own information systems, but also for their communication with technology and volunteer communities (Sandvik, 2016).

An increasingly important concern is the privacy of a POC and data protection. Given the low literacy, high poverty, high collectivism, an oral tradition of information dissemination, and the brittle infrastructure systems in developing countries (Venkatesh & Sykes, 2012), the digital divide and a neglect of unmonitored data and information increases the risk of distorted operations that focus on better developed area – just because there is more and better data that supports advocacy or accountability. The latter will be taken into account in the modelling process.

There is namely a drawback for NGOs gathering information and sharing that afterwards. NGOs are fighting each other over a place in the spotlight, which is not conducive to cooperation between NGOs, nor for information sharing to a coordinating entity (Stephenson, 2005). This is further elaborated in chapter 0. Next to that the presence of an NGO in a conflict area can be politicized. In Syria for example, there is only a very limited number of NGOs allowed by the government (Van De Walle & Comes, 2015). Since information is power, this limited group of NGOs is in a powerful position and can leverage the information and thus power they have in return for favors from other groups (Van De Walle et al., 2009).

If looked beyond political reasons not to share information, there are hurdles as well. Stephenson (2005) points out that information in conflict situation is often disputed. Because a humanitarian operation is multifaceted, complex and very fast changing, facts can change on a daily basis. Sharing information in a less dynamic way than the situation itself can cause misinformation, which is something NGOs want to avoid. This could lead to the responsibility for death or injury of a large number of people. Another complication, derived from a personal interview is that there is no clear overview of the information needs in a humanitarian operation. With that as an excuse, many organizations do not bother to share information available to them.

### *Processing & Analysis*

Analysis of data is understood as deriving information from data. Data analysis is typically preceded by a processing step, in which data is tagged, normalized and prepared for analysis. In the analysis the information is actually worked out to usable information.

In the past, it was considered as the main challenge to overcome the lack, uncertainty or vagueness of information. More information and a complete overview of the situation enable decision-makers to make better decisions. Today, however, the information landscape is more volatile and more dynamically evolving than ever before. Particularly in conflict situations, that are characterized by rapidly changing situations in combination with an on-going “information war” (Starbird, 2017), it is increasingly difficult to process and analyze data.

How to handle the emergence of an era of big and messy data that is hard to understand; classify and interpret is critical. With the increased automation of data analysis through data mining approaches and artificial intelligence it is necessary to ask how we would like the information to influence human sense making. What is required for better, objective and impartial decision support? How can such information be verified rapidly to avoid that rumors spread, or that the lives and safety of humanitarians and beneficiaries are at risk?

For more than a decade now, information has been recognized as aid (IFRC, 2005). The availability of relatively cheap technology for data collection and processing and the strong increase in computing power even on mobile devices, combined with availability of energy sources such as solar panels, have facilitated an unprecedented technology penetration even in the most remote and rural areas. Recognizing the potential of information to improve efficiency and effectiveness of humanitarian operations, humanitarian organizations have turned to new digital technologies. The design of technology, however, has value implications because new technologies shape work practices, thereby promoting or undermining certain values (Van de Poel, 2009).

Under increasing pressure from donors asking for transparency and better accountability recently confirmed at the World Humanitarian Summit (WHS, 2016), the push to introduce innovation and technology in disaster affected areas continues. With the introduction particularly of remote monitoring and tracking technologies, there is the widespread claim that efficiency and performance of operations can be improved, better protection to humanitarians and beneficiaries can be provided, and coordination can be better organized (Meier, 2015; Palen et al., 2010). There is, however, very little research on the impact of information on sense making, decision-making and performance of humanitarian operations. This research aims at contributing to that research by researching the impact of transparency on the efficiency of a humanitarian operation.

### *Communication & Feedback*

The communication of information is understood as the transmission of information in the broadest sense to partnering organizations. This information can be operational information, but also strategical and tactical information. Communication in crisis can be roughly separated in two different forms; formal and informal communication (Comes, Meesters, & Torjesen, 2017b). The informal communication is the communication which happens without prior verification from individual to individual. Formal communication is from organization to organization. This is taken into account in the modelling process.

One of the phenomena in the humanitarian sector is the large turnover in personnel. Fast (2017) describes this phenomenon as the ‘perpetual present’, in which aid workers are living in. They do not seem to use historical data into account when drawing up future

policies, and some of the related biases are described by Comes (2016). Feedback is thus important. In the modelling process, a turnover rate will be taken into account, in turn affecting the efficiency of the organization.

As with all aspects of improving the information sharing, there are risks associated with communication or a lack of communication in complex disaster relief. As aid workers are working in dangerous situations it is vital to know when previous attacks on aid workers have taken place. Through this communication aid workers can leave before incidents may happen (Hoelscher, Miklian, & Nygård, 2017). Another risk of communication in data creation through crowdsourcing is that before data is handed to humanitarian decision makers a number of mutations have already been applied to the data. Exemplary is the Nepali earthquake in 2015 where local knowledge was translated by bilinguals in Nepal. After that it was categorized by data processors all over the world. In these three steps, data can be strongly distorted and provide a faulty insight in the crisis (Mulder, Ferguson, Groenewegen, Boersma, & Wolbers, 2016). Communication is thus the same as sharing, but improving sharing takes improvement over the whole IM cycle.

### *Knowledge gap*

As has been shown in the previous sections, a fair number of papers has been written on information management in the humanitarian sector. These papers however all have in common that they are merely descriptive and based on case studies (Berti, 2015; Comes et al., 2015; Sida, Trombetta, & Panero, 2016; Tomasini & Van Wassenhove, 2009; Van de Walle & Comes, 2014). Also the papers published in this domain have a strong qualitative base, whereas papers with a more quantitative base are rare.

Some research has been done prescriptively and quantitatively. Altay & Pal (2014) have researched information sharing through an Agent-Based model, but have called for more extensive research to improve agent-behavior in their model.

In earlier papers there has been called for a social network analysis in the humanitarian sector (Saab et al., 2008). In the paper van Muhren, Van Den Eede & Van de Walle (2009), a conclusion is drawn that the focus of information sharing should not be only institutional information sharing, but also on the social aspect of information sharing. Both institutional and social information are looked at in this research.

I therefore propose a research in which a humanitarian operation with all its social aspects is modeled quantitatively and in which policies and scenarios can be implemented in order to see patterns in safety and efficiency as a result of those policies. These results can be used as input for policy-makers. The research is thus of a prescriptive and quantitative nature and the main research question is as follows:

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***Which policies are able to improve the performance of a humanitarian operation in a complex disaster through information sharing?***

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## **1.4 Research questions**

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In the previous section the knowledge gap was identified. A limited number of scientific papers on information sharing in complex disasters lead to the discovery of the necessity of

research in this field. The main research question that is thus to be answered is stated below. The main question is subdivided in four sub questions, stated after the main question.

### **Which policies are able to improve the performance of a humanitarian operation in a complex disaster through information sharing?**

6. How is information sharing in a humanitarian operation in a complex disaster organized; what are the characteristics of IM policies, and what are criteria to evaluate the impact of information sharing?
7. How can information sharing of a humanitarian operation be simulated in an Agent-Based model?
8. What are potential alternative policies and scenarios?
9. What is the impact of policies on the performance of a humanitarian operation for the identified scenarios?

## **1.5 Research approach**

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From the research question and from the sub questions can be derived that a combination of an exploratory approach and a modelling approach fits best in this case. An exploratory approach is described as follows:

*“Exploratory research tends to tackle new problems on which little or no previous research has been done”* (Brown, 2006 p. 43)

This description is well suited for this research proposal. There is no clear theory or outline on what good sharing policy is and there have been few modelling studies.

The modelling approach fits best with the first and second sub question. A research on how elements in a system interact with each other, such as the first sub question states, is defined as a modelling approach. Simulation in an Agent-Based model is typical for a modelling approach. The configuration of policies to be simulated in the Agent-Based model fits better with the exploratory approach as the way of researching the Agent-Based model is based on a stylized case study. The stylized case study implies that the research approach is more exploratory because the case study is only loosely based on real-world phenomena. The fourth sub question is a combination of the previously mentioned approaches. It is a modelling approach because of the usage of the model and an exploratory approach because of the use of the policies and scenarios.

To further understand the perspective of the research it is important to stress the exploratory nature of this research. It provides a better understanding of the factors which drive important characteristics of a humanitarian operation. This means the abstraction level of the research is high and the amount of hard data in the research is rather low. As a result the identification of uncertainties is critical in the final outcome of the model. A large number of assumptions had to be taken in order to create the model. However uncertain the humanitarian field is, a modelling study can show larger patterns in the humanitarian sector that can add to the understanding and lead to better decision-making in the future.

## **1.6 Research methodology**

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This section aims at identifying methodologies, methods and tools appropriate to answer the research questions defined in the previous sections. In the first part, an overview of methods and tools per sub question will be proposed. In the second part, a research flow will be

presented and elaborated on. This methodology as a whole will provide a basis to answer the research question in full.

*How is information sharing in a humanitarian operation in a complex disaster organized; what are the characteristics of IM policies, and what are criteria to evaluate the impact of information sharing?*

This question will be answered using a combination of qualitative methods. The case that will be used to identify information flows is the case of Syria. The case will not be used as exclusive input, but will be the main inspiration for information throughout the thesis. The factors that need to be identified are largely available online and partly identified through interviews with experts.

Extra input has been delivered by the iTrack workshops, organized April 19 & 20 2018. The iTrack workshop has been organized by the TU Delft HumTechLab and the iTrack consortium and has convened key decision-makers from international NGOs, humanitarian agencies and policy-makers to examine current policies and technologies to identify concrete mechanisms for improvement of the humanitarian sector.

The identified components and information flows and other findings will be compiled using the already existing frameworks by UNOCHA for a humanitarian operation and the IM cycle, as also used by UNOCHA.

*How can information sharing of a humanitarian operation be simulated in an Agent-Based model?*

The big advantage of Agent-Based modelling over other modelling techniques is that Agent-Based modelling is a bottom-up approach (van Dam, Nikolic, & Lukszo, 2013). It aims at modelling complex adaptive systems with possibly emerging behavior. Although humanitarian aid organizations show more and more characteristics of a professional bureaucracy instead of an adhocracy (Laan, Brito, Fenema, & Vermaesen, 2009), there are still many characteristics of an adhocracy. An adhocracy inherently means that many decisions in the field are hard to influence from a top-down perspective. Behavior of the model is therefore hard to describe from a top-down perspective. Since Agent-Based modelling is specifically designed to analyze bottom-up, this modelling discipline is well suited for this problem.

The data needed for this research will flow from the previous research question and will be taken from the former questions. It will be quantified so that the basic simulation without additional policy resembles real world sharing practices. For modelling NetLogo will be used. For data analysis R will be used.

*What are potential alternative policies and scenarios?*

After the first question in which the current state of a humanitarian operation is mapped, it's time to develop list of criteria to which the information sharing practice in the humanitarian operation need to adhere to. This list of criteria can be developed through interviews literature review.

The scenarios and policies will be developed based on policy and scenario levers identified in the first sub question and will aim to cover the most relevant range for this stylized case study of policy and scenario possibilities.

*What is the impact of policies on the performance of a humanitarian operation for the identified scenarios?*

The scenarios and policies found in the previous sub question will be projected onto the model that has been developed in the second sub question. The policy levers can be adapted

by policy makers, leading to a different behaviour in the simulation. This creates an intuitively visible impact of certain policies and will help policy makers to make a well-grounded decision.

The aim of this thesis is not to find a single policy which functions under every circumstance. This means the outcome won't be a single policy which will function as a "silver bullet" to information sharing, but will rather lead to an increased understanding of information sharing in complex disaster relief. This is in line with the exploratory nature of this research.

The conclusion will be based on the answers found in the results of this sub questions and among other will include increased understanding of the impact of policy variables under different circumstances and on different KPIs. The tools used here will be NetLogo and R.

Answers of sub questions		
Question	Answered by	Means of presentation
1	Literature review, interviews, XLRM-framework	Text, visuals, XLRM-diagram
2	Agent-Based model, interviews	Text, visuals, flowcharts
3	Literature review	Text, visuals
4	Data analysis	Text, visuals, plots

## 1.7 Research flow

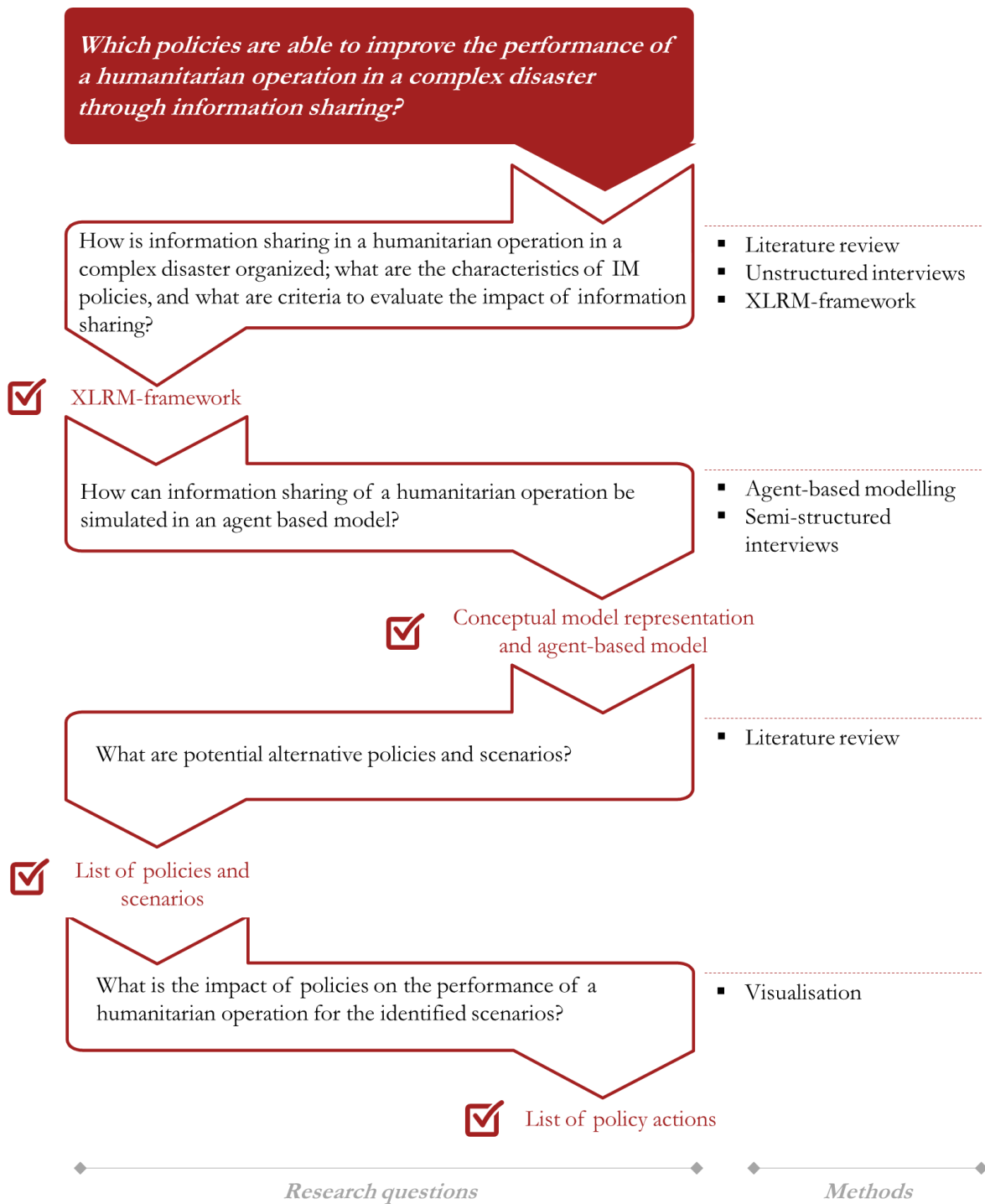


Figure 1.4 Research flow diagram



## 1.8 Terminology

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In the humanitarian sector, the terms which are used are delicate and confusion is looming when terminology is not used with care. To avoid confusion in this thesis, this section defines the terms which are most commonly used in the humanitarian sector. This section can be referred to throughout the following chapter.

### *Person Of Concern (POC)*

A POC is every person which according to aid organizations is in need of help. This does not mean that it has received help, but it does mean that it needs help. This term is most commonly used in the UN. In different organizations however, different terms are used. As the UN is the dominating organization, their terminology is used throughout the thesis.

### *Beneficiary*

A POC turns into a beneficiary the moment it has received aid. This does not distinguish the type of aid which has been received. The diagram shows the relationship; every beneficiary is POC, every POC is civilian.

### *NGO*

The term “NGO” (Non-governmental Organization) is used very broadly in this thesis. An NGO is an organization not affiliated to any government, yet executing a public function. Throughout this thesis, for modelling simplification purposes the term NGO is used for every organization providing aid to civilians in crisis situation. Also an INGO is (*International* NGO) is not functionally separated in this thesis.

### *Reporting*

Reporting carries a sense of hierarchy, which is mostly used for reporting to a donor. In this thesis, reporting is used in its broadest sense representing overall transparency of an organization. Reporting in the context of donor relations is not used in this thesis unless stated so.

### *Funding*

Funding is the money received by NGOs from donors

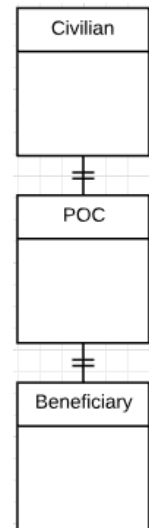


Figure 1.5  
Beneficiaries  
terminology





## 1920 – 1936

After a short-lived Arab Kingdom of Syria in 1920, the French took mandate over the Syrian territories. Between 1920 and 1936 the constitution of Syria changed multiple times, until in 1936 an independence treaty was signed. The picture shows Sultan Pasha el-Atrash who led the Great Syrian revolt. A country-wide rebellion against the French. This revolt later led to the independence in 1936.

# 2.

## Conceptualization

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*How is information sharing in a humanitarian operation in a complex disaster organized; what are the characteristics of IM policies, and what are criteria to evaluate the impact of information sharing?*

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In the conceptualization, the research problem is deepened and some initial scoping for the model is done. Along the way of the conceptualization, uncertainties are mapped and taken into account for future modelling. Firstly an understanding of a humanitarian operation, secondly a deeper look in what information exactly entails and thirdly a research on which factors decide how well a humanitarian operation performs.

### 2.1 Understanding a humanitarian operation

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To understand the importance of data in a humanitarian organization, we will have to start from the bottom up. The three components that are used to create an understanding of the humanitarian sector are the following:

1. Who are the players that are involved in a humanitarian operation and how are they organized?
2. What is information and why is it so important?
3. What are indicators of performance of a humanitarian operation?

As a concluding section an overview for the implications for modelling is given.

## 2.1.1 Who are the players that are involved in a humanitarian operation and how are they organized?

In a humanitarian operation there is a large variety of actors. This research subdivides its actor research in two groups: aid providers and beneficiaries.

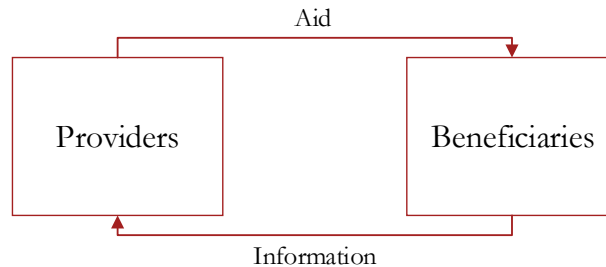


Figure 2.1 Simplified actor depiction

Based on this simplified categorization of actors the actor analysis will be deepened in the following section. The inspiration for the configuration of the network of actors is drawn from recent complex disasters. Among these crises are the humanitarian operations in Syria, D.R. Congo and Yemen.

### Providers

The base of the actor investigation for providers will be the cluster approach, introduced along with the humanitarian reform in 2005 (UN, 2005b). This reform aimed to “*improve the effectiveness of humanitarian response by ensuring greater predictability, accountability and partnership*”. This also aimed to clarify the roles of external organizations in a humanitarian organization, which is why it provides a suitable way to identify the different actors in the field in this context. The cluster approach is implemented every time an international response is needed in a crisis. The cluster is drawn up as follows:

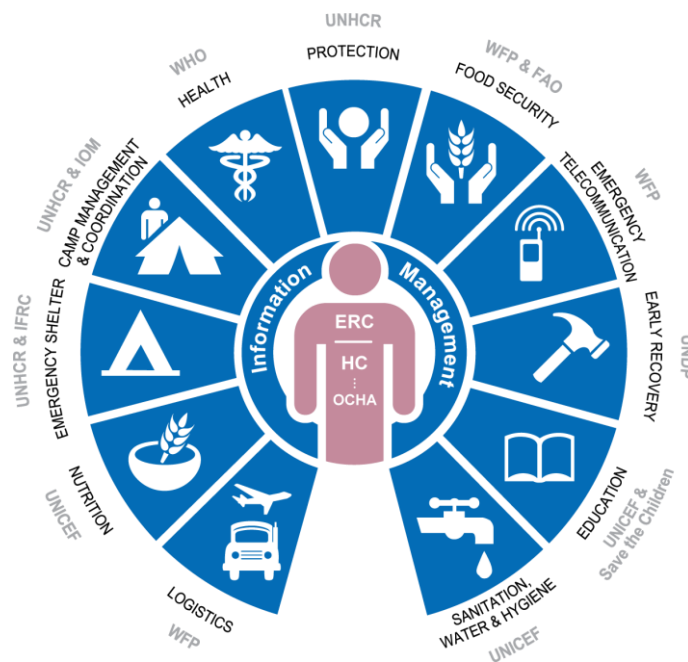


Figure 2.2 Cluster approach visualization (UN, 2005a)

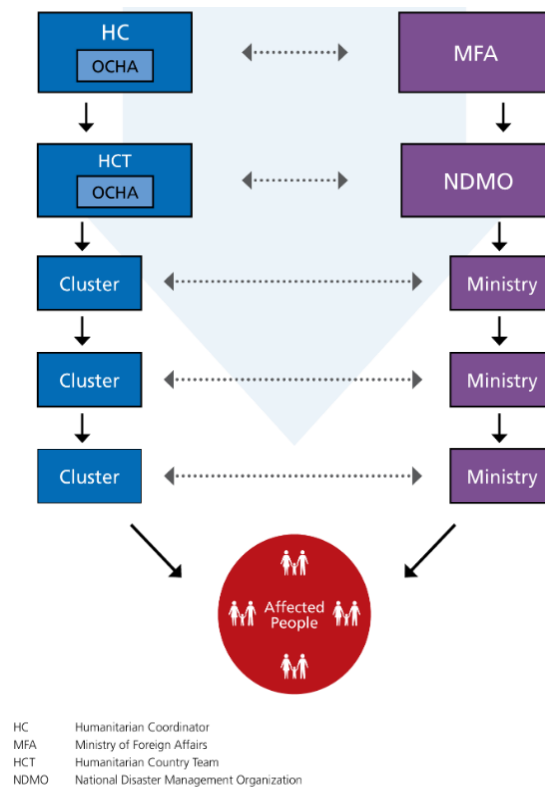
The cluster approach is to create an understanding of the context of a humanitarian operation. This actor specification will later aid to understand why certain modelling choices are made. The actors which are involved can be grouped roughly in five groups (Ververs, 2018):

4. Governments
5. United Nations
6. Non-governmental organizations: national and international
7. International Red Cross and Red Crescent Movement
8. Other actors

### *Governments*

The role of a “hosting” government in a humanitarian crisis is fourfold (Harvey, 2009). The first responsibility of a government is to call a crisis and to invite humanitarian aid actors into the country. This is vital, because if this official call for help is absent a humanitarian organization is breaking international laws if they arrive at the crisis location. The second responsibility is to provide assistance and aid themselves. Thirdly they are responsible for monitoring and coordination of external assistance. Fourthly they are responsible for setting a regulatory and legal framework governing assistance. Since the focus of this research is on complex disasters, mostly the first and fourth responsibility is of great importance.

The picture below shows how the cluster approach as implemented by the UN is designed to interact with the local government. There is an institutionalized interaction between the host government and the UN agencies. Depending on the nature of aid, the most logical ministry is designated for cluster interaction. The exact meaning of the abbreviations will be explained in the next section.



*Figure 2.3 HCT Coordination and Interface with Government*

## United Nations

The United Nations agencies are ubiquitous in humanitarian operations in complex disasters. To grasp how the UN are organized, the visualization below shows how different organizations interact. The chart shows a visualization of the chain of command of the UN in a humanitarian operation. The number of clusters that is implemented in a complex disaster is dependent on the nature of the disaster and the subsequent needs. Figure 2.2 is complementary to 2.1, because 2.1 shows the capacity of the different clusters and 2.2 shows the a more organizational view.

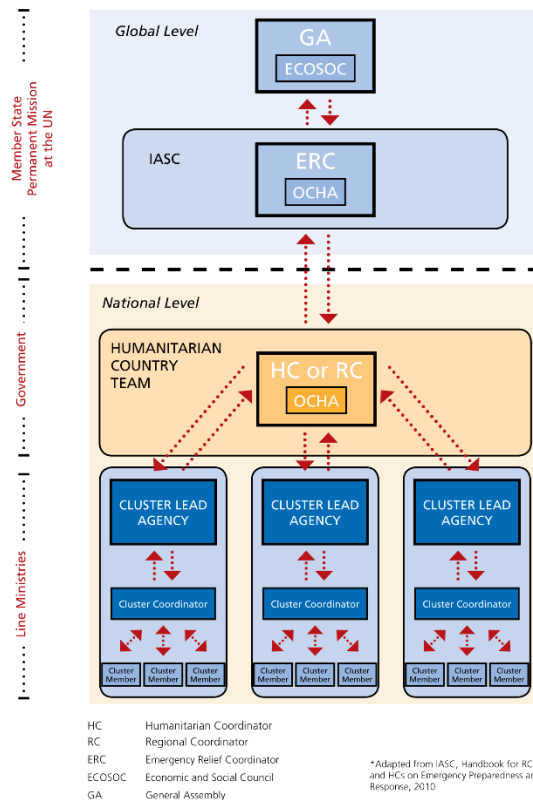


Figure 2.4 IASC Humanitarian Coordination Architecture

The following text is copied from the humanitarian response website (OCHA, 2014) and explains the different roles of the actors mentioned in the architecture shown above:

“The **Emergency Relief Coordinator (ERC)** is the Under Secretary General for Humanitarian Affairs, and leads the IASC. The ERC is responsible for the oversight of all emergencies requiring United Nations humanitarian assistance. In a country affected by a disaster or conflict, the ERC may appoint a Humanitarian Coordinator (HC). The ERC ensures IASC endorsement of the HC proposal for Cluster activation and Cluster lead appointments.

The **Inter-Agency Standing Committee (IASC)** is a unique inter-agency forum for coordination, policy development and decision-making involving the key UN and non-UN humanitarian partners. Under the leadership of the Emergency Relief Coordinator, the IASC develops humanitarian policies, agrees on a clear division of responsibility for the various aspects of humanitarian assistance, identifies and addresses gaps in response, and advocates for effective application of humanitarian principles.



*OCHA works closely with global cluster lead agencies and NGOs to develop policies, coordinate inter-cluster issues, disseminate operational guidance and organize field support. At the field level, OCHA helps ensure that the humanitarian system functions efficiently and in support of the Humanitarian Coordinator's leadership. OCHA provides guidance and support to the HC and HCT, and facilitates inter-cluster coordination. OCHA also helps ensure coordination between clusters at all phases of the response, including needs assessments, joint planning, and monitoring and evaluation.*

*The **Humanitarian Coordinator (HC)** is responsible for assessing whether or not an international response to crisis is warranted and for ensuring the humanitarian response efforts, if needed, are well organised. The HC is accountable to the Emergency Relief Coordinator. HCs lead the HCT in deciding the most appropriate coordination solutions for their country, taking into account the local situation. Agreement must be reached on which Clusters to establish, and which organizations are to lead them.*

*The **Humanitarian Country Team (HCT)** is a strategic and operational decision-making and oversight forum established and led by the HC. Composition includes representatives from the UN, IOM, international NGOs, the Red Cross/Red Crescent Movement. Agencies that are also designated Cluster leads should represent the Clusters as well as their respective organizations. The HCT is responsible for agreeing on common strategic issues related to humanitarian action.*

*Under UN General Assembly Resolution 46/182 of 19 December 1991, the affected State, i.e. the **government** and **national actors**, retain the primary role in the initiation, organization, coordination, and implementation of humanitarian assistance within its territory.*

*The **Global Cluster Lead Agencies** provide the following types of support to strengthen field response:*

- *Technical surge capacity*
- *Trained experts to lead cluster coordination at the field level*
- *Increased stockpiles, some pre-positioned within regions*
- *Standardised technical tools, including for information management*
- *Agreement on common methods and formats for needs assessments, monitoring and benchmarking*
- *Best practices and lessons learned from field-tests*

*The designated **Cluster Lead Agency** leads and manages the cluster. Where possible, it does so in co-leadership with Government bodies and NGOs. At country level, Heads of Cluster Lead Agencies are accountable to the HC, for:*

- *Ensuring that coordination mechanisms are established and properly supported*
- *Serving as a first point of call for the Government and the HC*
- *Acting as a provider of last resort in their respective sector*

***Cluster Coordinators** are responsible for ensuring that Cluster-specific concerns and challenges that cannot be solved within the Cluster are raised and properly discussed at the HCT, and that ensuing strategic decisions are shared and acted upon at operational level.”*

*(OCHA, 2014)*

Within the United Nations system, there is large number of separate aid agencies. In the context of the “Saving Lives Together framework”, the United Nations and some of the largest international organizations (namely ADB, IOM, EBRD, and ICC) have agreed to be referred to as a unified and aligned actor (UN, 2015).

## *NGOs and INGOs*

NGOs and INGOs are private organizations that are helping with the implementation of aid in the disaster-struck area. Each NGO has its own mandate and is specialized at something. They therefore all report to their own cluster. Examples of clusters are logistics, food security and shelter.

### *Red Cross*

The Red Cross is an INGO, but given the unique organization structure, it does not fall into one of the other given categories. The Red Cross is built up out of two building blocks. *The International Federation of Red Cross and Red Crescent Societies (IFRC)* and the *International Committee of the Red Cross (ICRC)*. The first is an organization which aims at relief of victims of mainly natural disasters. The organization is build up out of member societies of each country, formalized in law. The international organization aims to strengthen the national societies. The latter is an organization doing similar relief work, but is more focused on complex disasters.

### *Other actors*

A number of organizations fall in the category of “other important actors”, for example the military intervening in humanitarian aid, donors and sub-contractors. The categorization ‘donors’ is partly overlapping with other previously mentioned categorizations.

## ***Beneficiaries***

After this assessment of aid organization in a complex disaster, we should not forget what the purpose of a humanitarian mission is: to help the people in the disaster-struck area. This makes the second main category of the assessment of actors: *beneficiaries*. Beneficiaries are not always the same. The beneficiaries in this thesis are subdivided by a number of characteristics of which the most important are explained here. The grouping as defined here is chosen to fit modelling purposes and fit real-life characteristics of the stylized case study of Syria. Exact characteristics are further elaborated on in chapter 3.1.

### **2.1.2 What is information and why is it so important?**

#### *Two categories of information*

In the humanitarian sector there is a plethora of different types of information. Based on interviews with humanitarian information specialists, a decision is made to define two categories of information: *Operational & Planning information* and *Safety & security information*. Operational & Planning information is information which is used to plan the humanitarian mission and to define tasks of different NGOs. Safety & security information is information regarding the safety of the personnel of NGOs. This information contains details on incidents and areas of possible future incidents. It is important to make a distinction as such, because different standards regarding transparency and openness are made. There is a reluctance to share Safety and Security data, as too much transparency on incidents involving the NGO hurts the public image of the organization. As for operational & planning information, there is much less of an intentional reluctance to share data. This has more to do with a lack of capacity or other factors (Riege, 2005).

### *Understanding the reluctance to share information*

In this section there will be described why NGOs are often not willing to share all their data with other organizations. Understanding this reluctance is key to understanding why this research is necessary and how the behavior of agents in the model is specified.

The first reason, retrieved from proceeding of the iTrack workshop April 2018, is that NGOs are afraid of financial consequences of missteps in their security policy. NGOs in conflict area's operate under highly dangerous circumstances and are always risking an incident. Even though the security policy can be strict, there is always a risk of personnel complying to the policy. This means there is always someone with responsibility for the incident. Since these incidents strongly affect the image of the organization to the outer world, NGOs prefer to keep incidents to themselves. This also implies that the reporting of threats is to be kept strictly private. This unwillingness to share threats is a threat to security for a larger community of aid workers in the entire region. Currently they namely are still dependent on informants in the region and not on an organized platform reporting threats.

The second reason why NGOs are unwilling to share information is that there is competition between NGOs in the field. NGOs are dependent on donations from their home country and other international organizations and they are fighting each other for a place in the spotlight. Sharing operational information leads to a greater chance of NGOs coming to that region, leading to a lesser place in the spotlight (Stephenson, 2005).

Thirdly there is a practical drawback in sharing data. In order to facilitate efficient data collection and analysis a certain format needs to be maintained. This means that before being able to share the information, it needs to be formatted in the uniform format. Since many NGOs are relatively small and are occupied with other relief activities, there isn't always capacity to gather data and put it in the right forms. This practical drawback is mainly present in smaller NGOs (Jackman & Jones, 2002). Additionally an extra hurdle is identified where the communication between established and new NGOs is cumbersome. (Potapkina, 2009).

Lastly, a recent trend sees a rapid growth in the number of NGOs active in the humanitarian aid field. Since governments have found out that it is often more efficient for them to hire an NGO to do dangerous work instead of sending their own personnel, there is now a greater dependence on the information flow generated from NGOs to governments. NGOs recognize this tendency and realize its importance. This gives them a position of power where they can withhold from sharing data unless paid for: information is power (Laipson, 2007).

As a final contribution to the topic, a table from a research paper on information sharing in disaster response by Bharosa, Lee and Janssen (2010) is included. This table shows which factors influence information sharing in a natural disaster. As the focus of this paper was not strictly on complex disasters, the table is limited to operational factors and strategic concerns are left out. IOISS stands for Inter Operational Information Sharing Systems. MDM stands for Multi Agency Disaster Management.



Level	Factor
Community	<ul style="list-style-type: none"> <li>• Formal inter-agency communication channels</li> <li>• Structure &amp; procedures for MDM operations</li> <li>• Feedback/incentive mechanism (e.g., measurement, evaluation, reinforcement, mutual benefits)</li> <li>• Information filtering &amp; selective dissemination</li> <li>• Mutual adjustment through interaction and familiarity of others roles</li> <li>• Interface with mediators (i.e., Multiteam/ CITYGIS/ GMS operators)</li> </ul>
Agency	<ul style="list-style-type: none"> <li>• Norms for inter-agency info sharing</li> <li>• Knowledge about other agencies' operations</li> <li>• Alignment of primary duty and MDM duty</li> <li>• IOISS integration with organizational IT/routine use of ICTs</li> <li>• Technology training</li> </ul>
Individual	<ul style="list-style-type: none"> <li>• Workload for responsible duties</li> <li>• Motives to use IOISS</li> <li>• Relational power (rank)</li> <li>• Technology acceptance propensity</li> <li>• Trust in IOISS</li> <li>• Perceived information quality and system quality</li> <li>• IOISS familiarity &amp; training</li> </ul>

*Table 2.1 Factors influence information sharing in a natural disaster*

In this table, a distinction is made between three levels of information sharing. *Community level* refers to information sharing between organizations in a humanitarian operation. *Agency level* looks at information sharing within an organization and the *individual level* looks at information sharing from person to person.

### 2.1.3 What are indicators of performance of a humanitarian operation?

To measure the performance of a humanitarian operation, four categories of Key Performance Indicators (KPIs) are defined. These categories are the following:

1. Total aid delivered
2. Efficiency
3. Safety
4. Transparency

The categories will be broken down further in chapter 3.3. This will be done using variables which are used in the model.

#### *Total aid delivered*

The success of a humanitarian operation is not only depending on the efficiency of its aid delivery, but also on the total amount of funds it receives over time. A humanitarian operation can be efficient, yet not have a large amount of funds to spend. The first category therefore is *total aid delivered*.

### *Efficiency*

In literature, most KPIs can be found describing efficiency of a humanitarian logistical operation (Davidson, 2006). It is widely accepted that a clear measurement system improves a humanitarian operations' efficiency and effectiveness.

### *Safety*

As already briefly described before, risk management is an important topic for large international organizations. To describe the performance of a humanitarian operation, *safety* is therefore chosen as a category of KPIs.

### *Transparency*

Since this thesis researches information sharing in a humanitarian operation, a fourth category of KPIs is added. Transparency is an overarching category representing the willingness of NGOs to share information with their peers.

A more detailed break-down of the KPI categories can be found in appendix A.

## **2.2 Implications for modelling**

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### **2.2.1 Implications for actors in the model**

The decision is made to use a simplified two-actor Agent-Based model. The two actors that will be used are civilians in complex disaster and providers of aid. These two actor groups represent the core process of aid giving in a complex crisis situation: transferring goods and services from donor to recipient. Differentiation will be made through characteristics of civilians and providers. These characteristics will relate to the level of trust,

Next to that, the goal of the modelling study is to create a model that is generalizable for every crisis situation. The configuration of organizations' presence can differ strongly from case to case. To keep it generalizable, it is better to work with a high-level two-actor conceptualization.

In this thesis, all aid providers are called "NGOs", to reflect a recent transition in which traditional aid organizations such as the UN increasingly diminish their own presence on the ground. Within this new approach aid agencies remain in safer areas, often government controlled (Stoddard et al., 2017) while local or private parties are contracted. This phenomenon called "bunkerization" leads to larger organizations such as the UN to focus on funding of smaller NGOs to do the work, instead of actually executing labor themselves (Sandvik, Gabrielsen Jumbert, Karlsrud, & Kaufmann, 2014). This is especially the case when the work in the field is too dangerous to execute for themselves and therefore relevant in this research focusing on complex disasters. The possibilities of information technologies, such as geospatial information, contributed to this trend as there is mutual reinforcement between use of technology and distancing. The most problematic aspect, however, is that remote management leads rather to a "re-allocation of risks" (Duffield, 2013) than actual reduction of risks. Remote management can therefore not be fully considered as a de facto risk mitigation strategy, but rather a risk-transfer strategy in which the risks are shifted to local parties (Kalkman, 2018). This model study contributes to a greater insight in the actual risks that are still present for smaller contracted agencies.

## 2.2.2 Implication for information in modelling

In the modelling process, three main types of information will be used:

1. Information on incidents within the organization (*Safety & security Information*)
2. Information on needs in a camp (*Operational & Planning Information*)
3. Information on location of a camp (*Operational & Planning Information*)

The first type of information belongs to the Safety & security category of information, whereas the second and the third type of information belong to the Operational & Planning category of information. Based on the information policies found in chapter one and the identification of information types, the decision is made to model information sharing with limitations between NGOs, but not within NGOs. The limitations will decrease when two NGOs belong to the same cluster. Information sharing will be flawless when other organizations are in a close geographical perimeter.

## 2.2.3 Implications for modelling KPIs

The implications for modelling with respect to KPIs is that every agent in the model keeps track of its actions. There are no further implications for modelling for the KPIs.

## 2.3 System decomposition using the XLRM-framework

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From the last chapter it can be seen that there is a very large variety of components that play a role in information management in a humanitarian crisis. To map all those factors systematically, a framework by Lempert et. al (2003) is used: the XLRM-framework.

The XLRM-framework contains the following components:

- Exogenous uncertainties (“X”) are factors outside the control of decision makers that may nonetheless prove important in determining the success of their strategies.
- Policy levers (“L”) are near-term actions that, in various combinations, comprise the alternative strategies decision makers want to explore.
- Relationships (“R”) are potential ways in which the future, and in particular those attributes addressed by the measures, evolve over time based on the decision makers’ choices of levers and the manifestation of the uncertainties. A particular choice of Rs and Xs represents a future state of the world (Lempert et al., 2003).
- Measures (“M”) are the performance standards that decision makers and other interested communities would use to rank the desirability of various scenarios.

This framework forces the modeler to group every uncertainty in the model into one of the four groups. The uncertainties will be categorized with a level. The levels of uncertainty are derived from Walker et. al (Walker, Lempert, & Kwakkel, 2008). The levels are stated below, along with a brief explanation of these levels.

- *Level 1:* One is not absolutely certain, but is not willing to measure the degree of certainty.
- *Level 2:* The uncertainty that can be described adequately in statistical terms.
- *Level 3:* A number of alternatives can be listed and one is able to enumerate the alternatives with perceived likelihood
- *Level 4:* A number of alternatives can be set up, but one is not able to rank the probability of those likelihoods
- *Level 5:* The deepest level of uncertainty. One knows that one doesn’t know.

It also is relevant to define the origin of the uncertainty, which can be ontic or epistemic. This division defines whether the uncertainty stems from incoherent views on the subject (epistemic) or inherent variability of the situation (ontic). This adds value, because a better understanding of the origin of the uncertainty leads to a better understanding of how to model.

In the table below, the uncertainties will be presented. A goal-decision tree and an objectives tree which helped in finding the uncertainties can be found in appendix A.

XLRM-framework	
Exogenous uncertainties	
Subject of uncertainty	Nature and level of Uncertainty
Initial turnover rate	Level 3: Past turnover rates in companies are kept secret and therefore taken as uncertainty. Nature: Ontic (Inherent randomness) and Epistemic (Different ideas)
Type of war	Level 5: One never knows where and when which types of war are going to break out Nature: Ontic (Inherent randomness)
Spreading of the population	Level 4: Since location is unknown, spreading of people is unknown. The different types however can be predicted. Nature: Ontic (Inherent randomness)
Displacement rate of population	Level 4: The displacement rate is dependent on the population, and therefore uncertain. Nature: Ontic (Inherent randomness)
Trust	Level 5: One never knows how the attitude of civilians towards NGOs will be. Nature: Ontic (Inherent randomness)
Level of violence	Level 5: One never knows how violent civilians will be. Not towards NGOs, nor among civilians. Nature: Ontic (Inherent randomness)
Policy levers	
Subject of uncertainty	Related uncertainties
NGO transparency - <b>Shorten IM cycle</b> - <b>Increase willingness to share</b> - <b>Increase acceptance of incidents</b>	Level 3: Over the past, transparency levels are known. It is therefore known what is currently most likely. Nature: Epistemic (Different ideas)
Verification time - <b>Improve IT verification</b>	Level 2: Turnover levels of the past are known, but not available.

<ul style="list-style-type: none"> <li>- <b>Retain staff</b></li> <li>- <b>Lower verification priority</b></li> </ul>	Nature: Epistemic (No agreement on data)
Aid distribution <ul style="list-style-type: none"> <li>- <b>Time until moving to next camp</b></li> <li>- <b>Total money received</b></li> <li>- <b>Duration project</b></li> </ul>	Level 3: Not known in advance Nature: Epistemic (Not known in advance)
Trust in NGOs <ul style="list-style-type: none"> <li>- <b>Decrease risk-taking NGOs</b></li> </ul>	Level 4: There are options, but they cannot be weighed for likelihood. Nature: Epistemic (No agreement on ideas)
<b>Relationships</b>	
<b>Subject of uncertainty</b>	<b>Related uncertainties</b>
Aid efficiency	Level 3: Not known in advance Nature: Epistemic (Not known in advance)
Sensitiveness for incidents	Level 3: Not known in advance Nature: Epistemic (Not known in advance)
Willingness for transparency	Level 3: Not known in advance Nature: Epistemic (Not known in advance)
<b>Measures</b>	
<b>Subject of uncertainty</b>	<b>Related uncertainties</b>
Total aid delivered <ul style="list-style-type: none"> <li>- <b>Money distributed</b></li> <li>- <b>Covered area</b></li> </ul>	Not applicable
Efficiency <ul style="list-style-type: none"> <li>- <b>Percentage money converted to aid</b></li> <li>- <b>Average time to move to camp</b></li> </ul>	Not applicable
Safety <ul style="list-style-type: none"> <li>- <b>Fake news reaction</b></li> <li>- <b>Total incidents</b></li> </ul>	Not applicable
Transparency <ul style="list-style-type: none"> <li>- <b>Percentage of reported incidents</b></li> </ul>	Not applicable

Table 2.2 XLRM –Framework

## 2.4 Preliminary conclusion

---

The goal of this section was to take a deep-dive into information management of a humanitarian operation and structure it in such a way that it has quantifiable policy levers which can be used for future modelling. The question that was aimed to answer was the following:

*How is information sharing in a humanitarian operation in a complex disaster organized; what are the characteristics of IM policies, and what are criteria to evaluate the impact of information sharing?*

A first important finding is the distinction in types of information, which deserve different treatment. Planning & Organizational information and Safety & security information are the two different types of information and this information will thus be treated differently in the future modelling process.

An actor scan showed the large group of actors which is involved in a humanitarian operation. The decision has been made to continue the modelling process at an abstraction level where beneficiaries and providers of aid are the two groups that will be worked with.

Finally the KPIs have been defined. Categorized in four groups, being *total aid delivered*, *efficiency*, *safety* and *transparency*.



## 1936 – 1946

Even though French Vichy government proclaimed independence for the Syrian government, Syria remained under French mandate. While France was bombing Syrian capital Damascus in 1945, in order to arrest its democratically chosen leaders, Prime Minister Faris al-Khoury was present at the founding conference of the United Nations. He presented Syria's claim for independence from the French mandate. He succeeded, as France's last troops moved out of Syria in the beginning of 1946.



# 3.

## Model specification

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*How can information sharing of a humanitarian operation be simulated in an Agent-Based model?*

---

In this chapter, the third sub question will be answered. Firstly the agents in the model will be explained, using a UML table. Secondly the model logic will be explained. This will be done on two abstraction levels: first, a general model narrative will be given by means of a sequence diagram. This gives an overview of the most important processes. One level of abstraction lower, the individual processes will be explained. This provides a more detailed insight in the modelling processes. The chapter is concluded with a model verification and validation.

### 3.1 Agents in the model

---

#### *POCs*

A POC-agent in the model represents a group of civilians in a complex disaster. The following schematic depiction shows the attributes a POC-agent has. A POC should not be seen as a single person, but as a group of POCs. The amount of people one POC-agent in the represents is not stable. Depending on the rurality of the scenario a POC-agent represents a larger or a smaller amount of people. This will be further explained in chapter 4.

Group of POCs
<b>Primary key: Who-number</b>
Sum of money needed (USD)
Level of trust
Region
Displacement rate



Total humanitarian incidents caused
Money received last tick
Priority?

Table 3.1 UML depiction of POC attributes

A POC-agent is a group of people living in a disaster-struck area and is therefore in need of help. The total amount of *money* a POC-agent needs is dependent on the *region* it is currently in and the money it has already received from NGO-agents in the region. A POC-agent also has a *level of trust*. This level is decided by the aid it receives and the level of trust from its surrounding POC-agents. Trust is used as a measure to assess danger of a POC-agent towards surrounding NGO-agents. This may lead to a larger number of *incidents*. *Displacement rate* from a POC-agent decides if it is willing to travel to a different part of the map in order to receive help. A POC-agent only travels when it has not received help over the past days. *Priority* is a variable which triggers NGO-agents to move to new locations which have not been entered before. A POC agent looks around himself and when there are 5 or more POC-agents with a positive sum-of-money-needed, the *priority* attribute will be set to true.

### NGO-agents

An NGO-agent is an agent which distributes money. Once again, based on the UML depiction of the agent an elaboration is presented. The algorithms behind the attributes are presented in chapter 4. An NGO-agent can be every organization that provides aid to POC-agents. This can therefore depict the largest organizations such as the Red Cross, MSF and Oxfam, but also the smallest NGOs with only a few employees.

NGO
<b>Primary key: Who-number</b>
Cluster
Size
Risk willingness
Money spent in last tick
Money needed in camp
Reported money needed in camp
Cluster reported money needed in camp
Incidents
Reported incidents
Reporting
Cluster reporting
Location
Reported-location
Total money spent
Time in camp
Fake news reactions
Full camp knowledge
Incidents in reporting cycle

Incidents in previous reporting cycle
Funding delivered
Money Spent on Safety & security
Turnover rate
Information processing time needed
Information time
Project duration

Table 3.2 UML depiction of NGO-agent attributes

As was already presented in the introduction chapter, every NGO-agent is member of a *cluster*. A cluster subdivision is important to distinguish information sharing within and in between clusters. The *size* attribute shows the total number of POC-agents that one NGO-agent can help at the same time. *Risk willingness* is value between 0 and 1 assigned to every NGO-agent and decides to what extent an NGO is willing to move into dangerous region. Risk willing are NGOs over 0.67, neutral between 0.33 and 0.67 and 0.33 and lower are risk avoiding. *Money spent in last tick* is an attribute that represents how much money an NGO-agent has been giving to POC-agents in the past day. This represents its current activity and is a large influence on whether an NGO-agent moves on to a new location or not. *Money needed in camp* is an assessment of the money needed by POC-agents in the direct perimeter of an NGO-agent. A camp can be any amount of POC-agents requiring money from NGO-agents. This decides if it will call help from other NGO-agents. If so, it will *report* to other NGO-agents that money is needed and where other NGO-agents can go in order to provide their help. If an NGO-agent is not reporting, it does not call for help from other NGO-agents, even though it might actually be needed. *Incidents* is the number of incidents that happen to an NGO-agent, caused by a low level of trust from POC-agents. Not every NGO-agent *reports* the incidents, since that will affect their money flow (see chapter 3.3). *Location* represents the location where an NGO-agent currently is. Reported location is the location that is being transmitted to other agents. This location could be outdated information if the NGO-agent is not reporting its new location. *Total money spent* is a cumulative variable summing all the money an agent has spent. *Time in camp* is the total time that an NGO-agent has spent in a camp. It resets once it moves to another camp. *Fake news reactions* is the amount of time an NGO-agent moves according to false information. *Full camp knowledge* is acquired after a full assessment of a camp, or contact with an already present NGO-agent in a close perimeter. *Incidents* show the number of incidents that have happened to the NGO-agent, reported incidents are the ones that have happened while the NGO-agent is reporting. *Turnover rate* shows the percentage of staff turnover, leading to *information processing time needed*. *Information time* shows the total time an NGO-agent has been processing information. The *project duration* is a policy variable which shows how many days the projects of this NGO-agent take.

## 3.2 High level model narrative (sequence diagram)

This section how the implemented model functions. Section 3.3 elaborates in further detail. The model logic is inspired by the program cycle by UNOCHA as shown in chapter 1. The sequence diagram below shows all eleven steps that make up the model narrative. Every arrow represents a transaction of information or goods.

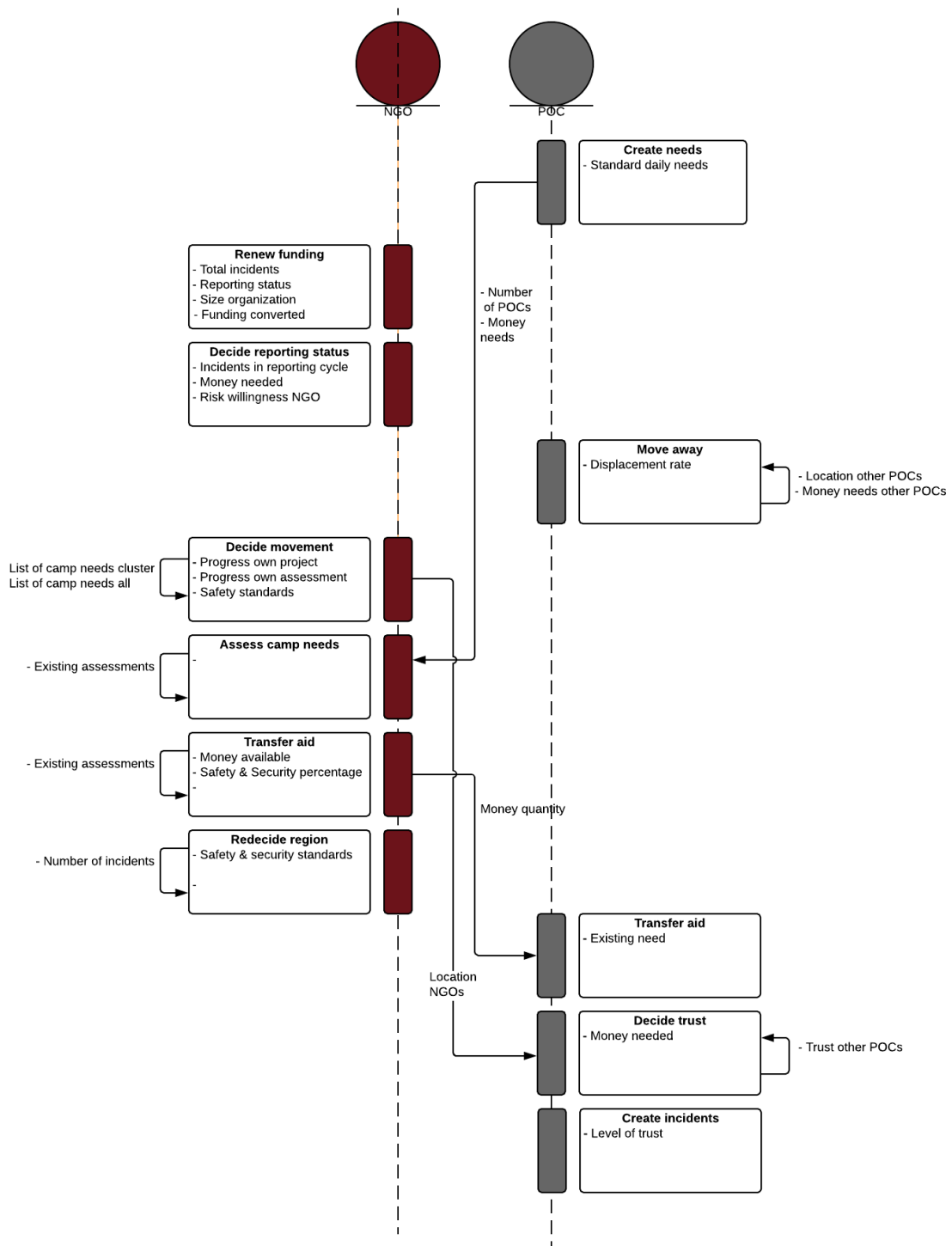


Figure 3.1 Sequence diagram

### 3.3 Detailed model narrative

In this section an elaboration on the ‘story’ of the model is presented. In this model in given chronological order a series of actions is executed. Each agent type (NGO and POC) has its own list of actions it runs through. The model specification is built on the conceptualization of the previous chapter and is a building block for generating results in the following chapters. An important note is that this model, however inspired by the Syrian crisis is not aiming at reproducing solely the Syrian crisis. It is aimed to be a generalizable model for other complex disasters.

This chapter firstly presents the chronological order of actions, after which through schematic depictions the separate actions are further elaborated on. Each separate action needed assumptions to function in the model. These assumptions are shown in the explanation. A distinction is made between structural assumptions and parametric assumptions.

The initialization of the model is a separate process from the stage where the model runs. The initialization process looks as follows:

Initialization	
POC	
1	Setup needs
2	Setup trust
3	Setup basic Parametric
NGO	
4	Setup willingness to take risk
5	Setup funding
6	Setup initial turnover rates
7	Setup basic Parametric
Land	
8	Setup regions

*Table 3.3 Initialization steps*

As was seen in the sequence diagram, the model runs according to the numbered chronological order. The table below shows the processes, split out by agent:

Processes	
POC	
1	Specify aid needs
4	Move to new location
8	Decide trust
9	Create incidents
NGO	
2	Renew funding
3	Decide reporting status
5	Decide if new location Move to new location Assess camp needs
6	Transfer aid
Land	
7	Decide region type

Table 3.4 Model processes

In the following section each process will be explained in further detail.

### 3.3.1 Initialization

#### *Setup needs (POC)*

The needs of the POC-agents are inspired by the needs of the needs of POCs in the Syria region in 2016 (UNOCHA, 2017). However there is a variety of commodities which are needed in real life, for modelling purposes the decision has been made to use money (USD) as a proxy for all needed commodities.

<p><i>Structural assumption: Population in dangerous areas require 20% more funds than people in neutral areas. Population in safer areas require 20% less funds than in neutral areas.</i></p> <p><i>Structural assumption: The needed commodities will all be expressed in dollars.</i></p> <p><i>Parametric assumption: The total financial need of the population in the model \$7.7 billion.</i></p> <p><i>Parametric assumption: 50% of funds is used for NGOs transactional costs.</i></p>
---

The first structural assumption is that there is a difference in needs between safer and more dangerous regions. The assumption is made to create a variance in the model. Since the spreading of POCs over different safety regions in the beginning phase is always equal, the total amount of money needed by the POCs is exactly as UNOCHA has reported (UNOCHA, 2017). 50% transactional cost assumption has been made to cover for the

operating cost of NGOs. The equation for individual POC-agent needs then looks as follows:

Equation 3.1 Specification needs of POCs

$$\text{Need of POC}(x) = \frac{\left(\frac{\text{Total initial needs}}{2}\right)}{\text{Total number of POC's}} * \frac{\text{multiplier for POC}(x) \text{ region}}{365}$$

### Setup trust (POC)

Trust is a soft variable which is hard to capture. Because of the importance of trust in the efficient operation of NGOs (Ron & Crow, 2015), the decision has been made to include it in the modelling process. Even though Agent-Based modelling is built to simulate complex-adaptive systems, the inclusion of qualitative variables for social systems is rather new (Sajjad, Singh, Paik, & Ahn, 2016). There has been proof that implementing qualitative variables such as trust of a POC-agent are possible to model (Ghorbani, Dijkema, & Schrauwen, 2015; Sajjad et al., 2016; Seidl, n.d.). Since the extraction of empirical data from communities in complex disasters is outside the scope of this thesis, the choice has been made to model trust based on 5 pillars which are weighed equally. The influence that these pillars have on the overall level of trust is equal, as there is no empirical source of the real-world levels of influence. The five pillars of trust look as follows:

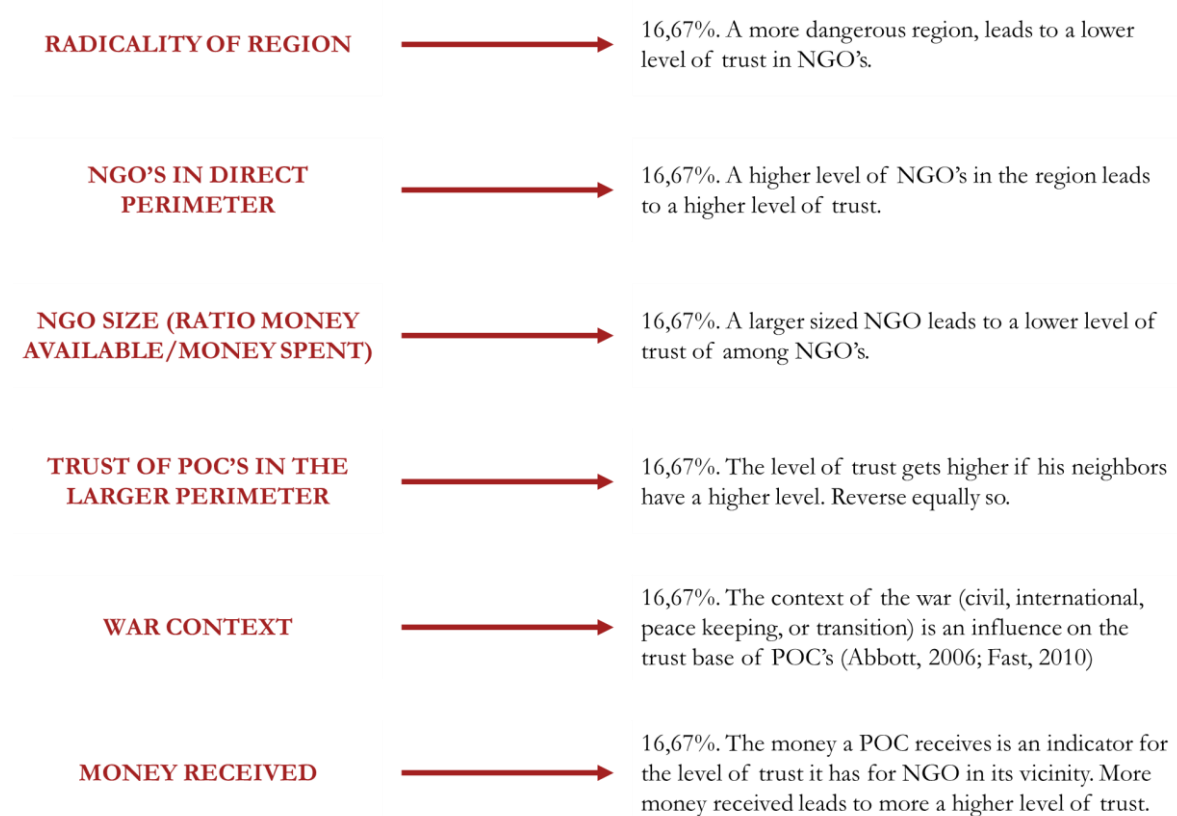


Figure 3.2 Definition of trust

In the following section 3.3.2 a further elaboration will be given on the way these pillars of trust develop over time.

### Setup basic parametric values (POC)

Variable	Value	Explanation
<b>Displacement rate</b>	Scenario variable between 0 and 10	Every POC-agent has a stochastic displacement rate and an adaptable displacement rate
<b>Priority</b>	True/False	If a POC-agent is a priority it means it is surrounded by 5 other POC-agent with money needed higher than 0

Table 3.5 Basic parameterization POC

An important decision to make is the total number of agents which are initialized. Since every agent in the model represents a share of POCs and the total amount of money needed remains constant, independent of the total amount of POC groups, the total number of POC-agents represent the granulation of the people in the modelled area. One could therefore choose for a larger number of POCs-agents for a more rural area and a smaller number of POCs-agents for a more urban area.

### Setup willingness to take risk (NGO)

The willingness to take risk by NGO-agents is a policy lever of three distribution functions, being uniform, beta risk taking and beta risk avoiding. The beta functions are modeled as below. A risk avoiding distribution means that there are less NGO-agents which are willing to move into dangerous territory. A risk-taking distribution means that there is a larger number of NGO-agents willing to move into dangerous territory.

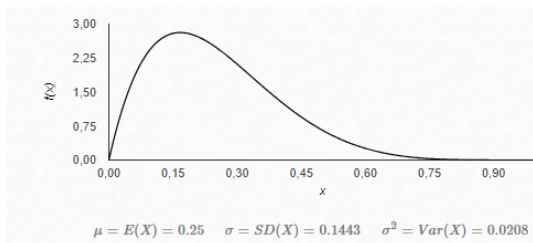


Figure 3.3 Beta distribution risk avoiding (Bognar, 2016)

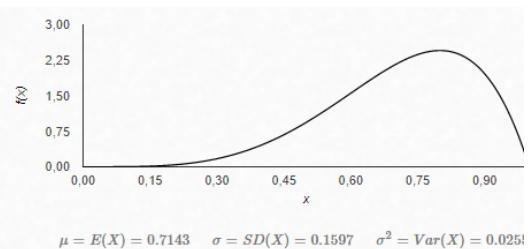


Figure 3.4 Beta distribution risk taking (Bognar, 2016)

### Setup funding (NGO)

In this model, the initial funding is based on the figures provided by UNOCHA on the Syria disaster (UNOCHA, 2017), amounting to roughly \$4.2 billion. There is no distinction between private and public funding; a simplification for modelling purposes. The exact amount of money one NGO-agent receives at the beginning of a model run is also dependent on the duration of its project. It is calculated as follows:

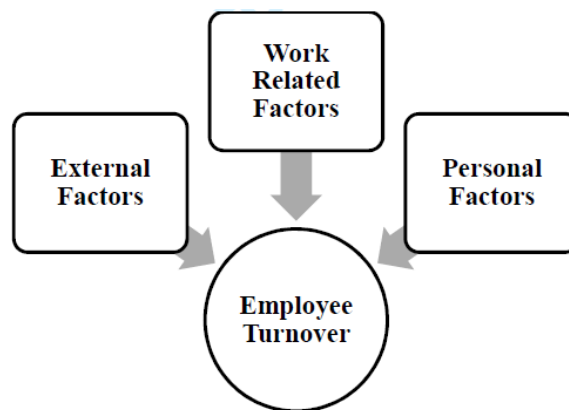
*Equation 3.2 Specification initial funding*

$$\begin{aligned} & \text{initial funding of NGO}(x) \\ &= \frac{\frac{\text{total initial funding}}{365} * \text{project duration}}{\frac{\text{Number of NGO – agent's}}{\text{Average NGO – agent size}}} * \text{size of NGO}(x) \end{aligned}$$

The size of the NGO-agent thus influences to a large extent the amount of funding it receives. Also this is only the initial amount of funding an NGO-agent receives. When a project finishes, the received amount will increase or decrease depending on a number of NGO-agent-characteristics. This is explained in the paragraph “*renew funding*”.

*Setup initial turnover rates (NGO)*

As disasters have gotten more and more complex over the past years (Tomasini & Van Wassenhove, 2009), so has the turnover rate of staff in crisis situations (Dubey, 2016). This Agent-Based model covers staff turnover in the form of a level of experience attributed to every NGO. The extent of staff turnover in the model is based on empirical research by Dubey (2016), which shows that there are three factors influencing staff turnover rate.



*Figure 3.5 Build-up of employee turnover rate (Dubey, 2016)*

Given the aggregation level of the model, the more detailed factors in the study by Dubey are left out. The model factors influencing employee turnover are:

1. An adaptable policy lever influencing external factors in employee turnover.
2. The risk-willingness of the NGO addressing the work related factors.
3. A stochastic variable representing the personal factors.

The article clearly states that the three factors of employee turnover do not have an evenly spread influence. The factors used in the model have been set according to the Average Variance Extracted (AVE) for the three different factors found in the article. This is respectively 0.37, 0.75 and 0.66.

The turnover rate in an organization is a cause for the time it needs to process and verify information. A high turnover rate means a low level of experience and therefore more time needed to verify and process information, because of the staff learning curve. The exact amount of extra time needed associated with a lack of experience is unknown and therefore a number of assumptions had to be made. A second identifier of extra time needed for processing of information is the size of the organization.



Turnover rate delay implications			
<b>High turnover rate (&gt;75%)</b>		<b>Medium high turnover rate (50% - 75%)</b>	
Size = 4	Size = 3	Size = 4	Size = 3
Delay = 8 days	Delay = 7 days	Delay = 6 days	Delay = 5 days
Size = 2	Size = 1	Size = 2	Size = 1
Delay = 5 days	Delay = 4 days	Delay = 3 days	Delay = 2 days
<b>Medium low turnover rate (25% - 50%)</b>		<b>Low turnover rate (&lt; 25%)</b>	
Size = 4	Size = 3	Size = 4	Size = 3
Delay = 5 days	Delay = 4 days	Delay = 4 days	Delay = 3 days
Size = 2	Size = 1	Size = 2	Size = 1
Delay = 2 days	Delay = 1 day	Delay = 1 days	Delay = 0 days

Table 3.6 Delay days of turnover rate

### Setup basic parametric values (NGO)

Every NGO has some characteristics which do not have a process to define the value of the variables. These variables with their values are stated below.

Variable	Value	Explanation
<b>Size of organizations</b>	Random between 1 (small) and 4 (large)	Every organization has a size randomly assigned between one and four. The number determines how many POC-agents it can help at the same time.
<b>Cluster</b>	Random between 1 and 7	This decides to which cluster the NGO-agent belongs.
<b>Reporting</b>	False	Determines if the NGO is currently transparent in its reporting. Set to false as default.

Table 3.7 Basic parametrization NGO-agent

### Setup regions (Land)

There is a total of three danger-qualifications for regions:

1. A region is considered to be safe,
2. A region is considered to unknown,
3. A region is considered to be dangerous.

*Structural assumption: The map is initially divided evenly between three regions.*

### 3.3.2 Processes

#### *Specify aid needs (POC)*

The needs for POC-agents are specified on a day-to-day bases. There is no difference in the formula compared to the initialization.

*Equation 3.3 Specify aid needs*

$$\begin{aligned} & \text{Additional need of POC – agent (x)} \\ &= \frac{\left(\frac{\text{Total initial needs}}{2}\right)}{\text{Total number of POC's}} * \frac{\text{multiplier for POC(x) region}}{365} \end{aligned}$$

This amount is added to the already existing need of the POC-agent.

*Structural assumption: The aid needs of POC-agents increase with the same amount every day.*

#### *Renew funding*

Renewing of funding is done on the basis of six components, together deciding a percentage by which the budget for the new project is going to increase or decrease. This approach has been chosen after Wildavsky:

*“The largest determining factor of this year's budget is last year's.”* (Wildavsky, 1988 p. 45)

The six factors equally determining the budget for the next project are:

1. Incidents occurred (-5% to + 5%)
2. Funding delivered to POCs (-5% to + 5%)
3. Reporting status (-5% to + 5%)
4. Funding converted to aid (-5% to + 5%)
5. Size (+5%)
6. Funding converted compared to last cycle (-5% to + 5%)

The first decider is the number of incidents that has occurred. Every NGO-agent keeps track (internally) of how many incidents have taken place within their organization. When the number of incidents is larger than it was in the last project, the funding will decrease by 5%. If it is lower, it will increase by 5%. The second factor measures to which extent the money that was funded in the last project is converted to actual aid. If the funding that is delivered is not used on aid, but on other activities the funding will decrease by 5%. The third factor takes reporting status into account. If an NGO-agent reports to other NGO-agents, funding increases by 5%. If it does not, it decreases by 5%. The fourth factor, funding delivered to POCs measures the total funds that are delivered to POC-agents in one project. This is an absolute number in USD. Funding delivered decreases when more money is needed for safety and security purposes. If the total amount of money delivered is lower than it was last time, funding will decrease by 5%. If it is higher, it will increase by 5%. The fifth factor represents size and reputation of an organization. A small organization (<2) will in no case receive this 5% increase. The larger organization (>2) will always receive a 5% increase. The sixth factor compares the percentage of the total aid converted to aid from last cycle to the percentage of the current cycle. If that has improved, the funding will increase by 5% and decrease by 5% if that is not the case.

### Decide reporting status (NGO)

The reporting status decides if and with whom an NGO shares its information.

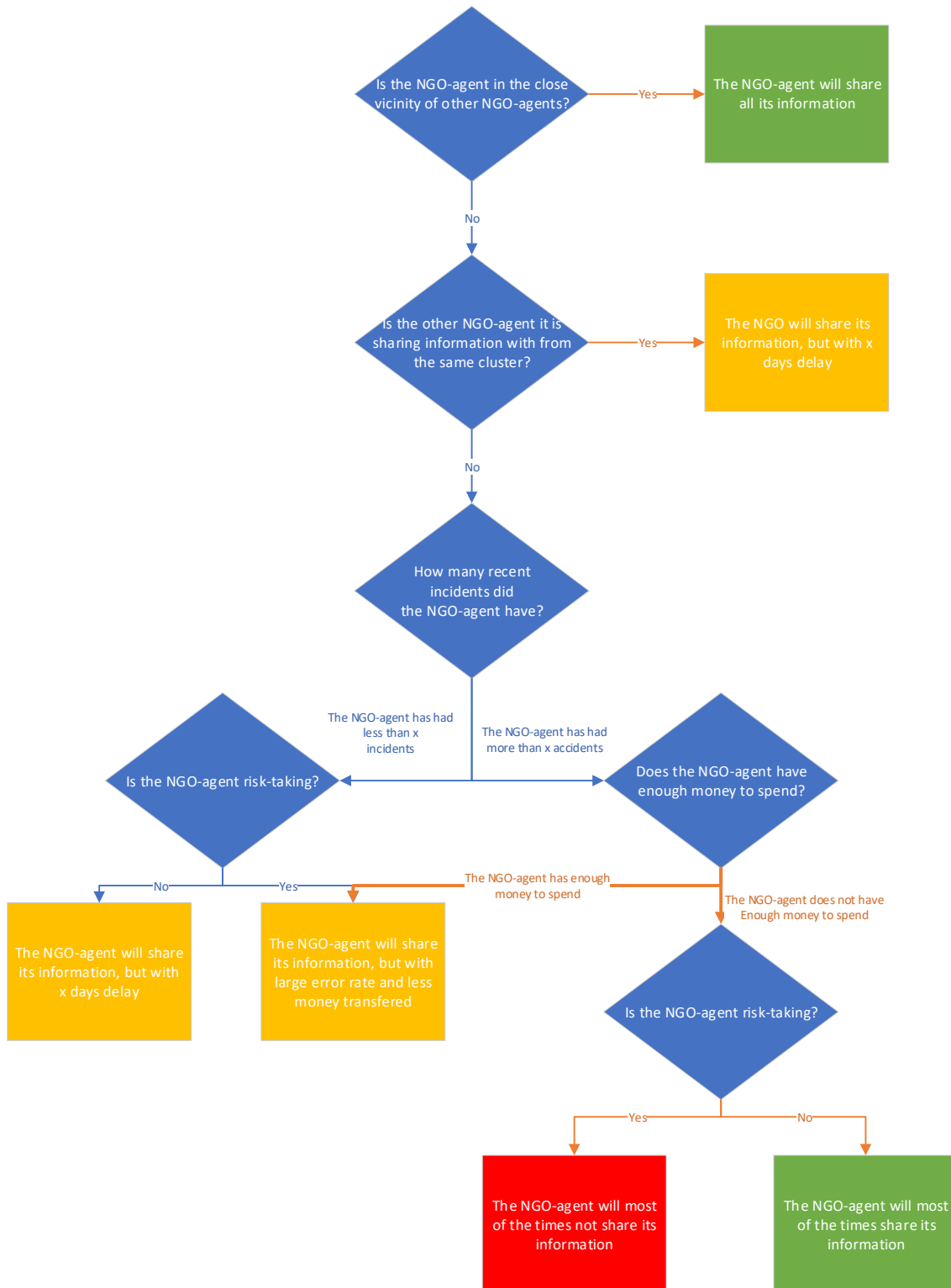


Figure 3.6 Decision tree reporting status

The information sharing decision is a process which is used by the NGO-agents. This critical process decides if and with whom they are willing to share information on their location,

POC-agents' needs and incident data. This is dependent on a list of factors, further elaborated in the next section. The assumptions made in this process are the following (Lopez et al., 2018):

*Structural assumption: Decision to share information is made derived from three factors:*

1. Money currently available
2. Willingness to take risk
3. Incidents that have occurred in the recent past

*Structural assumption: There is always a random factor involved in sharing the right or false information*

*Parametric assumption: There is always 20% more chance that an NGO-agent shares within its cluster, than with every other NGO-agent*

*Movement decision (POC)*

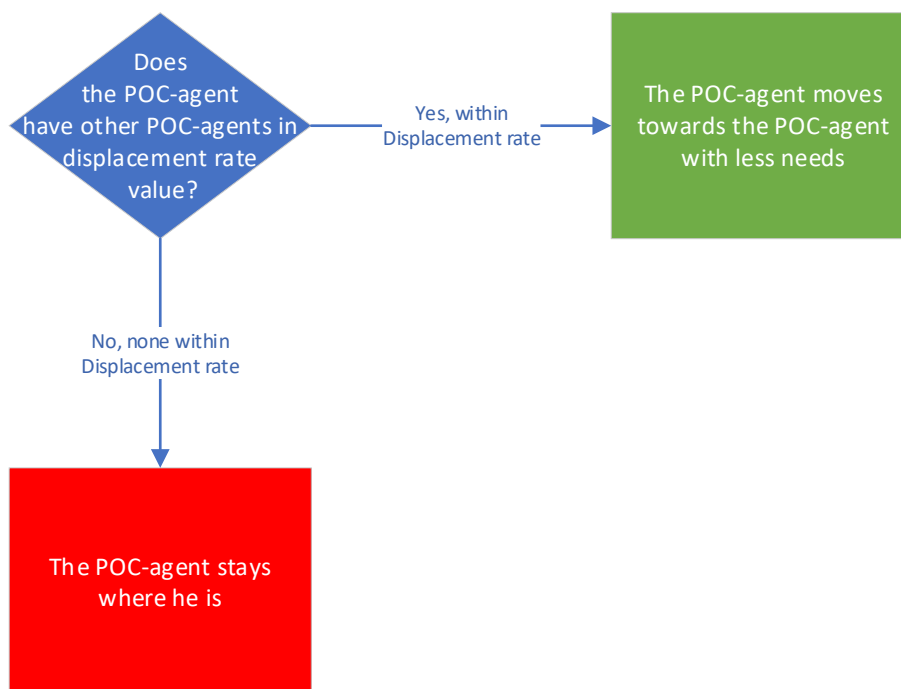


Figure 3.7 Decision POC movement

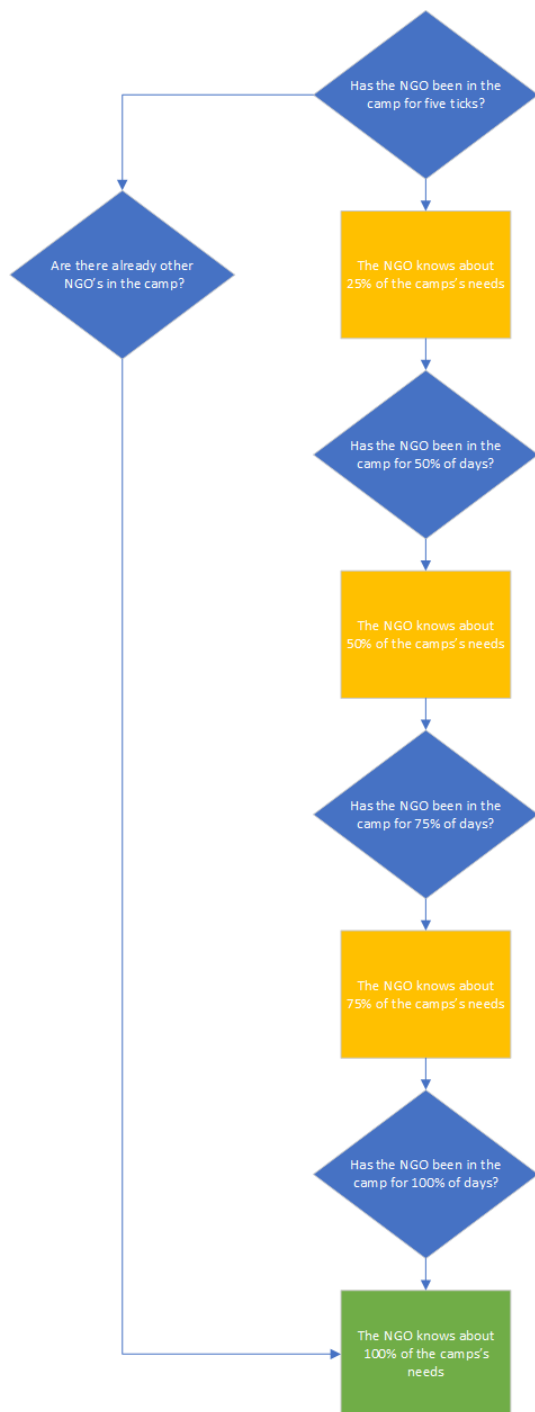
This decision depends on the variable “displacement rate”. This variable is a scenario variable and therefore differs per scenario (see chapter 4.1). If there are other POC-agents in the perimeter of the subject POC-agent which does not have lower needs, it will stay where it is.

*Structural assumption: A POC-agent moves when he has another POC-agent within his displacement rate value which has less needs than himself.*

*Structural assumption: The displacement rate is independent from the region.*



### Gather camp information



The process of gathering information for a camp is done by the first NGO-agent to arrive. Making an assessment takes between 7 and 30 days (UNOCHA, n.d.-b). This only has to happen when there is no NGO-agent already in the camp, which knows the needs already. If that is the case, every NGO-agent coming to that camp has full camp knowledge once settled in the camp. Costs of the assessment are estimated at 1% of monthly budget per day and is paid by the NGO-agents. If there are multiple NGO-agents at the time, they do not complement each other. They work separate and therefore both use money for their assessment. If one however has full camp knowledge earlier, it shares its complete camp knowledge with all surrounding NGO-agents.

*Structural assumption: When NGOs are in a POC camp together, the information on needs for the POCs are shared immediately and fully.*

*Structural assumption: Two NGO-agents doing an assessment at the same time do not complement each other's assessment.*

*Parametric assumption: Assessment and setting up of aid facilities takes between 7 and 30 days.*

*Parametric assumption: Making an assessment costs 1% of the monthly budget per day.*

Figure 3.9 Camp assessment NGO

### Transfer aid (NGO)

Transfer of aid can start once full camp knowledge is acquired by the NGO-agent. The transfer of aid depends on three main factors, shown in the figure below:

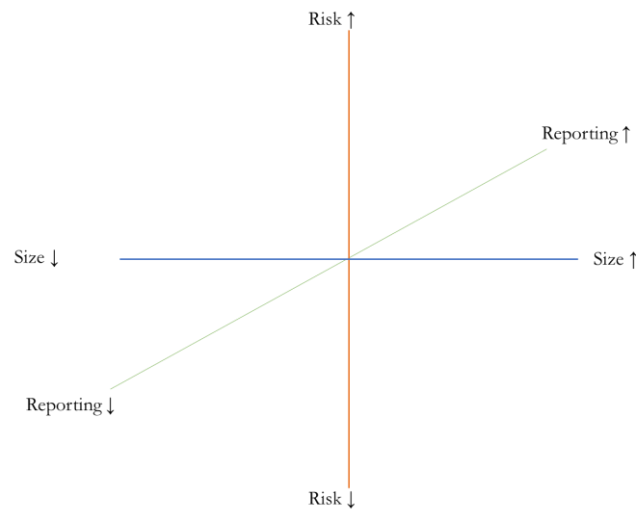


Figure 3.10 Variables influencing aid distribution

Per factor an explanation and a parameterization will be given. Firstly, risk willingness is not associated directly with the percentage of available funds for aid. It is a proxy for the percentage of available capital, which is spent on Safety and Security. The percentage of money that is going to Safety and Security is not documented and especially not openly available, so parametrical assumptions had to be made. These parametrical assumptions are presented in the table below. Reporting is assumed to be included in the percentages given below. The low risk-willingness NGO-agents only spend 80% on S&S if the region categorization changes while they are in that region.

Safety and security percentages (%S&S)				
<b>NGO (Risk-Willingness low)</b>		<b>Reg. 1</b>	<b>Reg. 2</b>	<b>Reg. 3</b>
	<b>%S&amp;S</b>	80%	70%	50%
<b>NGO (Risk-Willingness medium)</b>		<b>Reg. 1</b>	<b>Reg. 2</b>	<b>Reg. 3</b>
	<b>%S&amp;S</b>	75%	50%	25%
<b>NGO (Risk-Willingness high)</b>	The percentage for Safety & security is assumed to always be stable at 10%			

Table 3.8 Percentages aid distribution

Secondly the size of an NGO-agent affects the amount of aid an NGO-agent can provide. This is done through a structural construction. When an NGO has full camp knowledge it will every day consider all POC-agents in its surrounding and transfer the money available after safety and security expenses. It will then randomly choose a number of POC-agents



equal to the size of the organization and transfer all available money of that day. This is corrected for different amount of POC-agents in the model because of different settings for rurality. The money that is available for a day is calculated as follows:

*Equation 3.4 Daily money availability*

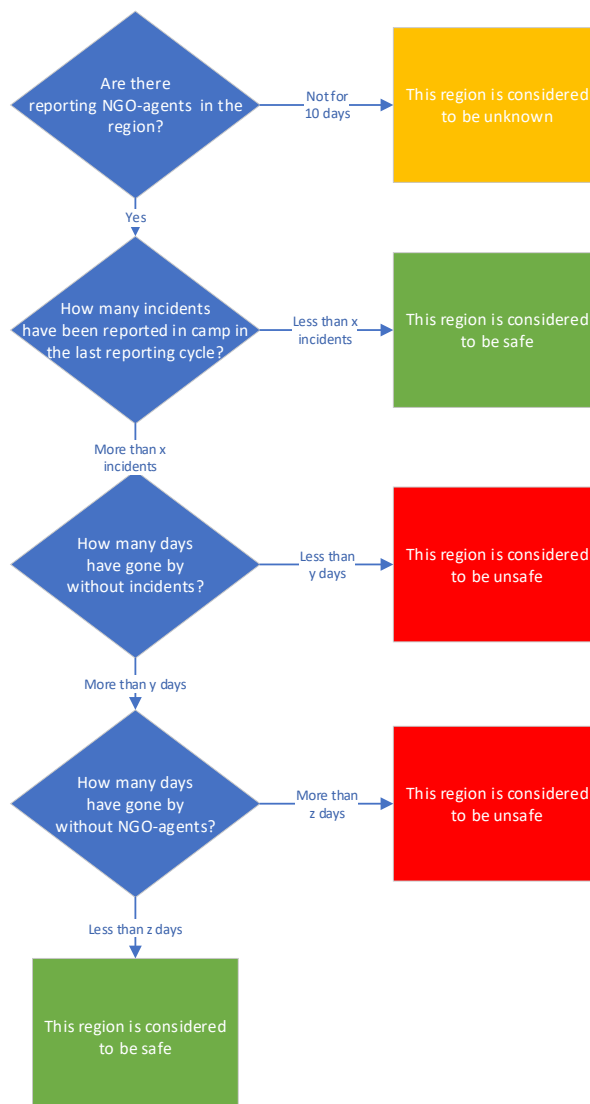
*Money available per day*

$$= \frac{\text{Total available funds}}{\text{Duration project} - \text{current day in project}} * S \& S \text{ percentage}$$

*Structural assumption: Full camp knowledge is required before transfer of aid can start.*

### *Decide region type (Land)*

The type of safety-region an area is, is depending on information provided by the NGO-agents. Looking at the region division in the model, we see the safety of the region as perceived by the NGO-agents. A low number of reporting thus lowers the accuracy of the perceived security. The decision of when a region is safe can be altered by a policy maker, but is the same for all types of NGO-agents. Altering this can lead to different modelling results. A different label does however not mean that there are necessarily less incidents.



*Structural assumption: The incident threshold of when a region is considered to be safe can be varied by the observer.*

*Structural assumption: Policy makers can alter safety standards to define which region is safe and which is not.*

*Figure 3.11 Decision region type*

### Trust build-up and incidents (POC)

The process of deciding trust in humanitarian assistance is no different from the trust decision made in the setup phase.

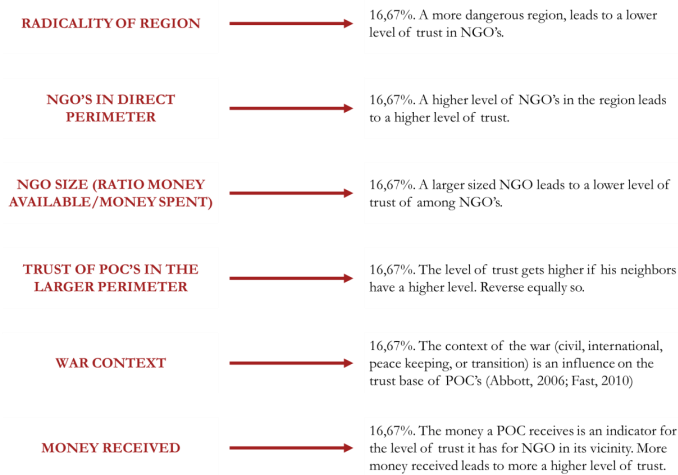


Figure 3.12 Trust build-up and incidents

The percentages are a means to show the impact on the final figure for trust every POC-agent has. Every POC-agent has a number between 0 and 10, which eventually decides the number of incidents it will cause to NGO-agents. The relation between incidents and trust is a stochastic one, with a different magnitude of chance depending on the level of trust. The chance distribution (an assumption), looks as follows:

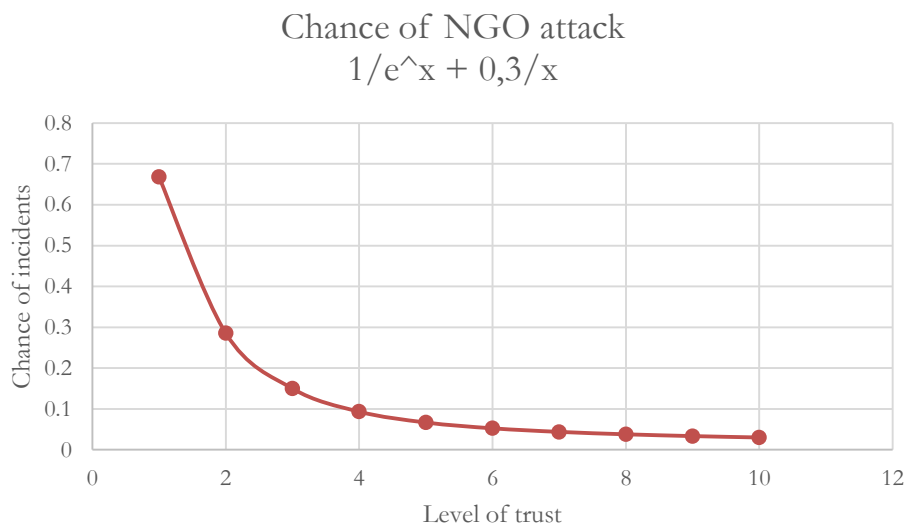


Figure 3.13 Graphical depiction of chance distribution of NGO incidents

It can be seen that when trust is very low, the chance of an incident rises to almost 70%. It then quickly drops and at a trust-level of 4, the chance of an incident already dropped to 10%. As there is no literature on the trust-incident relation, assumptions had to be made. To do so, the historical validation was leading. These model runs need to be roughly resembling to the Syrian case. Through this chance distribution, given multiple model runs the number of incidents amounted to the right dimensions. The figures for incident rates from a single model run and Syrian data (NGOsafety, n.d.) are shown below. The total amount of incidents is higher in the model run than in the Syrian case. This can be explained by the small reporting

number. The daily incidents multiplied do amount to the right dimension. The NGOsafety data are moreover also only reported incidents.

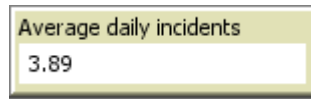


Figure 3.14 Average daily incidents single model run

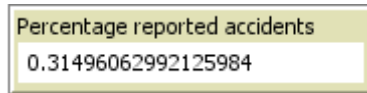


Figure 3.15 Reported percentage of incidents single model run

Total NGO Incidents per Month

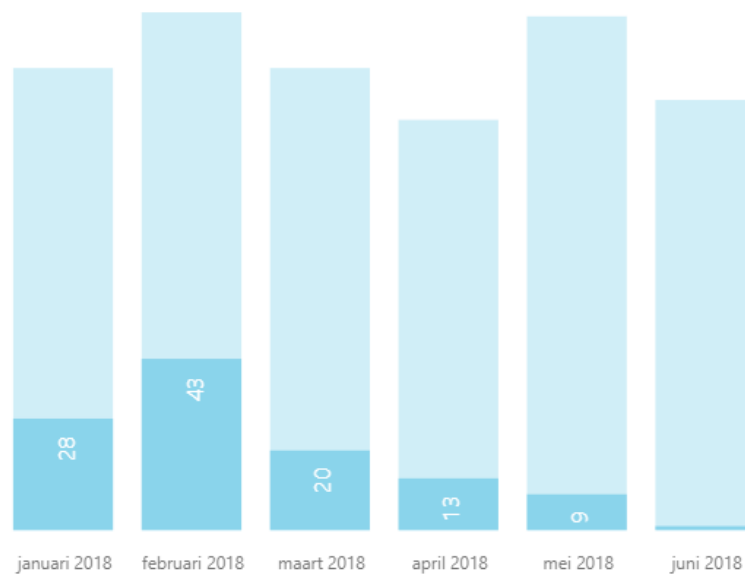


Figure 3.16 Monthly NGO incidents start 2018

If an incident takes place, the POC-agent selects a random NGO-agent in its direct vicinity and commits the incident to the respective NGO-agent.

*Parametric assumption: The chance of incidents lowers quickly given more trust*  
*Structural assumption: There is no distinction in types of incidents*

### 3.3.3 List of assumptions

ASSUMPTIONS	
Parametric assumption	
Assumption	Support of assumption
The total financial need of the population in the model \$7.7 billion	Simplification assumption based on funds used by humanitarian operation in 2017 (NGOsafety, n.d.)
50% of funds is dedicated to Safety & security	iTrack workshop June 2018
There is always 20% more chance that an NGO-agent shares within its cluster, than with every NGO-agent	Cluster meeting happen more frequent, therefore social relations are more inclined to lead to information sharing. 20% is estimate.
The chance of incidents lowers quickly given more trust	Graph fitted with the incident numbers taking place in Syria
Structural assumptions	
Assumption	Support of assumption
The map is initially always evenly divided between three regions	Because it is unknown, division is made evenly
Population in dangerous areas require 20% more aid, population in safer areas 20% less funds	As more dangerous regions suffer from more violence, it is assumed that less regular resources are available
The needed commodities will all be expressed in dollars	The most commonly used proxy for total aid
Factors deciding trust are divided evenly	Since there is no empirical data on factors deciding trust from POC-agent to NGO-agent, even division is assumed
There are three ways to decide the spread of risk-willingness of NGO-agents; uniform, risk taking or risk avoiding	Since willingness to take risk among NGO-agents differs, different chance of risk willingness is assumed
Land is initialization evenly divided in three categories of danger	As a starting point, evenly divided safety regions guarantees emergent behavior from an equal starting point
Decision to share information is made derived from three factors: <ul style="list-style-type: none"> <li>▪ Money currently available</li> <li>▪ Willingness to take risk</li> <li>▪ Incidents that have occurred in the recent past</li> </ul>	No empirical data available on willingness to share information. Decision has been made based on conversations on iTrack workshop.

The aid needs of POC-agents increase with the same amount every day	Factors deciding aid needs are not taken into account, therefore an aggregated number is used
There is always a random factor involved in sharing the right or false information.	Since information sharing is a not a standardized process, randomness is involved.
There is no distinction in types of incidents.	To be able to analyze on high level, incidents are not subcategorized.
An NGO-agents' primary information source to move, is information from other NGO-agents that need help to meet needs.	Every NGO-agent lists the needs to meet from other camps and then picks the NGO-agents which has the most unmet needs.
Risk-taking NGO-agents move to large groups of POC-agents if there is no NGO-agent yet.	Small NGO-agents are often local and know where needs are high. This is not done on the demand of large donors.
Two NGO-agents doing an assessment at the same time do not complement each other's assessment.	If one NGO-agent however has its assessment done earlier, it shares it with all surrounding NGO-agents.
Full camp knowledge is required before transfer of aid can start.	Assessment must be completed before aid can be provided.
A POC-agent moves when he has another POC-agents within his displacement rate which has less needs than himself.	POC-agents move only if there is a POC-agent better off within his displacement rate value.
The displacement rate is independent from the region	Simplification.
The incident threshold of when a region is considered to be safe can be varied by the a policy maker.	This can be seen as stringency of safety & security policy.

*Table 3.9 Assumptions overview*

## 3.4 Verification

---

In the verification step, a check is done to verify if the thing is modeled right (van Dam et al., 2013). In other words; is the pseudo code correctly translated into model code. Several verification steps have been executed to verify the model code in this research.

The detailed verification of this research is shown in appendix B.

## 3.5 Validation

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Validation for an Agent-Based model with a level of abstraction such as implemented in this thesis is challenging and a complete validation is out of scope of this research. Inspired by the book of Van Dam & Nikolic (2013), three types of validation have been chosen to execute. Execution of these validation steps do not imply full validation of the model, but show that the model is going towards the right direction. The types of validation are:

1. Face validation through expert consultation
2. Literature validation

### 3.5.1 Face validation through expert consultation

Face validation has been partly executed through a meeting with Christina Wille. Christina Wille is co-director of Aid in Danger. This is an NGO collecting data on events negatively impacting aid workers and aid agencies. This information it uses to make analyses which it makes available to policy makers. In this interview, assumptions have been partially validated. The model results however have not been validated. The interview can be found in the GitHub repository.

### 3.5.2 Literature validation

Quantitative literature validation is not possible. This is due to the relative new field of research, resulting in a lack of scientific literature on the subject and the impossibility of exact quantification of factors such as trust. What can be achieved by literature validation is to look at prior Agent-Based research in information sharing and derive validation techniques from their research. Altay and Pal (2014) conclude do not perform a full validation, but merely conclude that their assumptions are too restrictive and the interactions among agents are captured with sufficient detail to continue an exploratory modelling study. Given the two forms of validation done here and the interactions based on literature, there can be concluded that there is sufficient confidence in the validity of the model to derive results of an exploratory study.

#### *Incident numbers*

As was shown in section 3.2 on incident creation, there is a resemblance with the real-world Syria case with regards to the total amount of incidents.

#### *Clustering of POCs*

A final observation of resemblance between real-world and model behavior is the clustering of POCs. Whereas in the real world refugee flows also cluster in a camp (Berti, 2015), this behavior can be seen in the model too. This is combined with other population movement dynamics in the model, comparable to real-world dynamics. Rural poverty (Szonyi, De Pauw, La Rovere, & Aw-Hassan, 2006) and harder reachability for NGOs in the rural areas.

### 3.5.3 Validation conclusion

The conclusion that can be drawn after these steps of validation is that a full validation has not been achieved. There are too many uncertainties and the amount of specific data that is available for the validation of this model is very limited. Even though validation is achieved, the data that was available shows that the model is roughly modelling the right dynamics. The conclusion is that there is enough validation to continue

## 3.6 Preliminary conclusion

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In this chapter the implementation of the model has been laid out on two levels of abstraction. Also the agents along with their attributes have been elaborated on. The conclusion can be drawn that Agent-Based modelling is a suitable form of modelling for a humanitarian operation, but because of a lack of validated empirical information, the validation of the model as a whole is thus far not possible. The question this chapter aimed to answer is the following:

*How can information sharing of a humanitarian operation be simulated in an Agent-Based model?*

Based on ten core processes and eight initialization steps the model is implemented. The model logic is inspired by the program cycle by UNOCHA. A needs assessment is done by NGOs (needs assessment), after which other NGOs move to the camp where most aid is needed (strategic planning). Based on experience and size, a certain number of days are needed to move to the camp (resource mobilization). The NGO stays and provides aid until a certain threshold is met (implementation & monitoring). Its achievements with respect to safety and security and effectiveness of aid are monitored and used for evaluation of the budget. If it is positive, more money will be received, if negative, less money will be received (operational peer review & evaluation). After that, the cycle starts again.

Also model verification and partial validation have been done in this chapter. Even though small number of implementation errors have been found, there can be concluded that the model is implemented correctly. Full validation of the model is out of scope for this thesis, but has been done partially. There can be concluded that it has been done sufficiently to proceed with the analysis of the model.





## 1946 – 1963

The first years of the independent Syrian republic were marked by unrest. A large number of coups and constitutional changes took place and prevented Syria from becoming a stable country. The picture shows Egyptian and Syrian leader (Nasser and al-Khawatli) after a successful merge of their countries in 1958. The new country called United Arab Republic was shortlived and ended in 1963.

# 4.

## Experiment design

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### *What are potential alternative policies and scenarios?*

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For developing policies and scenarios, the Syrian crisis case is leading. The case is used in the form of a stylized case study. This means that the case of Syria has been simplified and quantified in order to be suitable for Agent-Based modelling. Agent-Based modelling requires making choices in trade-offs with regard to the inclusion of *complexity* in order to more closely capture real-world phenomena and *simplification* in order to achieve the level of abstraction needed for modelling. Understanding this trade-off is key to understand why simplification steps have been made.

To test the influence of a policy, one cannot simply assume a given future. For the testing of policies, this thesis proposes four scenarios. Every policy is tested over four scenarios. How these scenarios are designed, and why they are designed as such is described in the following section 4.1.

Subsequent section 4.3 describes policies. Four policies are designed and their influence on the KPIs identified in the conceptualization chapter is tested. As with designing the scenarios, the XLRM framework from chapter 2.3 is used as a basis for policy design. For the sake of simplification, a number of variables which are not directly related to information sharing are excluded. This simplification step is made in order to better be able to analyze the impact of different policies.

## 4.1 Scenario variables

The basis for scenarios will be the exogenous variables as specified in the XLRM framework in chapter 2.3. As specified in the framework, they are as follows:

Exogenous variable	Range	Source
Spread of civilians per region	Urban, moderately urban, moderately rural, rural	(Twigg & Mosel, 2018; Wille & Fast, 2010)
Initial turnover rate	20% - 120%	Ranges loosely based on (Mubondo, 2013)
Displacement rate of population	Internal variable, from 1 to 8 patches	(Richmond, 1988)

Table 4.1 Scenario variables

The units for the variables are specified as follows: the *spread of civilians* represents how many agents are present in the model. The total amount of civilians in the model is the same in every scenario. The amount of civilians one agent represents is dependent on the number of agents in the model, defined by the range from urban to rural. The more rural a scenario is, the more agents are present. The *initial-turn-rate* is simply the percentage of staff that leaves an NGO per scenario. The *displacement rate* is defined by an internal variable representing the number of distance-units an agent is willing to move to another agent with less needs. The more distance-units the agent is willing to move, the larger the camps are that will emerge and the less spread out the agent will eventually be on the map.

Twigg & Mosel (2018) and Wille & Fast (Wille & Fast, 2010) describe the different perspective on aid delivering between rural and urban communities. This differentiation is also included in scenarios, as aid-delivery is substantially different in rural and urban communities. There is however no quantified information available. By varying the spread of the population in future scenarios, an estimation can be made on the influence of the spread of the population on the ability to deliver aid.

As presented before in chapter 1.3, the turnover rate is influential in the humanitarian sector. The lack of experience and well-functioning information databases causes humanitarians to live in a ‘perpetual presence’ (Fast, 2017). It is known that this is problematic, but figures are hardly known (ReliefWeb, 2009). Empirical studies provide estimates (Mubondo, 2013), but are very case specific and are therefore hard to extract for use outside that specific case. That is why in this model the initial turnover rates in organizations differs per scenario. Scale estimations for turnover rates in this stylized case are drawn from Mubondo (2013).

Finally the displacement rate of the struck population is a factor in scenarios. Richmond (1988) states that the total number of proactive migrants is a function of distance to safety, intervening opportunity and obstacles. Since last two factors are not included in the model, only the first factor is included: distance to safety. This is translated as the displacement rate. The maximum displacement rate is an exogenous variable, varied in different scenarios.

## 4.2 Scenarios

Now that the variables and its ranges for scenarios have been analyzed, four scenarios will be presented. The model will verify that the policies proposed (presented in chapter 4.3) work in each of the four scenarios. The scenarios are designed to cover the full range of variable values and to represent a realistic picture of real world combination of factors. These scenarios is not meant to exactly model Syria, but is an inspiration for the variable values.

### 4.2.1 Scenario 1: ISIS/ISIL/Daesh taking over

The first scenario is based on ISIS/ISIL/Daesh taking over rural parts in Eastern-Syria and Raqqa. In 2017 over 200.000 Syrians fled their homes and found refuge in camps in Syria and neighboring countries (Loveluck & Zakaria, 2017). Translating that to figures for the scenarios, this results in a high spread of civilians (rurality) and a high displacement rate. The turnover rate is high, because condition were dire. NGOs therefore had difficulties to maintain their staff.

Scenario 1	
Spread of civilians	Rural
Initial turnover-rate	100%
Displacement rate	8 distance-units

Table 4.2 Scenario variables scenario 1

### 4.2.2 Scenario 2: Advanced in conflict of ISIS/ISIL/Daesh taking over

The second scenario describes a case in which the conflict of previous scenario has advanced for a given time. A number of camps have emerged, a phenomenon translated with the change from rural to moderately rural. Civilians that are still in the region have proved to have a lower willingness to move. This translates to the lower displacement rate compared to the first scenario. Finally working conditions for NGOs have gotten slightly less dangerous, leading to a smaller turnover rate.

Scenario 2	
Spread of civilians	Moderately rural
Initial turnover-rate	75%
Displacement rate	5 distance-units

Table 4.3 Scenario variables scenario 2

### 4.2.3 Scenario 3: Aleppo

The third scenario represent Aleppo two years into the war. The battle in Aleppo was one of the fiercest in Syria (ICRC, 2016). About two years into the siege, many people had already fled the city and those who were still there had no opportunity to flee. Translating this into numbers leads to a very urbanized scenario, with a relatively small ability to move. The turnover-rate is lower, as NGOs in the city are mostly staffed by local volunteers which do not have anywhere else to go (Lucas, n.d.).

Scenario 3	
<b>Spread of civilians</b>	Urban
<b>Initial turnover-rate</b>	50%
<b>Displacement rate</b>	2 distance-units

*Table 4.4 Scenario variables scenario 3*

#### 4.2.4 Scenario 4: North of Damascus

The fourth scenario represents a region in Syria which has been relatively stable. This region has been controlled by Assad's state army over the years (Syria Live, 2018) and has known relatively little violence. This is translated to a moderately urban area with a low displacement rate. There is relatively little willingness to move away. The turnover rate is low as NGOs are getting into relatively few dangerous situations. The area is controlled by Assad's state army and there are therefore no conflicts between rebels and the state army.

Scenario 4	
<b>Spread of civilians</b>	Moderately urban
<b>Initial turnover-rate</b>	20%
<b>Displacement rate</b>	1 distance-unit

*Table 4.5 Scenario variables scenario 4*

### 4.3 Policy variables

---

The next step is the definition of hypothetical policies that could affect the outcome of the model. Since the aim of this research is not to run already existing policies, but to analyze the impact of certain factors for future policy making, the variables are chosen so that they make a coherent set of input variables which could work as such in the real world. Comparable to the definition of the scenarios, four policies will be formulated. These policies will be formulated so that the ranges of the policy levers are explored and that the policies are coherent internally. The source for the values of the ranges are given below. The policy levers and their value range are the following:

Policy lever	Range	Source
Duration IM cycle	15 – 45 days	( <i>Whole of Syria 4W System (Who does What, Where, and When)</i> , 2015)
Retain staff	Efficient, Moderately efficient, Moderately Inefficient	(Dubey, 2016)
Information processing time	2 – 6 days	
Risk spread of NGOs	Risk avoiding, neutral, risk taking	(UNOCHA, n.d.-a)
Project duration	40 – 438 days	(Christian Els, Mansour, & Carstensen, 2016)

Table 4.6 Policy variables

The duration of the IM cycle is drawn from the Whole of Syria Approach. The Whole of Syria approach is an initiative by UNOCHA to combine coordination of humanitarian efforts in Syria, Jordan and Turkey. The diagram used to describe the information coordination is the following:

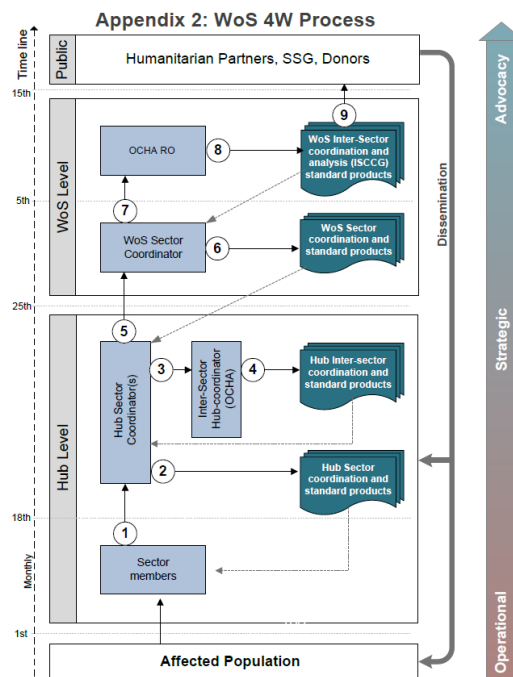


Figure 4.1 (*Who does What, Where, and When*), 2015)

The duration of the IM cycle which is initially maintained is the monthly cycle meeting of sector members with hub coordinators.

*“Sector members share data with the hub sector coordinator at the most granular level possible.”* (*Whole of Syria 4W System (Who does What, Where, and When)*, 2015)

The range which has been chosen to vary policies over is 50% up and 50% down (so 15 to 45 days). This is chosen so that the effects of an increase or decrease of duration of the duration of the IM cycle can be assessed.

The willingness to take risk is a policy lever, as UNOCHA has advocacy as one of their five core tasks. They describe this as follows:

*“To OCHA, advocacy means communicating the right messages to the right people at the right time. These people include humanitarian agencies, non-governmental organizations (NGOs), community-based organizations, national governments, local and international media, parties to conflict, companies, donors, regional bodies, communities affected by emergencies and the general public. The aim is that they increase urgent funding or support, change their policies or keep to their commitments.”* (UNOCHA, n.d.-a)

Advocacy is a concept which is very hard to grasp through numbers, so assumptions on quantification had to be made. The three options that have been provided here involving the willingness to take risk of NGOs, show the distribution of NGOs in the model regarding their willingness to go into unsafe areas. Willingness to take risk can be seen as a proxy for advocacy.

Retaining staff is a discrete variable, based on the paper by Dubey (2016). The AVE of work related factors, which can be influenced by policy is known. The possibilities of the policy maker are coded through values between -1 and 1, representing a positive impact (1) or negative impact (-1). The policies have different values, given the priority a policy maker gives to retaining staff.

The project duration is specified by a top boundary and a bottom boundary. Every NGO in the model has a random number between these two boundaries. The NGO always has projects of that duration. The boundaries of project duration are inspired by research of Els et. al. (2016).

## 4.4 Policies

---

Based on the ranges defined above, the different policies have been defined. As with the scenarios, this does not define already existing policies, but merely a combination of identified policy variables.

### 4.4.1 Policy 1: Low trust, high control

The first policy captures a situation where the policy maker decides for tight control on the incoming information. This results in a fairly high information processing time. The tight control implies that NGOs active under this policy will be more risk avoiding. The tight control also implies that every 15 days there will be an opportunity to share safety and security data among the NGOs. As control is high and the NGOs risk avoiding, the project duration is likely to be rather long. Changing project location comes with uncertainty, so this is avoided when possible. The working environment of the NGOs is fairly safe, so the policy for turnover rates can be effective.



Policy 1	
<b>Information processing time</b>	4
<b>Risk spread of NGOs</b>	Risk avoiding
<b>Duration reporting cycle</b>	15 days
<b>Project duration</b>	Between 292 and 438 days
<b>Effectiveness turnover rate policy</b>	Efficient

*Table 4.7 Policy 1 overview*

#### 4.4.2 Policy 2: High trust, low control

The second policy aims to define the opposite of the first policy. A let-go policy where the policy maker has high trust in the NGOs capacity to sort things out autonomously. This means the IM cycle is rather long. The NGOs are operating autonomously without strict safety and security policy of a superior and will therefore likely be more risk taking. More risk taking behavior is however associated with a more inefficient policy towards turnover rates. The project duration is shorter, as the intensity of projects is likely to be higher. Information processing time is lower, as NGOs spend less time verifying information.

Policy 2	
<b>Information processing time</b>	2
<b>Risk spread of NGOs</b>	Risk taking
<b>Duration reporting cycle</b>	45 days
<b>Project duration</b>	Between 40 and 60 days
<b>Effectiveness turnover rate policy</b>	Inefficient

*Table 4.8 Policy 2 overview*

#### 4.4.3 Policy 3: Organic development

Organic development is a policy which is built without extremes. It is an intermediate policy solution combining components of the first policy, as well as the second policy. The IM cycle is chosen as it is currently regulated. The information processing time is fairly long, as there is no policy pressure to reduce it. The NGOs are not specifically risk taking or avoiding and the project duration is also in between the two more extreme previous policies. The capacity to retain people in the organization is moderately inefficient, because this represents the mean between the last two policies.

Policy 3	
Information processing time	6
Risk spread of NGOs	Neutral
Duration reporting cycle	30 days
Project duration	Between 80 and 120 days
Effectiveness turnover rate policy	Moderately inefficient

Table 4.9 Policy 3 overview

#### 4.4.4 Policy 4: Combination

The final policy reuses components of the previous three policies and combines extreme values with more moderate values. This policy is not aiming to be a coherent set of values, but rather a combination of previous options. This policy has been chosen to enable analysis of the numerical influence of changing an input variable towards an output variable (KPI). A double policy can more accurately prove if a variable has indeed a strong influence on a KPI or not.

Policy 4	
Information processing time	4
Risk spread of NGOs	Risk taking
Duration reporting cycle	30 days
Project duration	Between 292 and 438 days
Effectiveness turnover rate policy	Efficient

Table 4.10 Policy 4 overview

## 4.5 Overview of experiments to run

The table below presents an overview of the experiments that are going to be executed. The abbreviations are used in the analysis chapter to indicate which experiments is referred to. Every combination is executed 100 times, to exclude skewed results because of stochasticity.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Policy 1	S1P1	S2P1	S3P1	S4P1
Policy 2	S1P2	S2P2	S3P2	S4P2
Policy 3	S1P3	S2P3	S3P3	S4P3
Policy 4	S1P4	S2P4	S3P3	S4P4

Table 4.11 Overview experiment combinations

## 4.6 Preliminary conclusions

---

This chapter aimed at identifying concrete quantifiable policies and scenarios which can be used to run experiments with the model. The question to answer was the following:

*What are potential alternative policies and scenarios?*

Four scenarios have been formulated according to the stylized Syria case study. A full range of variable space is covered and the variables are internally coherent. Subsequently, four policies have also been designed. Real-world policies in information management deal with policy variables in a qualitative way, so the policies that are defined in this thesis are hypothetical. The policies are defined to cover the full range of the identified variables and in a way that they are internally consistent.



## 1963 – 2000

The coup leading to the end of the United Arab Republic is known as Syria's 8 March revolution. The military committee of the Syrian branch of the Arab Socialist Ba'ath seized power. A new coup in 1966 brought an even more radical faction of the Ba'ath party to power and installed 1963 coup leader Salah Jadid as president. In 1970, a third coup followed which installed defense minister Hafez Al-Assad as president. He remained president until 2000. The picture shows 1963 coup leader Michel Aflaq (L) and Salah Jadid (R).

# 5.

## Analysis of results

---

*What is the impact of policies on the performance of a humanitarian operation for the identified scenarios?*

---

This chapter will show the results of the research on the impact that different scenarios and different policies have on the defined KPIs. As this is exploratory policy design, it is not only relevant which combination of factors leads to the best set of KPIs, but also the extent to which different factors in the policy design affect the eventual outcome of the KPIs.

The analysis chapter will consist of the following sections:

1. High aggregation results of policies per scenario
2. Elaboration per KPI of first scenario
3. Analysis of differences per scenario

Through this build-up a complete picture can be drawn on the results of this research.

### 5.1 High aggregation results of policies per scenario

---

#### 5.1.1 Steps towards high aggregation result table

This first section describes how every policy has functioned over the four different scenarios. This is done by means of a table, using a color code to describe the performance of the respective policy in the scenario. The results that are shown here give a high-level overview of the performance of each policy. The color codes represent a combined performance of the policies on all KPIs. The results are not weighed and every category of KPIs is considered to be equally important to the policy-maker.

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	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Policy 1				
Policy 2				
Policy 3				
Policy 4				

Table 5.1 Overall performance of policies

	Worse than average
	Slightly worse than average
	Average
	Slightly better than average
	Better than average

Table 5.2 Legend for overall performance table

To get to the table above, three aggregation steps were made:

1. *From numerical to color codes:* As can be seen in appendix E, the color codes derive from the analysis of performance on seven KPIs. How these color codes are defined precisely is explained in the next section.
2. *From individual KPI to categorical KPI.* All seven KPIs are specified into four categories of KPIs (total aid delivered, efficiency, safety and transparency). Their individual color codes are combined into one color code per category.
3. *From category to overall score.* The last step combines the scores per category into one final color code per policy, per scenario. This leads to the table shown above.

### 5.1.2 Lessons from high aggregation result table

#### *No extreme values in results*

Table 5.1 shows the results through color codes. The first observation from the table is that the most extreme color codes ('worse than average' and 'better than average') are not used. This means that none of the specified policies excel compared to the other policies in a single scenario.

#### *Not one robust policy*

A second observation is that there is no policy performing slightly better than average with all scenarios. Therefore it can be concluded that there is not a single robust policy which can be used in all circumstances.

#### *Implications for analysis*

The conclusion is that this table does not provide a clear answer to which policy performs best in any circumstance. To be able to draw conclusions from the model, we need to take a deeper look into the patterns that have led to the color codes in this table. The following chapter investigates how the policies behave in the first scenario, and which model patterns underpin that behavior.



## 5.2 Analysis per KPI of first scenario

---

### 5.2.1 Total funding available for NGO-agents

#### *Behavior description*

The total funding available for NGO-agents is the total amount of money that NGO-agents have at their disposal.

Observations from the single run figure 5.1 are the following. The first policy line (red) shows high peaks, interchanged with lower peaks. The peaks represent the moment when NGO-agents receive funding. The height of the peaks shows how much funds they have received. The second policy line (green) shows oscillatory behavior. Again the peaks show funding moments, but funding cycles are shorter. This means the peaks are lower, but closer together. An upward trend can also be seen, as well in the single run, as in the combined runs. The third line (blue) shows oscillatory behavior in beginning, after which it remains stable around  $0.5 \text{ e} + 09$  USD. This means that there is no more funding coming in. This behavior can be due to multiple reasons, but is not a trend seen which causes differences in the combined policies. The fourth line (purple) shows high and wide peaks, comparable to the first line. It remains stable at around 1100 days. This is again not behavior which influences average results, as can be seen in figure 5.2.

#### *Behavior analysis*

The high peaks in the first and fourth policy compared to the lower peak from the second and third can be explained by the longer project durations which are equal for one and four. Project duration is a good indicator for the height of the peaks, because money is allocated to agents which are both in need of money and have a good track-record in converting money. The agents with a longer project duration have more time to spend money between day zero and their first funding renewing. They have thus been able to use more money, leading to a higher need for new money. This subsequently leads to a higher new funding. The conclusion therefore is that a longer duration of the projects leads to more money availability for NGO-agents. This is also supported by the average size of the surface under the lines.

The size of the surfaces of the line graphs are shown in table 5.3. The surface for all runs have been calculated as a mean. This shows that the area under the fourth policy lines are larger than the all other policy lines. Conclusion that is to be drawn is that not only the duration of the reporting cycle is an indicator for the amount of money that is available to NGO-agents. The first and the fourth policy namely have the same project durations, but a different size under the graph. To explain the differences between the two well-performing policies (one and four), it is relevant to look at how the policies are built up. The most striking difference between the first and fourth policy, which is not associated with the duration of the projects, is the willingness to take risk. Whereas the first policy has NGO-agents which are risk avoiding, the fourth policy has NGO-agents which are risk-taking. More risk means that the NGO-agents spend less money on safety and security. This means that the conversion rate of funding is likely to be higher in the fourth policy, leading to a higher funding.

Other criteria for the level of renewal of funding, next to *funding converted* and the *efficiency of spent money*, are the *reporting status* and the *incidents*. The reporting status of the first and fourth policy are significantly worse throughout all model runs, leading to a tempered height of funding. The number of incidents is high for the second policy, among others

leading to a lower funding for the second policy. The conclusion is that a bad reporting status can be compensated through other criteria.

### Conclusions

The conclusions drawn from the analysis of this KPI are threefold:

1. *NGOs will have more funding at their disposal when the project durations are longer.*

The most obvious conclusion is that the best indicator for the level of funding for NGO-agents is the duration of the project. This is explained by the fact that there are less transactional costs and there is a long time to spend the money. The latter means that all money is spent and that the conversion rate is therefore positive.

2. *Level of risk of an NGO-agent alone is not a good indicator for available funds.*

A high level of risk for an NGO-agent is in this scenario beneficial for the total amount of fund available for the NGO-agent. It is specifically positive in this scenario, as there are not many dangerous moment leading to incidents.

3. *A low score for reporting does not weigh up to other funding criteria.*

The first and fourth policy both have low scores for reporting, but still receive most funds.

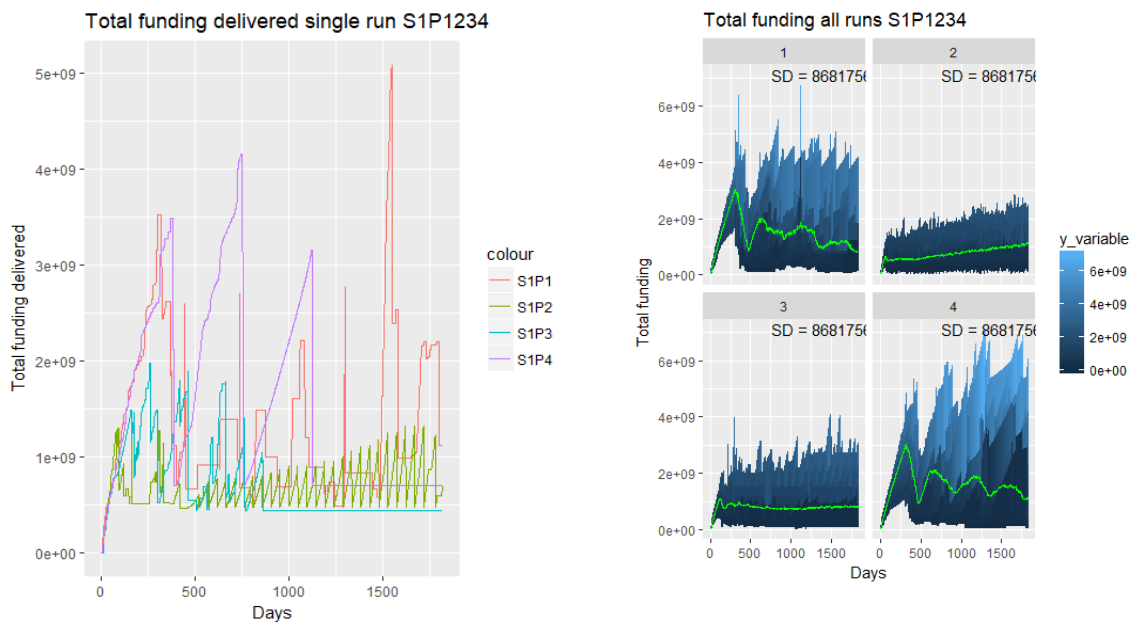


Figure 5.1 Funding available to NGOs, single run

Figure 5.2 Funding available to NGOs, all runs,

Policy	Area under line single run	Average area under line all runs
1	$2.41 * 10^{12}$	$2.75 * 10^{12}$
2	$1.23 * 10^{12}$	$1.52 * 10^{12}$
3	$1.26 * 10^{12}$	$1.69 * 10^{12}$
4	$2.76 * 10^{12}$	$4.37 * 10^{12}$

Table 5.3 Surfaces under the graphs

## 5.2.2 Total percentage of POC-agents helped

### *Behavior description*

The percentage of POC-agents which is helped shows which percentage of all POC-agents has an NGO-agent in its vicinity.

The percentage of POC-agents which is covered is differing strongly among the four policy lines as visible in figure 5.3. The first policy (red) shows a gradual dip in the percentage covered, followed by a spike. The second policy (green) shows a large increase from the first moment on. It remains at 100% covered until around 1500 days into the modelling cycle, after which it dips to 70% covered. The third policy (blue) and the fourth policy (purple) show very similar behavior. They both decrease from about 70% to a stable ~ 40%.

When juxtaposing figure 5.3 with 5.4 and 5.5, it can be seen that the differences in policy lines in 5.3 do not show general behavior for all runs. 5.4 shows that all policies show approximately similar behavior, apart from the third policy performing approximately 10% lower than the rest of the policies. The density plot in 5.5 underlines that statement.

### *Behavior analysis*

When looking at the percentage that is receiving help over time, one element catches the eye. In figure 5.3, it is visible how the second policy is significantly more able to cover a large percentage of the POCs in the model. If this is however compared to the density plot of all runs on all policies, it is also visible that the second policy is not significantly closer to 100% than other policies. Through this example, the conclusion can be drawn that coverage of POCs is strongly dependent on the randomness inherent to the movement of agents in the model.

In figure 5.4, it can be seen that the only significantly deviating policy is policy 3. The average amount of POC-agents helped at a time is lower. The unique features of the third policy are its relatively long information processing time, along with a longer duration of the reporting cycle. The longer duration of the reporting cycle is playing a role in the coverage of NGOs. A longer reporting cycle means that the information on safety of a region lags behind. As there is increasingly more trust towards NGO-agents in this scenario, it means that the NGO-agents in the third policy refrain from entering regions which are unsafe according to them. These regions are however actually safe, so this leads to a lowered coverage.

### *Conclusions*

1. *Coverage of POCs is strongly dependent on the randomness of movement of agents in the model.*

Based on figure 5.3 and 5.5, it can be concluded that randomness of movement of POC-agents is key in the percentage of coverage for NGO-agents. When POC-agents cluster together faster, a larger share of POC-agents can be helped.

2. *The duration of the reporting cycle influences the coverage of NGO-agents negatively.*

A short reporting cycle causes NGO-agents to avoid regions which are actually safe enough to enter.

3. *The willingness to take risk is not an important factor for the coverage of the POCs.*

Willingness to take risk is not a key factor in the covered percentage in this scenario. This is supported by tables 5.7 to 5.9.

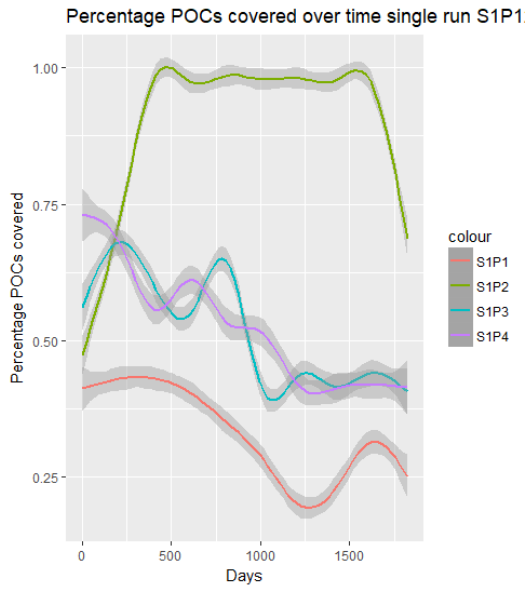


Figure 5.3 Smoothed percentage covered POC-agents. Single run.

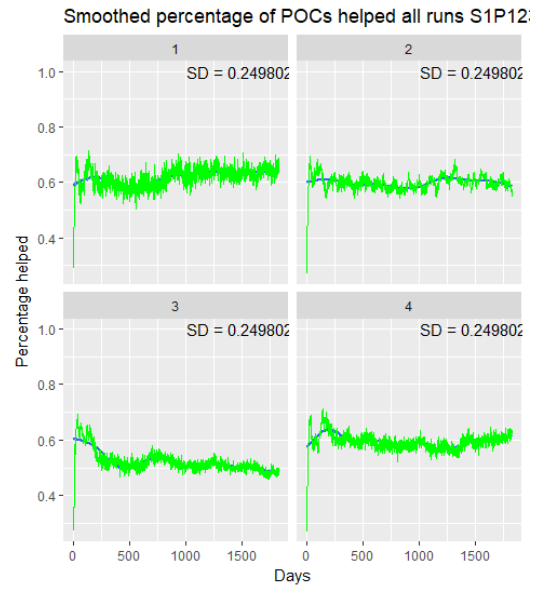


Figure 5.4 Smoothed percentage covered POC-agents. All runs.

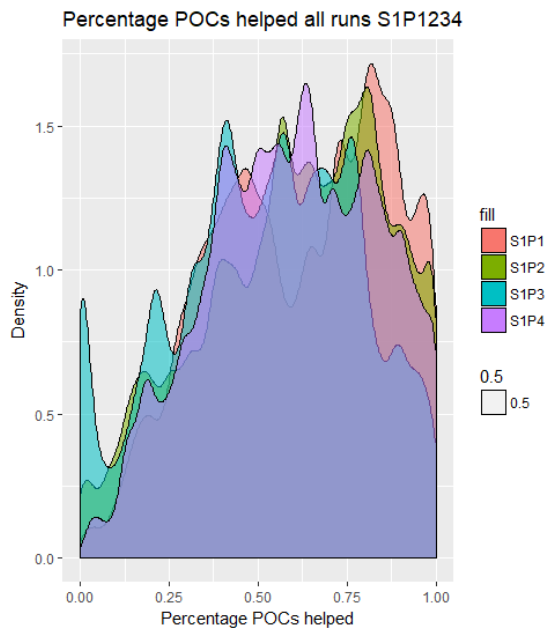


Figure 5.5 Density plot covered POC-agents. All runs

### 5.2.3 Percentage of funding converted

#### *Behavior description*

The percentage of funding converted shows which percentage of the total money available to NGO-agents is eventually converted to aid, instead of safety & security. This is different than the percentage of funding delivered, which measures which percentage of money received by donors is eventually used.

Figure 5.6 shows that all policies converge to around 91% converted funding. The third policy (blue) shows a slightly lower conversion rate than the first and fourth policy. The second policy (green) shows a decreasing line over time.

#### *Behavior analysis*

Remarkable behavior for this KPI is the converging behavior for all policies but the second. The percentage of converted funding declines over time not only in the single run, but also within the curve representing all runs. This behavior can be explained by the short project duration and the relatively long reporting cycle of the second policy. The short project duration means that there is often a period of transaction period between an old and a new project.

If the project duration would be the only indicator, the third policy should also have a dip in conversion rate. This is however not the case. The further the model advances, the more clustered the POC-agents are. This means that in order to move to a new project, the camps are bigger and there is a smaller percentage of POC-agents still in the more desolated areas of the model. This means there is a lower likeliness of ‘aggressive’ POC-agents. Risk taking NGO-agents do however move to those areas and are to a lesser extent able to transfer aid efficiently.

#### *Conclusions*

1. *A short project duration has a negative effect on the conversion rate of funding*

A short project duration causes frequent changes of project. The chance of ending up in a dangerous region is higher, and therefore more money needs to be allocated to Safety & security.

2. *Taking risk is not beneficial for the conversion rate of funding in a scenario with clustered POC-agents.*

Even though the second policy shows risk-taking NGO-agents (i.e. little Safety & security spending), their conversion rate is relatively low. This means that risk willingness is not a decisive factor for the conversion rate of funding.

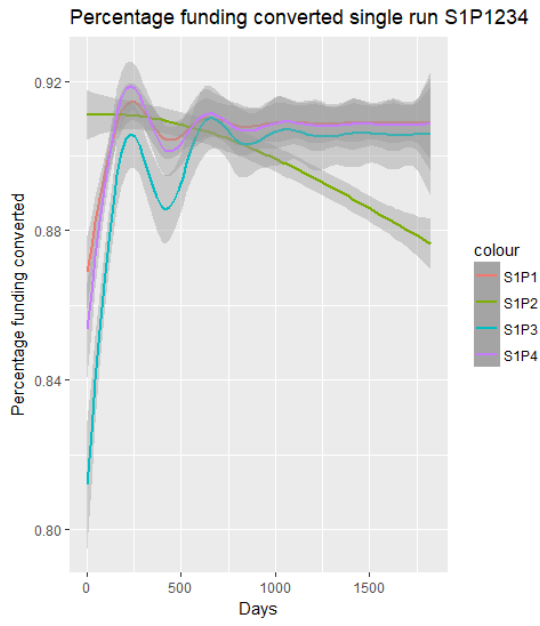


Figure 5.6 Smoothed graph percentage funding converted pver time. Single run.

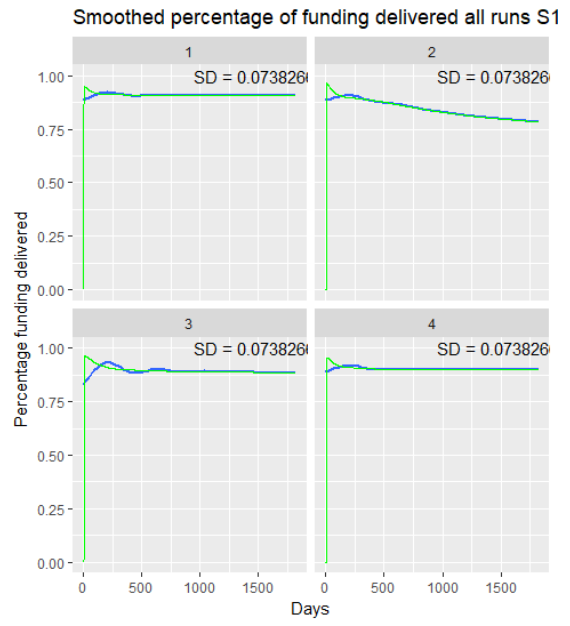


Figure 5.7 Smoothed graph percentage funding converted pver time. All runs.

## 5.2.4 Total time to move to camp

### *Behavior description*

The total time to move to camp shows the cumulative time which is needed by all NGO-agents to move from one camp to another. The lines are linear, as project durations are set as a constant at every modelling instantiation.

In figure 5.8, the first policy line (red) is the most efficient one. If this is however compared to all runs, it can be seen that this line is merely a good extreme from the first policy. Looking at the surfaces under the combined graphs, it can be seen that it is second policy, not the first policy that shows the best results.

### *Behavior analysis*

The differences in transaction time can be explained. The second policy has risk taking NGO-agents which do not spend much time verifying new information. This means they are quickly off to a new location without further delays. This is combined with a very low information processing time, automatically leading to a faster processing time. This last variable also explains why the fourth policy, also with a risk-taking group of NGO-agents, is not moving from camp to camp faster.

### *Conclusions*

1. *Information processing time is the most important indicator for the transaction time.*

The time it takes to verify and act on a piece of information is lowest for the second policy. This shows in the total time needed to move to a camp, which is lowest for the second policy.

2. *Risk willingness is an indicator which influences the transaction time.*

A more risk willing policy leads to more occasions where a new camp needs a needs assessment. This shows in table 5.4, where policy four has higher camp movements compared to one and three. Two is left out the equation, as their information processing time is low.

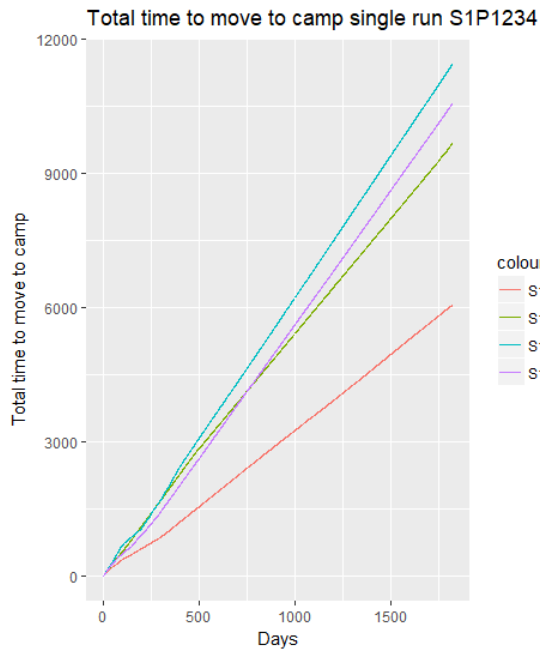


Figure 5.8 Total time to move to camp of all NGO-agents over time. Single run.

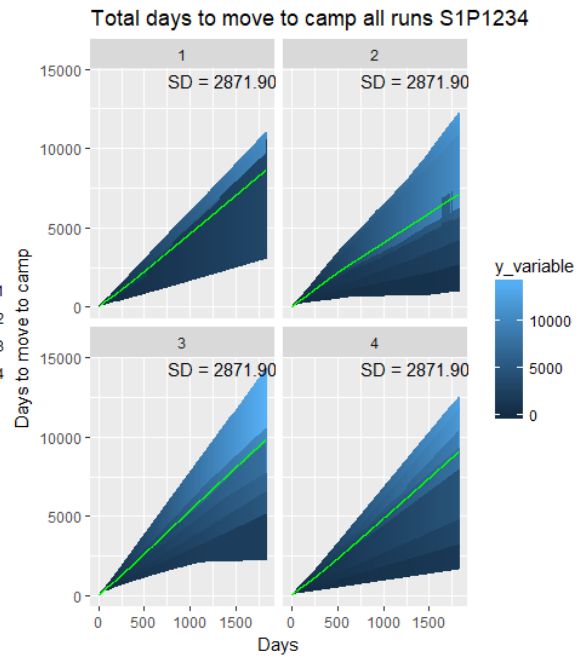


Figure 5.9 Total time to move to camp of all NGO-agents over time. All runs.

Policy	Area under line single run	Average area under line all runs
1	5426025	8450510
2	8993127	5715219
3	10358235	8663635
4	9355456	9092989

Table 5.4 Surfaces under lines of time to move to camp.



## 5.2.5 Total incidents

### *Behavior description*

The total amount of incidents shows the incidents that are experienced by NGO-agents. These can be NGO-internal and NGO-external incidents.

Even though incident behavior at first glance seems to be linear, deviations arise. The first policy shows the least amount of incidents, but this is not generalizable. The average line shown in the first policy graph in figure 5.11 shows that the average is higher than the line in the single run. The second policy shows the largest amount of incidents in the single run, but shows a relative extreme value as can be seen in 5.11. The third policy starts linear, shows a nod shortly before the 1000<sup>th</sup> day, after which it again continues linear. These nods are seen more often, as can be seen on the low and high boundaries in the combined graphs. Finally, the fourth policy shows linear behavior, with a small downturn in steepness over time.

### *Behavior analysis*

As visible in the average areas under all runs, the difference in total incidents between scenarios is very limited. No conclusions on differences among policies can be drawn in this case. The only difference between different scenarios is the range in which the lines are. This implies that there is a chance for a lower total number of incidents. Because of the wider range, there is also a chance for a larger chance for incidents.

A phenomenon that can be seen from this graph is that in some model runs the rate of incidents suddenly drops. This can be explained by the sudden area safety judgement. If a region suddenly swaps from unsafe to safe it is less likely that incidents happen in that specific area. If the amount of POC-agents in the respective area is high, this change can be noted on overall graph. Most times, the region decision swaps after approximately 1000 days.

The policies do not have a strong influence on the incident number in this scenario, but do have an impact in other scenarios. This is further explained in chapter 5.3.3.

### *Conclusions*

1. *Safety and security situations can change quickly after a categorization swap.*

The speed at which incidents occur changes quickly once POC-agents are clustered in the same region and the safety categorization of NGO-agents changes. This causes NGO-agents to move into that region and provide aid, leading to higher trust and less incidents.

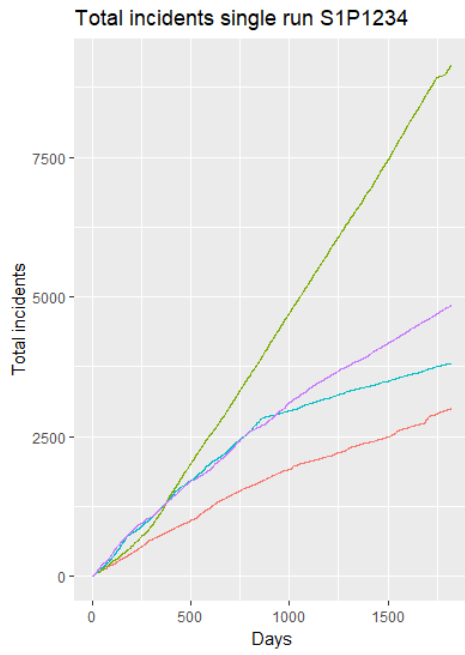


Figure 5.10 Total incidents over time. Single run.

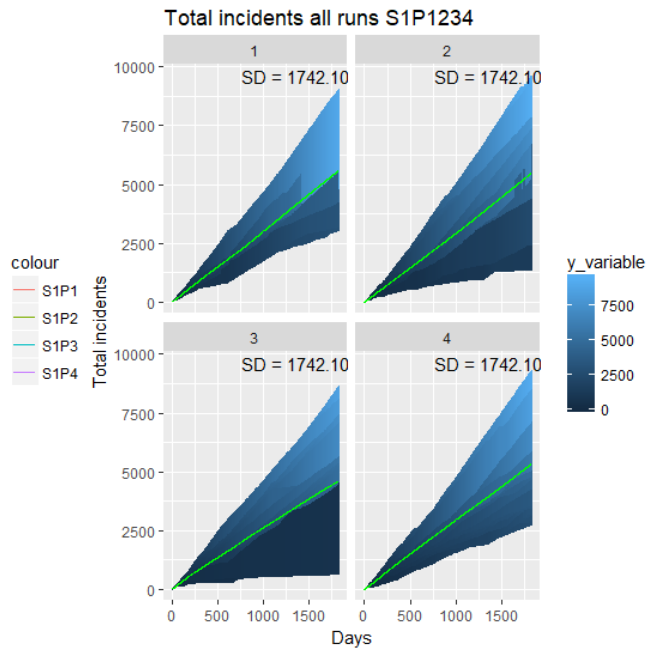


Figure 5.11 Total incidents over time. All runs.

Policy	Area under line single run	Average area under line all runs
1	3008598	4695195
2	7838893	4301837
3	4458008	4206525
4	4934265	4627039

Table 5.5 Surfaces under lines of total incidents

## 5.2.6 Fake news reactions

### *Behavior description*

Fake news reactions show the total amount of fake news reactions of all NGO-agents. A fake news reaction can happen when an NGO-agent moves towards a new project. Depending on how much risk it is willing to take, there is a stochastic chance it reacts to a fake news source.

The behavior for all four policies is linear with noise. This linearity is caused by the project duration, which is a constant. Therefore the opportunities for fake news reactions also remain stable. Other observations from figure 5.12 are that the second and fourth (green & purple) policy jointly react significantly more often to fake news than the other two (blue & red). This is not generalizable behavior, as can be seen by the average area under all lines. The difference under the lines for the single run and all runs is remarkable and will be further explained in the following section.

### *Behavior analysis*

Fake news reactions are related to the likeliness of an NGO-agent going after a fake-news source: every time an NGO-agent moves away, there is a chance that he moves to the wrong destination. The explanation for the higher values of fake news reactions in the first and fourth policy can be found in the next section, where one can see that, in the policy options one and four, the NGO-agent does not disclose their incidents and thus is not reporting their information. This is again due to their longer projects, which stimulate a more closed and less transparent way of working through their larger availability of money. So even though there are less opportunities for a fake news reaction due to the less frequent project changes, the closedness of the organizations leads to more fake news reactions after all.

An effect worth mentioning is the larger ranges of the second and fourth policy, as can be seen in 5.13. This is caused by the larger willingness to take risk of the NGO-agents. This leads to a higher chance of fake news reaction. Both policies are risk taking, but the fourth is fortified by the longer project duration. There is a chance that with the second policy a very high number of fake news reactions takes place, but on average the fake news reaction is relatively low.

### *Conclusions*

1. *A long project duration causes a larger number of fake news reactions, because of the lack of transparency in long-lasting projects*

NGO-agents with a long project duration have little incentives to share information, as their money source is relatively certain. This leads to a very closed off group of NGO-agents, which is again leading to a lot of fake news reactions. NGO-agents simply do not know where to go and therefore react to false news.

2. *The willingness to take risk increases the chance for fake news reactions.*

The willingness to take risk automatically increases the chance of false news reactions, for every time an NGO-agent moves to a new location. If an NGO-agent however needs to move to a new location often, the chances are still higher that the cumulative number of fake news reactions stays high.

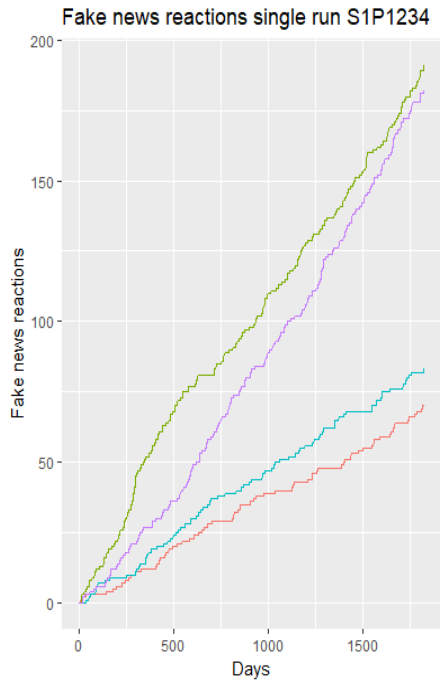


Figure 5.12 Total fake news reactions over time. Single run.

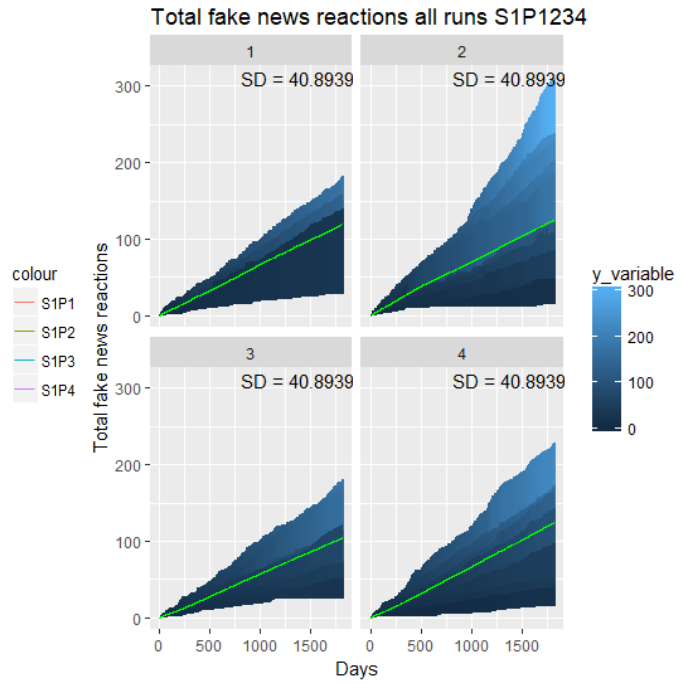


Figure 5.13 Total fake news reactions over time. All runs.

Policy	Area under line single run	Average area under line all runs
1	61844	142138.5
2	181247.5	103828.5
3	77764.5	104930
4	150823	140186

Table 5.6 Surfaces under lines of fake news reactions

## 5.2.7 Percentage of reported incidents

### *Behavior description*

The percentage of reported accidents shows the total percentage of incidents which are reported by all NGO-agents.

The first policy (red) shows a strong decline in figure 5.14 and remains at approximately 20% reported incidents. The third and fourth (blue & purple) policy show similar behavior, where initially percentage reported drops quickly, after which it recovers over time to almost 40%. Finally the second policy (green) drops quickly, after which it recovers steadily. Behavior for policy one and two is generalizable. The third policy shows a slower recovery rate than all lines combined, whereas the fourth policy increases fairly strong in the single run, which does not happen in the combined runs.

### *Behavior analysis*

The difference in percentages of reported incidents is best visible in figure 5.15. The factors deciding if an organization reports its incidents are: (I) *more incidents than in the previous project*, (II) *the amount of money they currently need* and (III) *an autonomous variable*, different for more risk taking or less risk taking NGO-agents. What can be seen in the density graph is that NGO-agents in the two policies with a long project duration (one and four) are very unlikely to share their information, as they are not lobbying for more money. NGO-agents in the second policy however are very likely to share information. This is because they are constantly lobbying for more money.

### *Conclusions*

#### **1.** *A long project duration causes for an un-transparent organization*

As is visible in figure 5.16, NGO-agents in the first and fourth policy hardly share their information on incidents. This is because the agents are not lobbying for new money and therefore have no incentive to share information. Their non-transparency covers up for the incidents, which allows them to also have high funding, as was already concluded in 5.2.1.

#### **2.** *More risky NGOs are more inclined to share data than risk avoiding organizations*

The second policy shows that a more risk taking policy is more inclined to share information. This leads to less funding. There can be concluded that there is a trade-off between transparency and total available funds for NGO-agents. A policy maker cannot prioritize transparency and available funds at the same time.

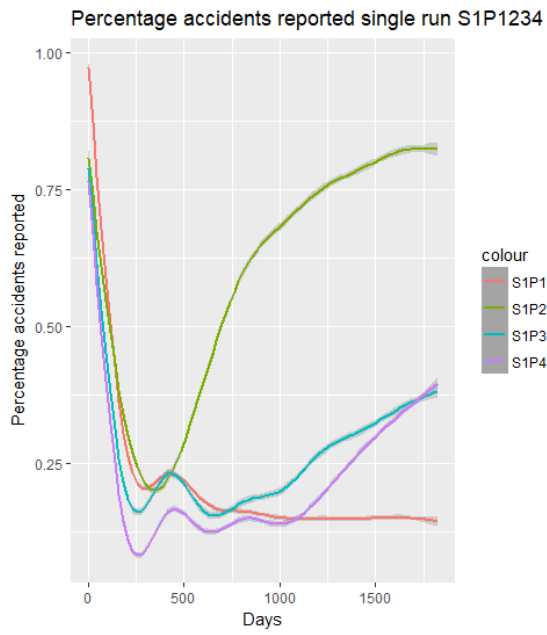


Figure 5.14 Smoothed percentage incidents reported. Single run.

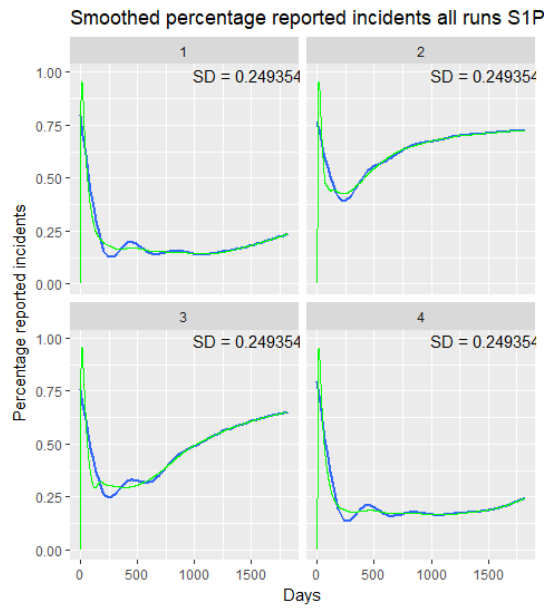


Figure 5.15 Smoothed percentage incidents reported. All runs.

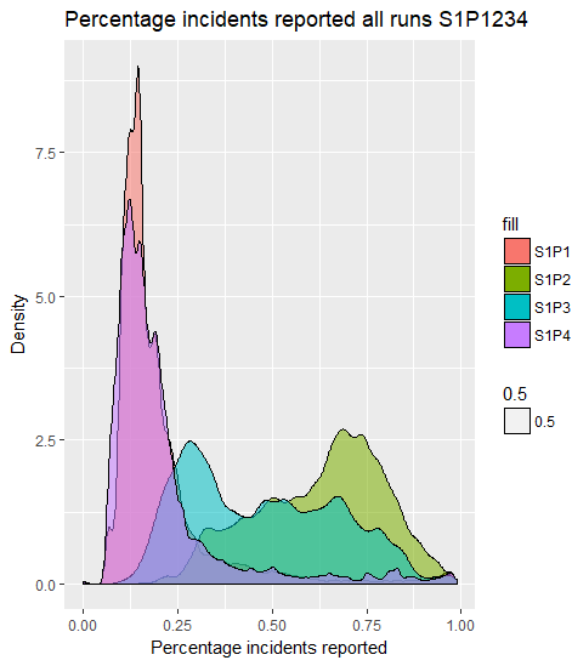


Figure 5.16 Density plot percentage reported incidents. All runs.

## 5.2.8 Preliminary conclusion

Having looked at all policies, the table below presents an overview on which policies work best given the circumstances of the first scenario.

Scenario 1	Funding available	Percentage covered	Percentage converted	Total processing time	Total incidents	Fake news reactions	Percentage reported incidents
Policy 1	Yellow	Green	Green	Pink	Yellow	Pink	Pink
Policy 2	Pink	Green	Pink	Green	Yellow	Green	Green
Policy 3	Pink	Yellow	Green	Pink	Yellow	Green	Green
Policy 4	Green	Green	Green	Pink	Yellow	Pink	Pink

Table 5.7 Results overview table scenario 1

Pink	Worse than average
Yellow	Average
Green	Better than average

Table 5.8 Legend overview table

There can be concluded that under the circumstances given here, it is dependent on the policy makers' priorities which policy delivers the highest performance. Given the limitation of the model, it can be concluded that a long funding cycle is beneficial for NGOs. They will have more money to spend and can convert a larger part of their funding. Regarding transparency, these long term project cycles are not beneficial. NGOs will have more money at hand and will thus not be inclined to spend time on lobbying through open information.

## 5.3 Functionality of policies in different scenarios

An analysis similar to the previous chapter, can be done for the four different scenarios. These analyses can be found in appendix D. Visualization in the same way as performed for the first scenario shows the following results:

Scenario 2	Funding available	Percentage covered	Percentage converted	Total processing time	Total incidents	Fake news reactions	Percentage reported incidents
Policy 1	Green	Green	Green	Pink	Yellow	Pink	Pink
Policy 2	Pink	Green	Pink	Green	Yellow	Green	Yellow
Policy 3	Pink	Yellow	Green	Pink	Green	Yellow	Green
Policy 4	Green	Green	Green	Pink	Yellow	Pink	Yellow

Table 5.9 Results overview table scenario 2

Scenario 3	Funding available	Percentage covered	Percentage converted	Total processing time	Total incidents	Fake news reactions	Percentage reported incidents
Policy 1							
Policy 2							
Policy 3							
Policy 4							

Table 5.10 Results overview table scenario 3

Scenario 4	Funding available	Percentage covered	Percentage converted	Total processing time	Total incidents	Fake news reactions	Percentage reported incidents
Policy 1							
Policy 2							
Policy 3							
Policy 4							

Table 5.11 Results overview table scenario 4

A number of elements catch the eye when comparing these tables. The following will be elaborated on:

1. The best ‘Funding available’ results switch between the first and fourth policy depending on the scenario.
2. The total processing time differs strongly between the third and the other scenarios.
3. The total amount of incidents for the third policy range from best performer to worst performer across the scenarios.
4. Fake news levels for the second policy differ strongly between the third and the fourth scenario.

### 5.3.1 Differences in maximum funding

A remarkable difference across the scenarios, is the way total funding changes. The first policy receives more funding for more urbanized regions. How does that work? A more spread-out environment means that larger parts of the model are unknown to NGO-agents with regards to safety. More risk-taking NGO-agents are then still willing to move into the unknown areas, while risk-avoiding NGO-agents are not. This leads to risk-taking agents being able to spend more money and thus receive more money as well. This effect means that the other factors in funding are in this case less relevant. Since both policies don’t report, lack of reporting is not a limiting factor. The fact that they don’t report does not weigh out their positive scores on the other factors.

The fourth scenario deserves some extra attention, as this is initially not as spread out as the other three scenarios. Because of the small displacement rate, the POC-agents stay relatively spread out and that is why the fourth policy performs well again on the fourth scenario. The conclusion is that a more risk-taking approach is most appropriate for a more spread-out environment.



### *Conclusions:*

1. *NGO-agents function better in a rural area when they are risk-taking. When an area is more urban, the level of risk a group of NGO-agents take is less relevant.*

In a more rural area, there are more unknown regions with POC-agents. A risk-taking approach allows NGO-agents to move in those regions, while a risk-avoiding approach limits NGO-agents to move into those regions. Therefore a risk-taking approach is more suitable for a more rural area, with regards to the total funding which is delivered.

### **5.3.2 Different processing times**

A first thing to notice when looking at the total processing time, is the overall decrease of processing time from the first to the fourth scenario. This is related to the initial turnover rate in NGO-agents which is lower for every subsequent scenario. Apart from the downward trend, another aspect is remarkable: the third policy goes from worst performer in the second scenario to best performer in the third scenario for processing times. This change can be attributed to the specific characterization of the third scenario, in which the POC-agents have locations which can be described as a mix of rural and urban. Given that the third policy has agents over the entire spectrum from risk-taking to risk-avoiding, the NGO-agents all find their place and stay there without having to move to another location. This assures a stable location and little project changes. Despite the long processing time, little time is wasted overall and total processing times remain low.

### *Conclusions*

1. *When an area is characterized by a mix of rural and urban areas, a neutral risk-approach makes a group of NGOs more efficient.*

This is attributed to the less frequent changes of project location for NGO-agents. Less frequent change means less time spent in transaction.

### **5.3.3 Third policy changing from good to bad for incidents**

The third policy option shows the lowest level for incidents compared to all policies in the second scenario. It shows the second highest level for incidents in the fourth policy. This can be attributed to the duration of the reporting cycle. The second scenario shows a more urban region, whereas the fourth scenario shows a spread-out area. As was already found out in section 5.3.1, the level of risk is less relevant for safety in a more urban area.

Still, both the third and the fourth policy perform poorly in the fourth scenario. This lower performance can be attributed to the duration of the reporting cycle and the level of risk. The performance of the first policy is good, as they are risk avoiding. The performance of the second policy is good, as they are very frequently updated on what is safe and what is not. The third and fourth policy have a reporting cycle of 30 days and therefore the NGO-agents encounter problems more often with outdated information. Given their levels of risk the fourth policy encounters most problems and the third policy follows shortly after.

### *Conclusions*

1. *A short reporting cycle is especially important for safety in a more rural area in combination with a longer duration of projects.*

A short reporting cycle helps to keep safety categorizations up to date, which is especially important in a dynamic scenario. A scenario with more spread-out POC-agents has less

NGO-agents per group of POC-agents and therefore a shorter reporting cycle is of larger value.

### 5.3.4 Different fake news levels

A fake news reaction takes place when an NGO-agent is moving from one project to the next. The reason why NGO-agents in the first and fourth policy are often reacting to fake news, is because there is a larger number of non-reporting NGO-agents. This causes NGO-agents to more often having to react to news which is not derived from a trusted source.

The reason why fake news reactions for the second policy and third scenario suddenly spike, compared to other policies is the following: the second policy is a risk-taking policy in a very concentrated scenario. This does not fit well, because NGO-agents do not often have to take risk to reach POC-agents. The fourth scenario is, even though initially fairly urbanized, relatively spread-out given the low displacement rate of POC-agents. This fits better with the risk-taking policy than with the urbanized scenario. This difference in policy means that the coverage is better suited for the second policy and that the amount of opportunities for a fake news reaction is significantly lower for the fourth scenario compared to the third scenario.

#### *Conclusions*

1. *The extent to which a risk strategy is suitable for an area influences the level of fake news reactions*

Based on the stability of camps, which differs per scenario, a different configuration of policy is needed in order to keep fake news reactions low. It is therefore not only risk-willingness which influences fake news reactions, but merely the appropriateness of risk-willingness to the scenario which influences fake news reactions.

## 5.4 Preliminary conclusion

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This section has shown the analysis of the results of the model and it aimed to answer the following question:

*What is the impact of policies on the performance of a humanitarian operation for the identified scenarios?*

In this analysis chapter, the impact of five policy factors have been projected on three scenario factors, representing a stylized real-world situation. The preliminary conclusion is that there is an influence of policy variables on nearly all stated KPIs. The conclusion is that there is not one single best policy which works in every scenario. Different configurations of policies function better in different situations. Another conclusion is that there is trade-off to be made in policy-making between transparency and total aid delivered. A policy cannot perform better than average on both KPI categories.



## **2000 – 2011**

When Hafez Al-Assad died in 2000, his second oldest son Bashar Al-Assad was appointed President of Syria. A quick change in constitution lowered the minimum age for a Syrian president from 40 to 34 years old. It was no coincidence that Bashar Al-Assad was exactly 34 years old at the time. A referendum was held on 10 July 2000 and 99,7% of the Syrian voters voted in favor of Bashar Al-Assad's presidency.

# 6.

## Evaluation & Limitations

This chapter presents a review and a reflection on the various phases of the research process. The components of evaluation are the following:

- Conceptualization
- Model data
- Model verification
- Model validation
- Model output
- Scenario and policy choice
- Scientific contribution
- Societal contribution

Together these eight component will form the evaluation of the research study and will put the results into perspective. In chapter 8 ‘reflection and recommendation for further research’ I will look back on what could have been improved in the process.

### 6.1 Conceptualization

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The conceptualization used in the run-up for the model study as performed in this thesis is very specifically designed for the purpose of modelling in an Agent-Based context. The humanitarian sector is a highly complex and dynamic field with a wide range of factors that can influence the overall functionality of humanitarian operation. Given the requirements for an Agent-Based model, the reality had to be abstracted to a fairly large extent. The limitations for conceptualization because of the type of modelling that was chosen had its influence on the policies that were researched. As the real world had to be simplified to a large extent, so were the policies. A policy in the humanitarian sector regarding information sharing, is however not easily broken down into a handful of quantifiable policy variables. Policy in the field of humanitarian sector information management is a very qualitative field, depending a lot on trust and interpersonal relations. Even though Agent-Based modelling is mainly used for the study of social sciences, this thesis has been a study which had many components which were hard to quantify. This has been a limitation with respect to the mapping of real-world policies and led to a model execution with hypothetical policies.

A second limitation to the implementation of the conceptualization is the rather large number of assumption that had to be made. These assumptions (structural and parametrical)

were necessary to create a working model, but are currently also a limiting factor in validating the model. A future study could address the limitations by involving aid workers and policy makers in the humanitarian sector to validate the basic structural assumptions as they were made in this research via a questionnaire. Such future studies could strongly improve the quality of the conceptualization and with that the model that is eventually created.

## 6.2 Model data

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Already briefly touched upon in the previous section 6.1, the quality of the model data is rather low. The problem that is dealt with is of a very exploratory yet specific nature, and on top of that dealing with classified information. Combined, these factors make it virtually impossible to find reliable open source data. The data that is needed in this model is however not of a quantitative nature, making it possible to run the model despite the lack of open source data. As with the structural assumption touched upon in the previous section, the parametric assumptions would also gain in quality when they would originate from questionnaires on real-world systems.

## 6.3 Model verification

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Apart from a number of details, partly corrected after the modelling phase, the overall conclusion can be that the model is implemented correctly after the conceptualization. The details that are not modeled are the following:

1. A movement to a fake information source does not cost time and money, this should actually cost both.
2. Incidents take place when NGOs are in radius of a POC. When the scenario however dictates that there is rural environment, there are more agents in the model. This leads to a larger number of incidents, while this is not necessarily the case.

The exact steps of verification are further discussed in appendix B on verification.

## 6.4 Model validation

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Exact validation of this model is out of the scope for this thesis. A review on the relevance and absence of validation is however still very relevant.

The absence of complete validation has a strong impact on the usability of the results of this thesis, because the outcome is not irrefutably true. That, combined with the lack of quality data means that exact interpretation of numerical data is basically irrelevant. What however is useful of this thesis is the internal relationships between policy levers and KPIs, as was explained in the analysis. This provides a new insight for future policy makers on what to focus on, if the strategy is to increase or decrease one of the KPIs. The abstraction level of this thesis is therefore the strength, but also the weakness of this thesis.

The validation that has been done in this thesis is of function though. Despite not completely executed because of the aforementioned reasons, the validation does show that the model represents society to a certain extent. The structural assumptions have largely been validated, so that does mean validation is assumed to a certain extent. This makes it possible to conclude on internal dynamics. Optimization conclusions can thus not be drawn, but other qualitative and quantitative conclusions can be drawn.

## 6.5 Model output

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The model output shows results that are well-interpretable and shows differences for every scenario and every policy. The surface under the graph presents a novel way of interpreting a large number of runs and allows for a better analysis of the model results. The results are therefore better interpretable and can be used for Agent-Based studies in the future.

A side note for the model output is that the validation is largely absent and the exact numbers cannot be interpreted. More empirical data would validate the model and would thus make the model output more valuable.

## 6.6 Scenario and policy choice

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The choice for a stylized case study was the only option in this modelling study. As the policy options are not empirically proven, this can imply internal inconsistencies. Empirical research can prove useful identify internal dilemmas in policies. Scenarios are simplified. The scenarios however do present a resemblance to real-world dynamics and can therefore be useful for policy-makers.

## 6.7 Scientific contribution

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As has been stated in the knowledge gap in the introduction chapter 1, the research on information sharing in a humanitarian operation in a complex disaster was merely qualitative and descriptive. This research has added a quantitative and prescriptive method to the base of literature. This is the main scientific contribution of this thesis. There are also more fine grained contribution to the scientific literature.

The need for a structural social network analysis has already been stated in 2008 (Saab et al., 2008). They stated that there was a need to explore network structure characteristics that might influence collaboration in humanitarian information sharing network. This research has aimed to do so.

This is however not the first research aiming at creating a greater insight in humanitarian information sharing practices. The other scholars have however always noted that future research was needed on this topic.

*Utilizing social network theory, a network topology could be used to model social connectivity of agents, rather than an agent randomly roaming.* (Altay & Pal, 2014 p. 1025)

This research has improved the agent behavior and information sharing of social connectivity through close-distance information sharing and turnover rates leading to less social connectivity and therefore a less efficiently operating NGO-agent in an Agent-Based model. This creates a wider insight in information sharing practices, compared to the earlier more specific research. A research with a wider scope goes at the expense of detailed information, but does provide a wider look. This research has done so.

A call for further research on the knowledge gap of the social aspect of information sharing in a humanitarian operation (Muhren et al., 2009) has also been fulfilled. Whereas



most information sharing research is aiming to analyze information system analysis, this research has provided insight in the social aspect of information sharing through bottom-up modelling.

A final scientific contribution is to further explore the field of Agent-Based modelling of information sharing in the humanitarian sector. Scientific literature on information sharing is relatively limited and it is a relatively new field of research. The pool of scholars working on the subject is small. Through this research I have aimed to look at the situation with a unprejudiced view and provide a contribution to the scientific literature in a way which has rarely been done before. This may (re-) spark the interest of social modelling in the field of humanitarian information management which can be very beneficial for as well the Agent-Based community as for the humanitarian information management community.

## 6.8 Societal contribution

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The review of the societal contribution is strongly interdependent with the review of validation. Since the validation of the research is insufficient, the numbers resulting from the model are unfortunately not practically usable. However, the dynamics that have been drawn up are useful for policy makers. It shows that policy regarding information sharing cannot be the same in every complex disaster and that there are trade-offs which need to be taken into account. So despite the limited interpretability of the numerical results, the outcomes can be very interesting for practice.

Apart from information for policy makers, this research can start a new interest in modelling the humanitarian sector. Increasingly detailed and better validated models can bring a consciousness regarding information sharing to NGOs which are currently not willing to share their information. This greater consciousness might even lead to less Safety & security incidents which might thus even save lives of humanitarians.







## 2011 – now

On 15 March 2011, as part of a wider wave in Arabic countries, protesters marched Syrian capital Damascus. They demanded democratic reforms and release of political prisoners. President Bashar Al-Assad reacted violently. His security forces opened fire on the protesters, which led to more clashes between government rebelling groups. By the end of may 2011 over 1000 civilians died and 150 soldier died. The conflict between rebelling groups and government forces is still going on today.

# 7.

## Conclusions

In this chapter, the conclusions of this thesis will be summed up and summarized, based on the sub- and main questions that have been posed in the introduction and the preliminary conclusions that are at the end of every chapter. The questions that have been posed were structured as follows:

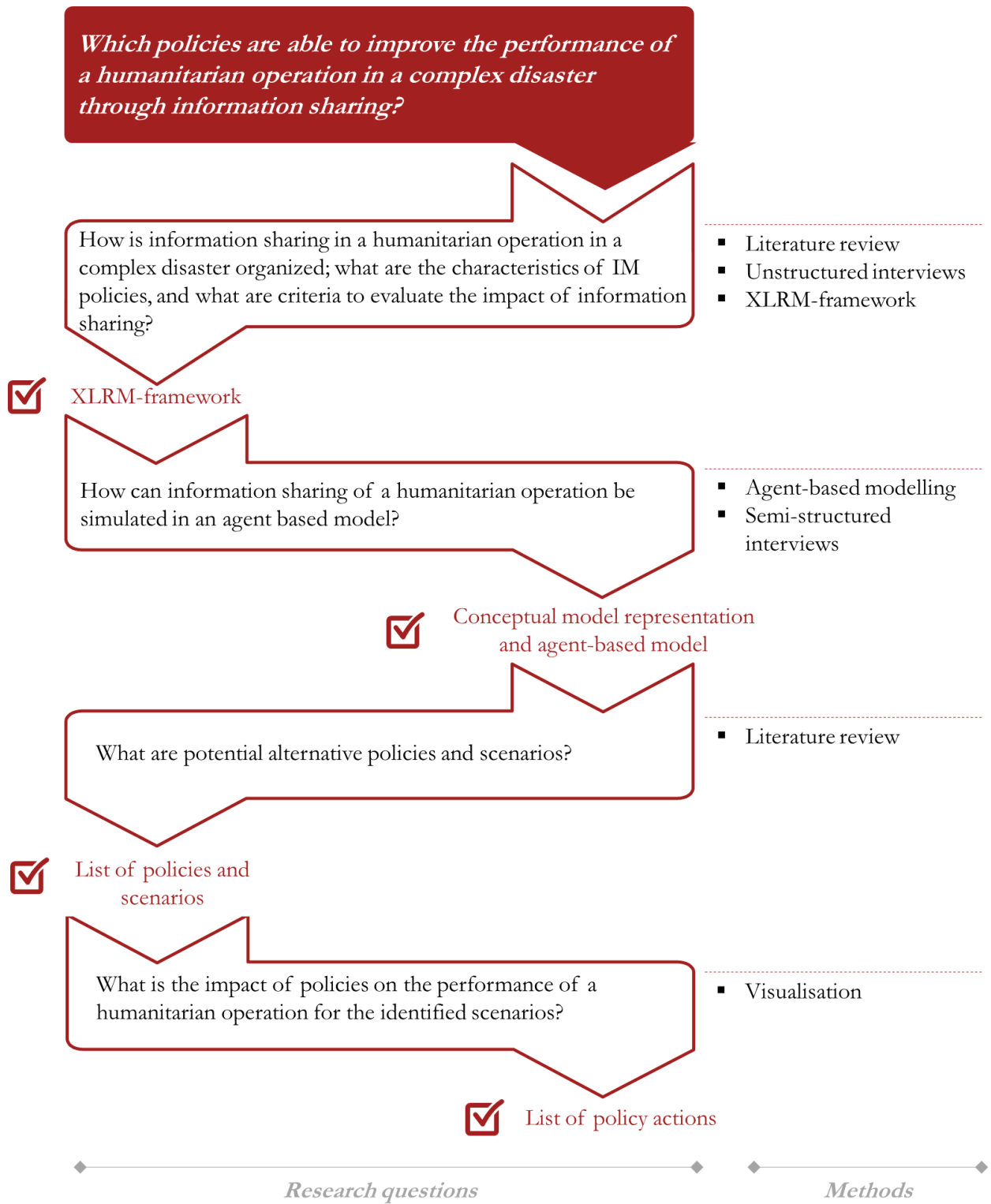


Figure 7.1 Thesis structure

## **Which policies are able to improve the performance of a humanitarian operation in a complex disaster through information sharing?**

1. How is information sharing in a humanitarian operation in a complex disaster organized; what are the characteristics of IM policies, and what are criteria to evaluate the impact of information sharing?
2. How can information sharing of a humanitarian operation be simulated in an Agent-Based model?
3. What are potential alternative policies and scenarios?
4. What is the impact of policies on the performance of a humanitarian operation for the identified scenarios?

### **7.1 Sub question 1: Information structure, policies and barriers**

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The information flows in a humanitarian operation are structured differently on different levels. Three important distinctions can be made:

1. Information in general does not exist and can be categorized in two types of information: Safety & security Information and & Organizational and Planning information. Both types are dealt with differently in the humanitarian sector.
2. Information sharing happens in two ways: through bureaucratic systems and through social connections among aid workers. Both need to be taken into account when looking at information sharing operation-wide.
3. Policy is designed in two ways: quantitative and qualitative. The policy which steers humanitarian information management is largely qualitative.

A second sub-conclusion is that there is a plethora of actors active in a humanitarian organization. Every actor has its own characteristics and deals with information sharing in a different way. These characteristics are included in this research through the willingness to take risk, priority of information verification, experience within the organization, acceptance of incidents and a general willingness to share information. These factors influence how information is dealt with in the modelling context of a humanitarian context. The categorization which has been used in this thesis is between recipients and providers of aid.

The overall operation of a humanitarian operation is captured by the program cycle, which identifies 5 key processes:

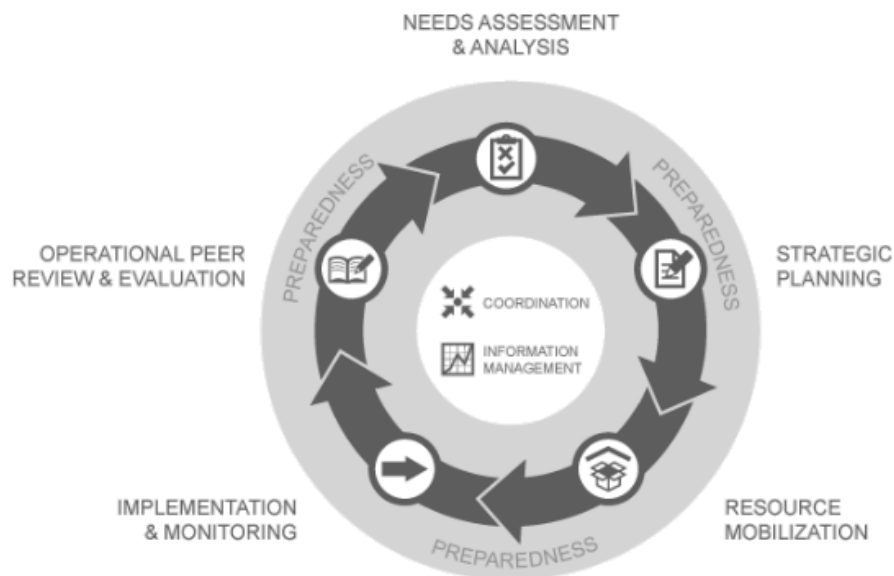


Figure 7.2 Humanitarian program cycle (UNOCHA, 2017)

## 7.2 Sub question 2: Simulation in an Agent-Based Model

There can be concluded that simulation in an Agent-Based model is a suitable way of modelling information sharing in a humanitarian operation. A very important side note for this thesis is that the research is not fully validated and the numerical results are so forth not valuable to a limited extent. Numerical patterns give insight in the functioning of the humanitarian operation, but numerical results on their own cannot be interpreted. It can be concluded through verification of the model that the model is implemented as foreseen in the conceptualization phase.

## 7.3 Sub question 3: Policies and criteria to evaluate those policies

The policies that have been formulated are based on the policy levers that are identified in the first sub question. As numerical examples with policy levers as such do not exist, the choice has been made to utilize hypothetical policies. The hypothetical policies are inspired on real-world policies. The policies are the following:

1. Low trust, high control
2. High trust, low control
3. Organic development
4. Combination

The policies are subsequently tested over four scenarios. The scenarios are hypothetical, but based on the following four real-world situations:

1. Scenario 1: ISIS/ISIL/Daesh taking over
2. Scenario 2: Advanced in conflict of ISIS/ISIL/Daesh taking over
3. Scenario 3: Aleppo
4. Scenario 4: North of Damascus

The criteria that are used to evaluate the outcomes of the policies are those that are identified in the XLRM-framework.

## 7.4 Sub question 4: Impact of policy on performance

There is not one robust policy which works for given scenario which is used in this thesis. A policy maker will have to prioritize categories of KPIs over other categories in his decision for a policy. The result of the performance per policy per scenario is visually shown as follows:

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Policy 1				
Policy 2				
Policy 3				
Policy 4				

Table 7.1 Overall performance of policies

	Worse than average
	Slightly worse than average
	Average
	Slightly better than average
	Better than average

Table 7.2 Legend for overall performance table

The conclusion that can be drawn from the tables above is that there is not one robust policy, working well in all scenarios. More conclusions can however be drawn through further analysis of the patterns leading to the high aggregation results.

### *Total aid delivery:*

The total delivery of aid is very strongly dependent on the duration of the projects. As organizations with a long project duration manage to spend their money in cash before a new funding round comes around, these NGO-agents have spent more of their money and thus have better chances of receiving more funding. It takes less time to calibrate to the right amount of funding.

The coverage of POC-agents from NGO-agents differs very strongly per run and a firm conclusion cannot be drawn with respect to coverage based on the model runs done for this thesis. Based on differences in maximum funding between the scenarios, the conclusion can be drawn that the level of risk that NGO-agents are willing to take is less relevant for funding when the area of the humanitarian operation is more urban. The large number of NGO-agents jointly care for a safe environment to operate, which does not happen when NGO-agents alone operate in remote areas.

### *Efficiency:*

A conclusion that can be drawn is that the strongest indicator for an efficient spending of funds is the duration of the project cycles. As there is less time wasted on transaction between

to projects, a long project duration is most beneficial for an efficient conversion of funds to aid.

As this influences the efficiency so strongly, the other factors are less important. An interesting factor however is the willingness to take risk from NGO-agents. Initially risky NGO-agents spend less money on their safety and security operation. Only in a safe area they spend an equal amount of money. This leads to the conclusion that in a scenario with a high displacement and clustered POC-agents, the level of risk of NGO-agents is not relevant with regards to funding conversion. If the displacement is low and the area is still rural, the more risk taking agencies have a more efficient way of transferring aid.

The total transaction time is most strongly influenced by the initial information processing time included in the policies. This is however not the only indicator. The risk an organization is willing to take decides how much time they spend on verification. A risk-avoiding group will spend more time on verification, especially when they need to move to a new location often. They however don't often go to a completely new location. This is why a risk-taking organization still spends more days in transaction in total.

A final general remark on efficiency is that the level of risk needs to be chosen based on the characteristics of the area. It shows that in a mix of urban and rural, the transaction times for a neutral risk approach are little and same goes for a very dispersed area with a risk-taking approach.

#### *Safety:*

The most important KPI for safety is the number of incidents. As with other factors, the project duration is an important factor. The safety in this case is lower when project cycles are long, as organizations tend to be less transparent with regards to their safety and security data. This causes for, despite their less frequent change of location, for a high number of incidents for long project duration policies.

Another finding is that the duration of the reporting cycle is not equally important for each scenario. In a scenario where the displacement rate is high and POC-agents quickly cluster into larger groups, the frequency of meeting does not necessarily have to be very high. In a more spread-out scenario however, a short duration of a reporting cycle is crucial to keep the amount of incidents as low as possible.

Some attention also needs to be given to fake news reactions. The results have shown that risk-strategy needs to be well suited for the area that the policy is projected on. A risk-avoiding strategy in a dispersed area leads to fake news reactions, and so do risk-taking strategies in urbanized scenarios.

#### *Transparency:*

A number of factors influence transparency, but the most remarkable and strongest influencer of transparency of organizations is the duration of projects. As a transparent organization is mostly beneficial for a strong lobby for new funding, a frequent change of funding requires more transparency. A longer project cycle leads to more money in cash and therefore less incentives for transparency.

Scenarios with a high displacement rate combined with a long duration of a reporting cycle lead to a large number of incidents in the beginning as POC-agents are finding their positions in camps. This leads to an increased number of incidents. As the number of incidents keeps rising during this period, it is a period in which the reported number of incidents is low. As soon as the situation has stabilized, reporting numbers start increasing.



There can be concluded that especially in the beginning of a humanitarian operation a very frequent information exchange is important to assure continuing transparency.

## **7.5 Main question: Which policies can improve performance?**

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As was stated in the conclusion on the fourth sub question, there is not one single robust policy which works in every scenario. There are however important lessons that can be learned from this thesis with regard to policy-making:

1. *A policy needs to be tailor fit for the situation in which it operates.*

The high-aggregation table in the previous section shows that every policy is working to a lesser extent compared to other policies in certain situations. The conclusion can therefore be that there is not one robust policy which works in any situation.

2. *A policy maker will always deal with trade-offs when making policy-decisions.*

A policy maker will always face a trade-off between transparency and total aid delivery. A greater transparency is achieved by a shorter project duration, but a shorter project duration also comes at the cost of larger transactional costs.

3. *The duration of a project is a crucial factor for many KPIs.*

Upon analysis of all KPIs, project duration repeatedly came out as crucial policy lever. The longer a project duration, the more aid a humanitarian operation could deliver. A downside is that the transparency of the humanitarian operation lowers, due to the lack of incentives for transparency. Also efficiency is affected by the project duration. A longer project duration causes NGOs to spend less time in transaction and therefore spend more money on aid. There can be concluded that a change in project duration has its effect in all four KPI categories.

4. *The more spread-out POCs are, the shorter the reporting cycle has to be.*

The reporting cycle defines how often NGOs share information among each other, to redefine safety & security categorization of regions. Conclusion is that the more rural an area is, the more often pre-defined moments need to be set to share information. In a more urbanized region, NGOs will be in touch through social contacts and will therefore less often need pre-defined moments of information sharing.

5. *Risk approach needs to be tailored to the situation.*

A risk approach needs to be tailored to the situation of the complex disaster. A risk avoiding policy concerns more spending on safety & security, while this is not needed in a complex disaster where POCs already are in camps, clustered together. The relatively large presence of NGOs already causes POCs to be less violent towards NGOs. A risk taking approach is therefore more efficient. However, risk taking NGOs are also more inclined to move to new projects, whereas risk avoiding NGOs remain at already existing projects. Risk taking policies therefore spend more on transactional costs. A balance has to be found between these two findings.





## 2014 – now

An exceptionally brutal episode of the recent Syrian history is the rise and fall of Islamic State (IS). IS emerged from the remnants of Al-Qaida in Iraq and started spreading over the Middle-East in 2014. Supported by foreign fighters from all over Europe, IS captured major Iraqi and Syrian cities and proclaimed Raqqa as their capital. Tens of thousands of US-led airstrikes later, most IS-captured territory is liberated. However, some territories in Eastern Syria are in control of IS.

# 8.

## Reflection and recommendation for further research

This chapter aims at reflecting on the process of this research and pointing out recommendations for further research. The reflection will be build up out of two components:

1. Reflection on the chosen method
2. Reflection on usability for practice

The recommendations for further research follow subsequently.

### **8.1 Reflection on Agent-Based modelling methodology**

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Looking back on the thesis as a whole with the knowledge I have now, I do not look back only positively on using Agent-Based Modelling as a modelling technique. Even though Agent-Based Modelling has unique features in showing emergent behavior in a social system, I believe that the subject of research is of a more discrete and more certain nature than is actually suitable for exploratory research using Agent-Based Modelling. Along with the latter reflection, it can be concluded that Agent-Based Modelling requires modelling on a very high level of abstraction. This non-existent level of abstraction means that there is no data available to feed the model. To be able to find patterns of information sharing in the humanitarian field through Agent-Based modelling required such a level of abstraction that it was subsequently hard to derive practical results from a research that was so abstract.

As this research was of abstract nature, a complementation towards more abstraction could also be made. The exploratory use of Agent-Based Modelling in this research can very well be complemented with the Exploratory Modelling Analysis (EMA) (Kwakkel & Pruyt, 2013).

## 8.2 Reflection on the usability for practice

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The usability for practice is present, but thus far limited. There is a potential to be very useful for practice when a better validation is put into place. The build-up of the model however and the conclusion that have been found present a new angle to decision-making in the humanitarian sector.

The usability for the scientific community is larger than the direct usability for practice. This exploratory research continues and opens up new fields of social behavior patterns analysis through Agent-Based modelling and is promising for more research to come.

## 8.3 Recommendation for further research

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The first recommendation is further research on the hypothesized policy levers that have been formulated in this research. A hypothesis is formed to be tested and that is most needed. As was already discussed in the section on reflection on the methodology, two types of modelling are recommended to use for further research in information sharing in the humanitarian sector:

1. Discrete Event Simulation
2. Exploratory Modelling Analysis

The addition of the first modelling technique would be merely for a contribution to practice. By combining a logistics model with potential benefits of faster information, a better estimation can be made on the benefits of information transparency in a humanitarian operation. This can spark a greater awareness at NGOs to increase their policy on openness of data. Validation of the logistics model is to for validation.

Exploratory modelling means an expansion of the already done research in this thesis. Whereas this research works with four hypothetical scenarios and four hypothetical policies, EMA would provide the ability to perform analysis on possible combination of scenarios and policies and even optimize the policy levers towards a certain KPI. A better validated Agent-Based model combined with EMA could lead to very interesting results. Directions for improvement of the Agent-Based model are improved financial frameworks and a more detailed intra-organizational dynamic. Also improved sampling using Latin hypercube or Monte Carlo sampling would improve the model.

A third opportunity would be to define what trust is. This is research in a more sociological direction, but it would strongly contribute to the quality of all future quantified research of information sharing. Sharing information between actors in the humanitarian field is in practice a combination of many sometimes quantifiable, but often non-quantifiable factors. Think of cultures of NGOs, overlapping religions, personal relationships established contacts in previous projects.

A final recommendation is to use a case study approach to the model. The models defined in this thesis are inspired on a the Syria case, but do not represent the exact war. A decision to exactly represent a certain situation will lead to a larger availability of data and can lead to a model that is better to validate.



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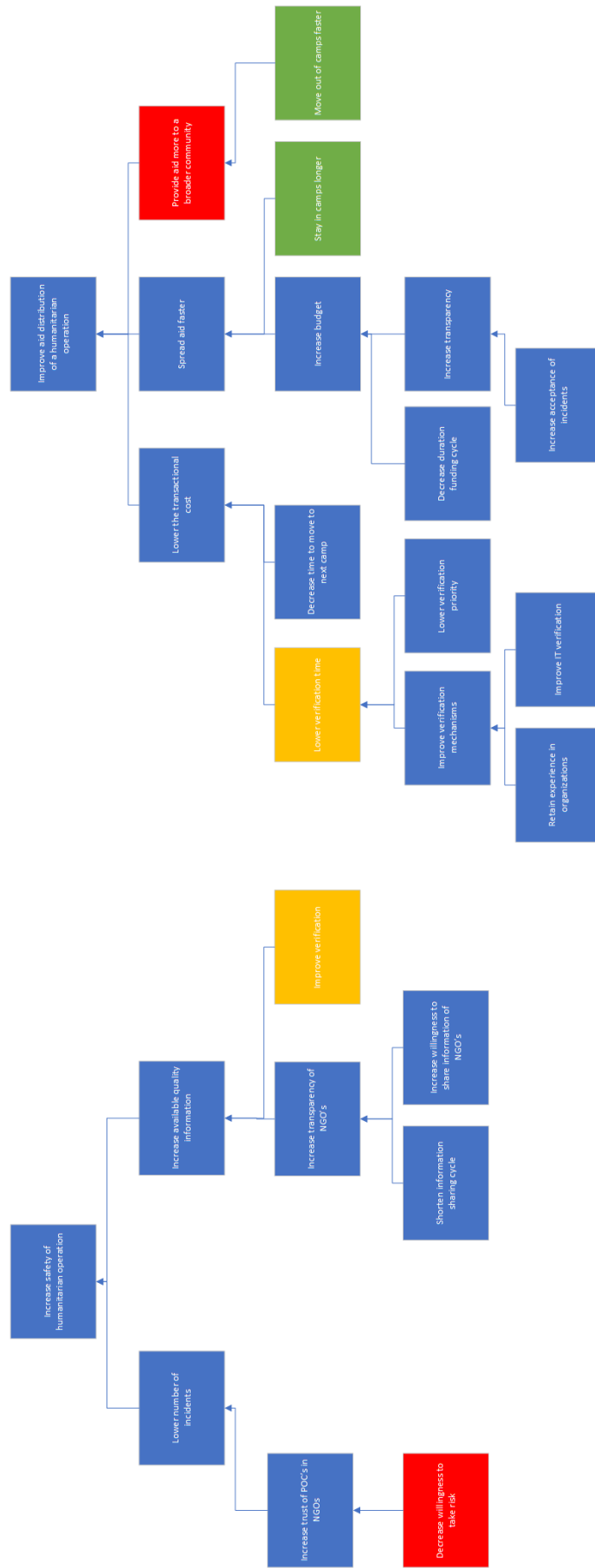


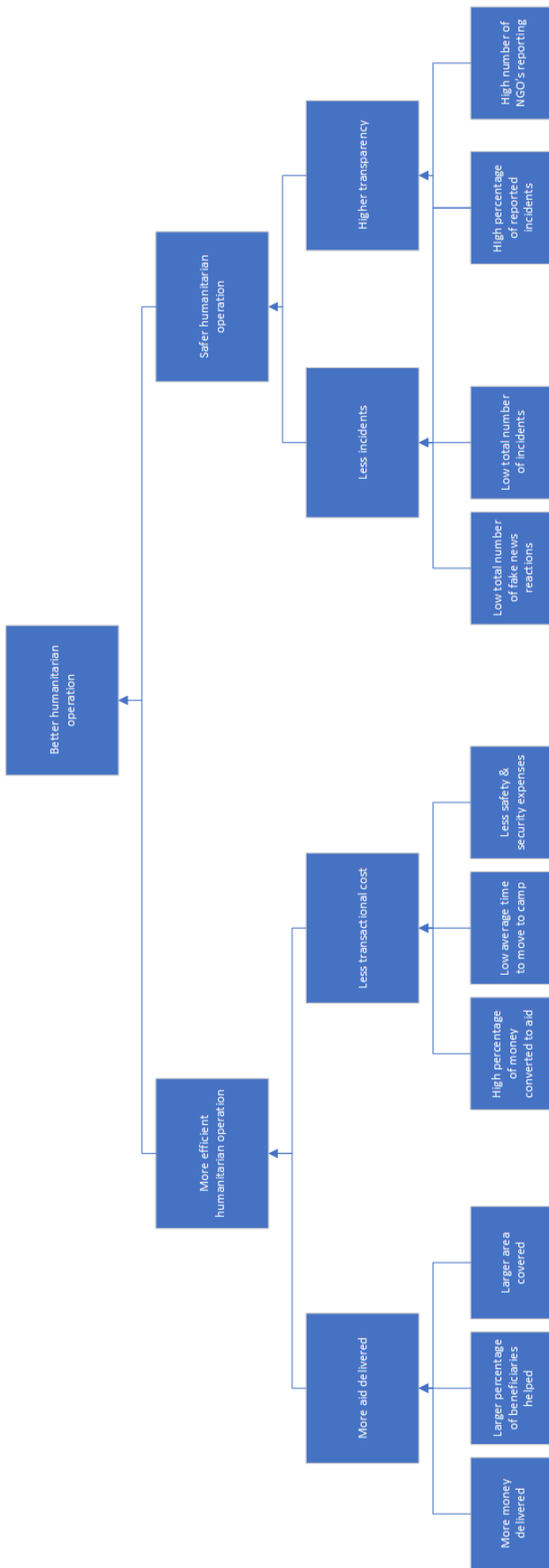
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VIII. APPENDIX A  
CONCEPTUAL  
MODELS





**XLRM-framework**

**Exogenous uncertainties**

<b>Subject of uncertainty</b>	<b>Nature and level of Uncertainty</b>
Initial turnover rate	Level 3: There is a past of turnover rates in companies. This however is kept secret and therefore taken as uncertainty. Nature: Ontic (Inherent randomness) and Epistemic (Different ideas)
Type of war	Level 5: One never knows where and when which types of war are going to break out Nature: Ontic (Inherent randomness)
Spreading of the population	Level 4: Since location is unknown, spreading of people is unknown. The different types however can be predicted. Nature: Ontic (Inherent randomness)
Displacement rate of population	Level 4: The displacement rate is dependent on the population, and therefore uncertain. Nature: Ontic (Inherent randomness)

**Policy levers**

<b>Subject of uncertainty</b>	<b>Related uncertainties</b>
NGO transparency <ul style="list-style-type: none"> <li>- <b>Shorten IM cycle</b></li> <li>- <b>Increase willingness to share</b></li> <li>- <b>Increase acceptance of incidents</b></li> </ul>	Level 3: Over the past, transparency levels are known. It is therefore known what is currently most likely. Nature: Epistemic (Different ideas)
Verification time <ul style="list-style-type: none"> <li>- <b>Improve IT verification</b></li> <li>- <b>Retain staff</b></li> <li>- <b>Lower verification priority</b></li> </ul>	Level 2: Turnover levels of the past are known, but not available. Nature: Epistemic (No agreement on data)
Aid distribution <ul style="list-style-type: none"> <li>- <b>Time until moving to next camp</b></li> <li>- <b>Total money received</b></li> <li>- <b>Project duration</b></li> </ul>	Level 3: Not known in advance Nature: Epistemic (Not known in advance)
Trust in NGOs <ul style="list-style-type: none"> <li>- <b>Decrease risk-taking NGOs</b></li> </ul>	Level 4: There are options, but they cannot be weighed for likelihood. Nature: Epistemic (No agreement on ideas)

**Relationships**

<b>Subject of uncertainty</b>	<b>Related uncertainties</b>
-------------------------------	------------------------------

Aid efficiency	Level 3: Not known in advance Nature: Epistemic (Not known in advance)
Sensitiveness for incidents	Level 3: Not known in advance Nature: Epistemic (Not known in advance)
Willingness for transparency	Level 3: Not known in advance Nature: Epistemic (Not known in advance)
<b>Measures</b>	
<b>Subject of uncertainty</b>	<b>Related uncertainties</b>
Total aid delivered - <b>Money delivered</b> - <b>Number of beneficiaries helped</b> - <b>Covered area</b>	Not applicable
Transactional cost - <b>Percentage money converted to aid</b> - <b>Average time to move to camp</b> - <b>Safety &amp; security expenses</b>	Not applicable
Incidents - <b>Fake news reaction</b> - <b>Total incidents</b>	Not applicable
Transparency - <b>Percentage of reported incidents</b> - <b>Total number of transparent NGOs</b>	Not applicable

# IX. APPENDIX B

## VERIFICATION

In the verification phase, a thorough assessment is made to verify if the model is technically doing what it is supposed to do as conceptually laid out. The verification of the Agent-Based model proposed here will be done according to the verification structure as described by van Dam, Nikolic & Lukszo (2013). They propose a fourfold method:

1. Recording & Tracking of agent behavior
2. Single-agent testing
3. Interaction testing
4. Multi-agent testing

In the recording & tracking part, an agent will be followed through the entire model narrative and every step will be controlled for justness. As for this model, NGOs, POC and land will be followed for a model run to control for correctness.

Single-agent testing refers to two tests which will be executed. A theoretical prediction along with a sanity test and secondly a test where the agent is tested to its limits to verify it will not break under extreme conditions. In the interaction testing the model will be stripped to a bare minimum in which the interaction between one POC and one NGO is tested. Finally in the multi-agent testing phase the model will be tested as a whole. All agents will be present and the model will be tested for extreme values, trying to break the model. Additionally there will be variability testing and sanity tests, further elaborated on the respective sections. These tests will be done following the structure posed in the model formalization section. To avoid redundancy, steps that are repeated every step in the procedures exactly as in the setup are not verified separately. The structure that is used then looks as follows:



Initialization	Processes
<b>POC</b>	
<b>1. Setup needs</b>	<del>1. Specify aid needs</del>
<b>2. Setup trust</b>	3. Move to new location
<b>3. Setup basic Parametric</b>	<del>8. Decide trust</del>
	9. Create incidents
<b>NGO</b>	
<b>4. Setup willingness to take risk</b>	2. Decide reporting status
<b>5. Setup funding</b>	4. Decide if new location Move to new location Gather camp information
<b>6. Setup initial turnover rates</b>	5. Transfer aid
<b>7. Setup basic Parametric</b>	7. Renew funding
<b>Land</b>	
<b>8. Setup regions</b>	8. Decide region type

## *Recording & Tracking of agent behavior*

### *Recording & Tracking of agent behavior of Initialization*

In this section, all initialization processes will be verified through recording and tracking of the agents. A simplistic simulation setup will be made and the respective variables after initialization will be elaborated on. The variables of the three model components look as follows after setup:

#### **Confirmed**

who	7
color	95
heading	0
xcor	-13
ycor	12
shape	"house"
label	""
label-color	9.9
breed	ngos
hidden?	false
size	1
pen-size	1
pen-mode	"up"
link-max	0
size-of-organisation	3
cluster	3
money	4.171232876712329E8
money-funded	4.171232876712329E8
risk-willingness	0.83
information-level	0
region-now	0
regions-possible	[1 2 3]
info-region1	0
info-region2	0
info-region3	0
money-spent-last-tick	0
initial-money-needed-in-camp	0
money-needed-in-camp	0
known-money-needed-in-camp	0
reported-money-needed-in-camp	0
cluster-reported-money-needed-in-camp	0
accidents	0
reported-accidents	0
reported-accidents-in-reporting-cycle	0
reporting	false
location	0
reported-location	0
cluster-reporting	false
total-money-spent	0
time-in-camp	0
fake-news-actions	0
full-camp-knowledge	true
cycle-accidents-previous-cycle	0
cycle-accidents	0
funding-delivered	0
funding-delivered-previous-cycle	0
funding-converted	0
funding-converted-previous-cycle	0
money-spent-ss	0
money-spent-to-poc	0
reporting_no	0
cluster-reporting_no	0
level-of-experience	0
initial-turnover-rate	0.23700000000000001
info-progress	0
total-time-waiting-for-info	0
info-process-time-needed	3
total-processing-time	0

who	32
color	25
heading	319
xcor	-1
ycor	-3
shape	"face sad"
label	""
label-color	9.9
breed	pocgroups
hidden?	false
size	1
pen-size	1
pen-mode	"up"
money-needed	219748.85844748857
threat	0
region-poc	2
total-links	0
willingness-to-travel	7
humanitarians-killed	0
money-received-last-tick	0
context-trust	2.085
surrounding-trust	1.5
ngo-size-trust	1
general-region-safety	0.5
ngo-in-perimeter-trust	0.5
money-trust	2
total-trust	7.585
priority	false

pxcor	0
pycor	-11
pocolor	22
plabel	2
plabel-color	23
region	2
info-on-patch	0
recent-accidents	0
streak-clean	0
streak-kill	0
surrounding-ngos	0
ticks-with-ngos	0
ticks-without-ngos	0
streak-clean-in-reporting-cycle	0
streak-kill-in-reporting-cycle	0
streak-unknown-in-reporting-cycle	0
days-without-informers	0

### Setup needs (POC)

The money needed by a POC is calculated by the following function:

Equation 8.1 Needs of POCs

$$Need\ of\ POC(x) = \frac{\left(\frac{Total\ initial\ needs}{2}\right)}{Total\ number\ of\ POC's} * \frac{multiplier\ for\ POC(x)\ region}{365}$$

In this example parameters set by the modeler are:

- Total initial needs: 7.700.000.000
- Total number of POCs: 48
- Multiplier for region: 1

Equation 8.2 Exemplary needs equation

$$\text{Need of POC}(x) = \frac{\left(\frac{7.700.000.000}{2}\right)}{48} * \frac{1}{365} = 219748,86$$

label-color	9.9
breed	pocgroups
hidden?	false
size	1
pen-size	1
pen-mode	"up"
money-needed	219748.85844748857
threat	0
region-poc	2

**Confirmed**

*Setup trust (POC)*

who	32
color	25
heading	319
scor	-1
year	-3
shape	"face sad"
label	""
label-color	9.9
breed	pocgroups
hidden?	false
size	1
pen-size	1
pen-mode	"up"
money-needed	219748.85844748857
threat	0
region-poc	2
total-links	0
willingness-to-travel	7
humanitarians-killed	0
money-received-last-tick	0
context-trust	2.085
surrounding-trust	1.5
ngo-size-trust	1
general-region-safety	0.5
ngo-in-perimeter-trust	0.5
money-trust	2
total-trust	7.585
priority	false

The initial total trust of this POC is built up out of six factors, together forming the total trust. Each component will be calculated and checked for below:

1. *Context trust:* The type of humanitarian operation for this verification is "no violence". The context trust should then therefore amount to  $1.5 + 1.5 * 0.39 = 2.085$
2. *Surrounding trust:* The surrounding trust for this NGO means that it has NGOs in a perimeter of 2 patches of land. This is according to spreading of the agents in the model.
3. *NGO size trust:* The NGO in the perimeter of the subject POC is a small NGO and the size trust should then indeed be 1.
4. *General region safety:* The environment of the POC is region 2. The region safety should then be one.
5. *Money trust:* It is an assumption that money trust is maximal at the start. Thus 2.
6. *Surrounding trust:* There are no POCs in the region with a higher trust than this POC. His surrounding trust should then indeed amount to 0.5.

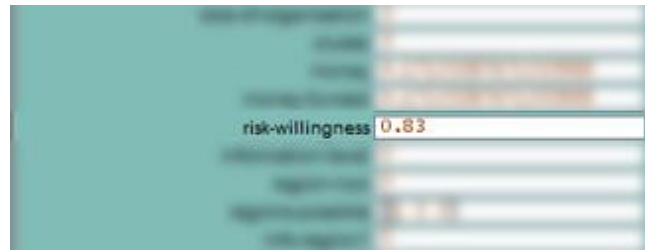
*Total trust:* The total trust is a sum and sums up to

7.585. We can conclude that trust is implemented correctly.

**Confirmed**

### Setup willingness to take risk (NGO)

The willingness to take risk was on this example uniformly distributed. As this is only one sample, this verification phase does not provide possibilities to verify distribution of risk willingness. The fact that risk willingness is at 0.83 and that that gives possible regions 1,2 and 3 is implemented correctly.



### Confirmed

### Setup funding

Since an error came to light at this step of verification, another example has been used after model improvement. The characteristics of that model NGO were the following

- Money funded in total: \$2.780821917808219E8
- Total initial funding: \$6.090.000.000,-
- Project duration: 100 days
- Number of NGOs: 12
- Average NGO size: 2
- Size of NGO: 1

Filling this out in the formula gives:

*Equation 8.3 Funding of NGO example*

$$\text{initial funding of NGO}(x) = \frac{\frac{6.090.000.000}{365} * 100}{\frac{12}{2}} * 1 = \$278.082.191,78$$

After the improvements of the model, there can be concluded that the implementation is correctly.

### Confirmed

### Setup initial turnover rates

The turnover rate formula looks is one with a large randomness in it. The deciders in the formula are:

1. Initial turnover rate (as defined by modeler):
  - a. 0.5
2. Work related factors: AVE work related factors \* (-1, 0 or 1 for risk-willingness)
  - a.  $0.75 * 0 = 0$
3. External factors: AVE \* effectiveness policy turnover rate (as defined by modeler):
  - a.  $0.37 * -1 = -0.37$
4. Personal factors:: AVE \* random number between 0 and 1
  - a.  $0.66 * x = y$



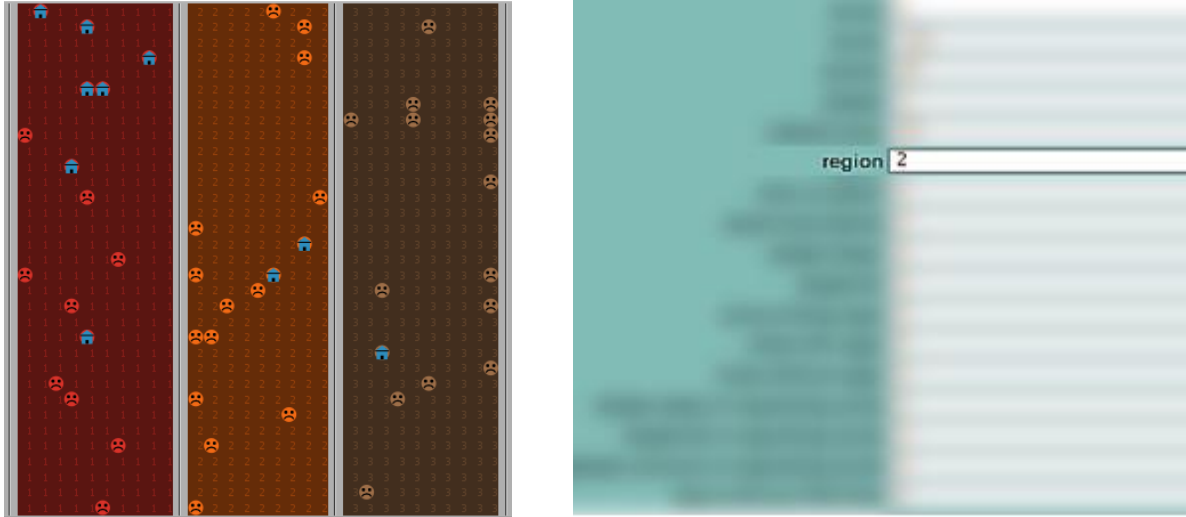
The total turnover rate as seen in the model is in the range where it is supposed to be according to the formula.

## Confirmed

### *Setup regions (Land)*

As can be seen in the images below, the division of land is done as is supposed to be.

## Confirmed



### *Recording & Tracking of agent behavior of processes*

To check for the processes, the decision has been made run the model for 101 ticks. This causes the model to finish one project of 100 days. The agents that are investigated for verification are:

#### **POC:**

Move to new location

Create incidents

**NGO:** Decide reporting status

Decide if new location

Move to new location

Gather camp information

Transfer aid

Renew funding

#### **Land**

Decide region type

who	7
color	45
heading	337
xcor	-7.382754770883082
ycor	-10.219060761767441
shape	"house"
label	""
label-color	9.9
breed	ngos
hidden?	false
size	1
pen-size	1
pen-mode	"up"
link-max	2
size-of-organisation	1
cluster	6
money	2.319913688881667E7
money-funded	6.952054794520548E7
risk-willingness	0.4
information-level	0
region-now	1
regions-possible	[[]]
info-region1	0
info-region2	0
info-region3	0
money-spent-last-tick	1.6603657764416393E7
initial-money-needed-in-camp	-1445737.6338628558
money-needed-in-camp	3.2030922138606135E7
known-money-needed-in-camp	-1445737.6338628558
reported-money-needed-in-camp	0
cluster-reported-money-needed-in-camp	0
accidents	8
reported-accidents	0
reported-accidents-in-reporting-cycle	0
reporting	false
location	0
reported-location	0
cluster-reporting	false
total-money-spent	2.343874925377908E8
time-in-camp	4
fake-news-actions	6
full-camp-knowledge	true
cycle-accidents-previous-cycle	1
cycle-accidents	0
funding-delivered	0
funding-delivered-previous-cycle	8085109.686530921
funding-converted	0
funding-converted-previous-cycle	0.6456899651899941
money-spent-ss	5882842.560483796
money-spent-to-poc	1.0720815203932596E7
reporting_no	0
cluster-reporting_no	0
level-of-experience	0
initial-turnover-rate	0.6120000000000001
info-progress	2
total-time-waiting-for-info	0
info-process-time-needed	2
total-processing-time	42

who	32
color	15
heading	301
xcor	-7.3002383460492855
ycor	-13.796933628703119
shape	"face sad"
label	""
label-color	9.9
breed	pocgroups
hidden?	false
size	1
pen-size	1
pen-mode	"up"
money-needed	9499408.853182627
threat	0
region-poc	1
total-links	0
willingness-to-travel	8
humanitarians-killed	3
money-received-last-tick	1553289.5976136688
context-trust	2.085
surrounding-trust	1.6666666666666665
ngo-size-trust	0
general-region-safety	1.6666666666666665
ngo-in-perimeter-trust	1.6666666666666665
money-trust	0.24527151451533696
total-trust	7.330271514515336
priority	true

pxcor	0
pycor	-11
pcolor	22
plabel	2
plabel-color	23
region	2
info-on-patch	0
recent-accidents	0
streak-clean	101
streak-kill	0
surrounding-ngos	0
ticks-with-ngos	0
ticks-without-ngos	101
streak-clean-in-reporting-cycle	0
streak-kill-in-reporting-cycle	0
streak-unknown-in-reporting-cycle	0
days-without-informers	4

### *Move to new location (POC)*

The movement of a POC in the model is tested in the next section of validation where a single agent will be tested.

### *Create incidents (POC)*

The subject POC has caused a total of 3 humanitarian incidents. Given a trust level of 7.3 this leads to a chance of incident creation of approximately 5% every day. This means over a time span of a 100 days, the expectation is 5 incidents. 3 incidents is in range, given stochasticity.

**Confirmed**

### *Decide reporting status (NGO)*

The subject NGO has reporting status false. This is correct given that it is a non-risk taking NGO and it has plenty of money to spend. There is so forth no incentive for this NGO to share information.

**Confirmed**

### *Decide if new location (NGO)*

The process of new location decision will be verified in the following section.

### *Transfer aid*

The transfer aid process is working correctly. There is money needed in the camp and there is money which has been spent in the past day.

**Confirmed**

### *Renew funding*

The funds received in the first funding round was approximately \$69,000,000. The initial funding for this NGO was 1.3904109589041096E8, and the funding delivered amounts to \$8085109. This means that the funding which is delivered is less than the money they still have and that this NGO does not receive any new funding. The money funded is therefore still the money funded from the previous (initial) cycle. Verification in other NGOs have shown that when this is not the case, the implementation is done correctly.

**Confirmed**

# X. APPENDIX C

## INTERVIEW C. WILLE

The interview with Christina Wille can be found in the GitHub Repository:

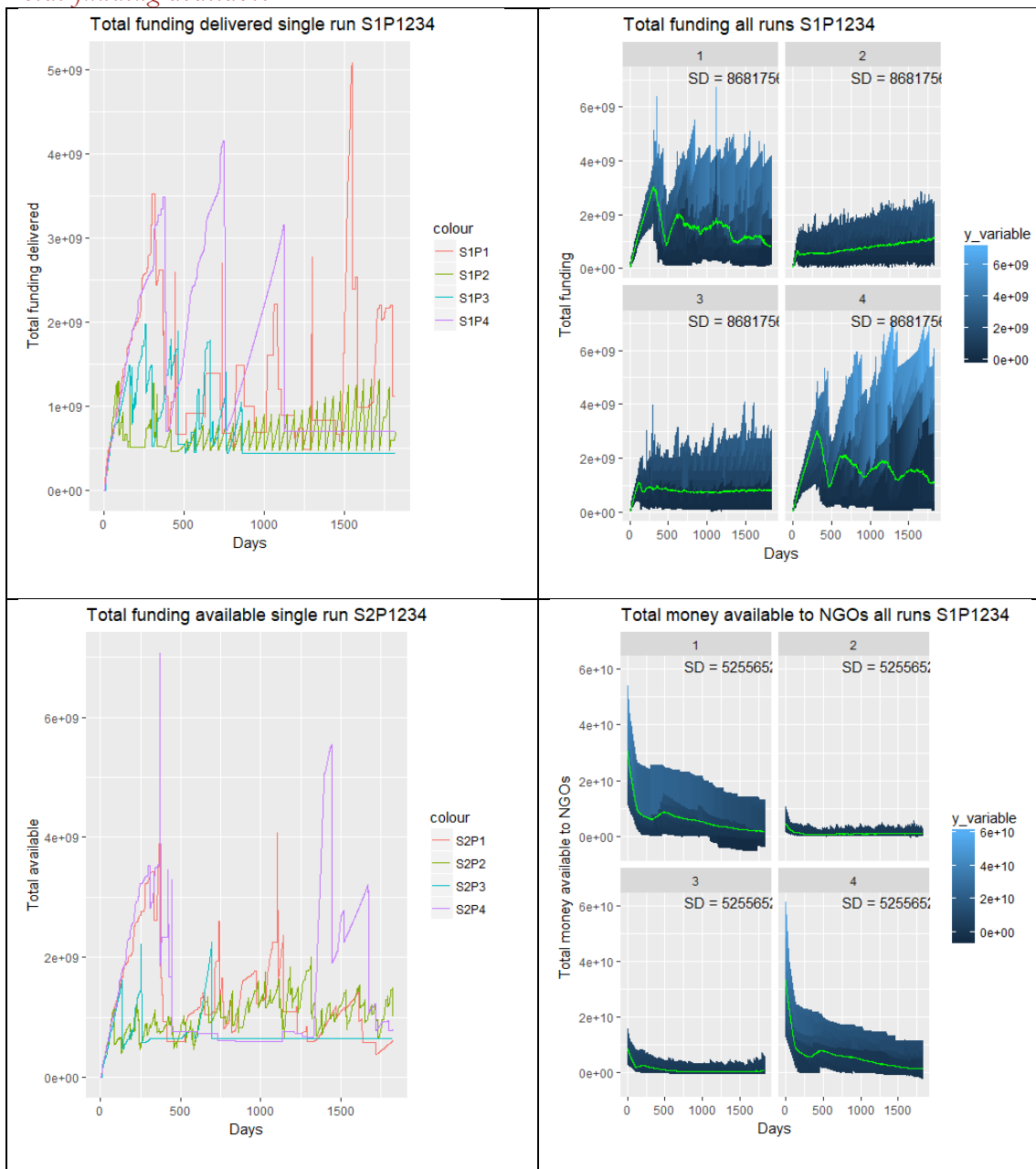
<https://github.com/laurensdekok/ThesisLdK>

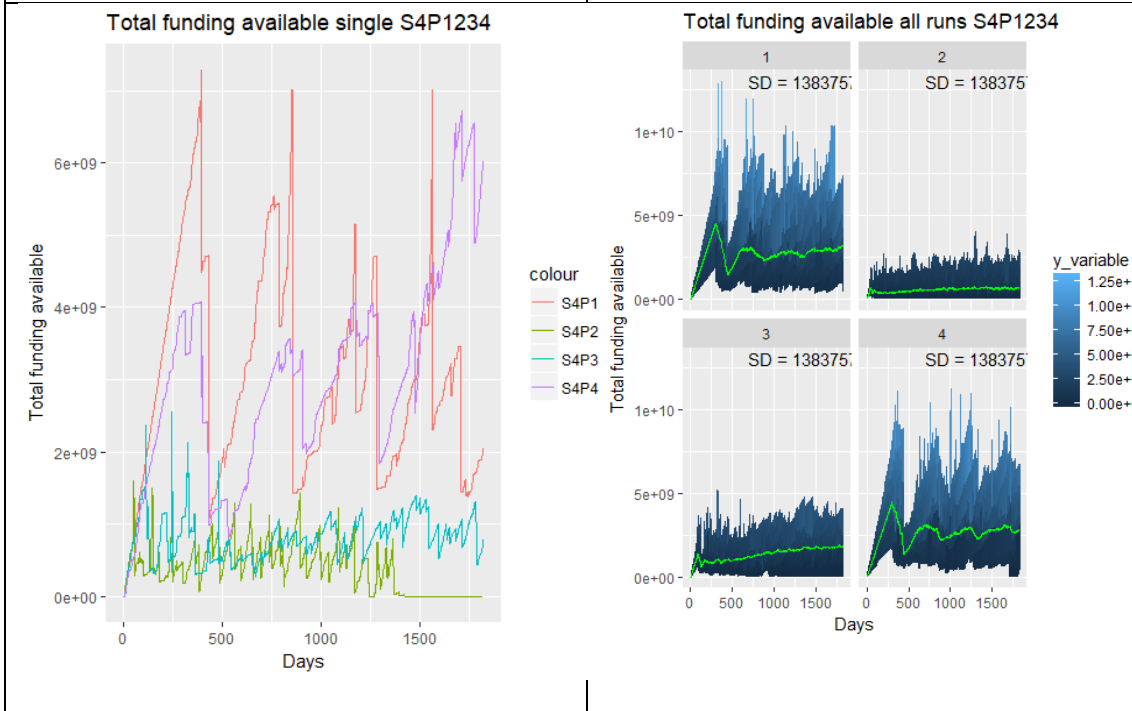
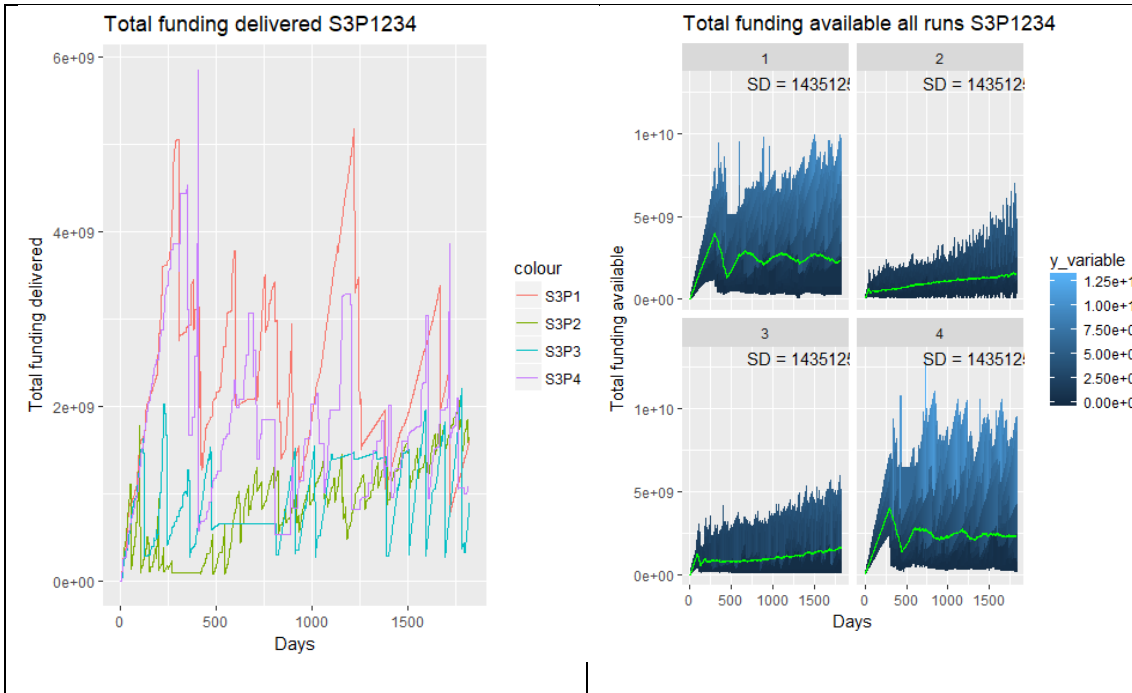


# XI. APPENDIX D

## EXTENDED RESULTS

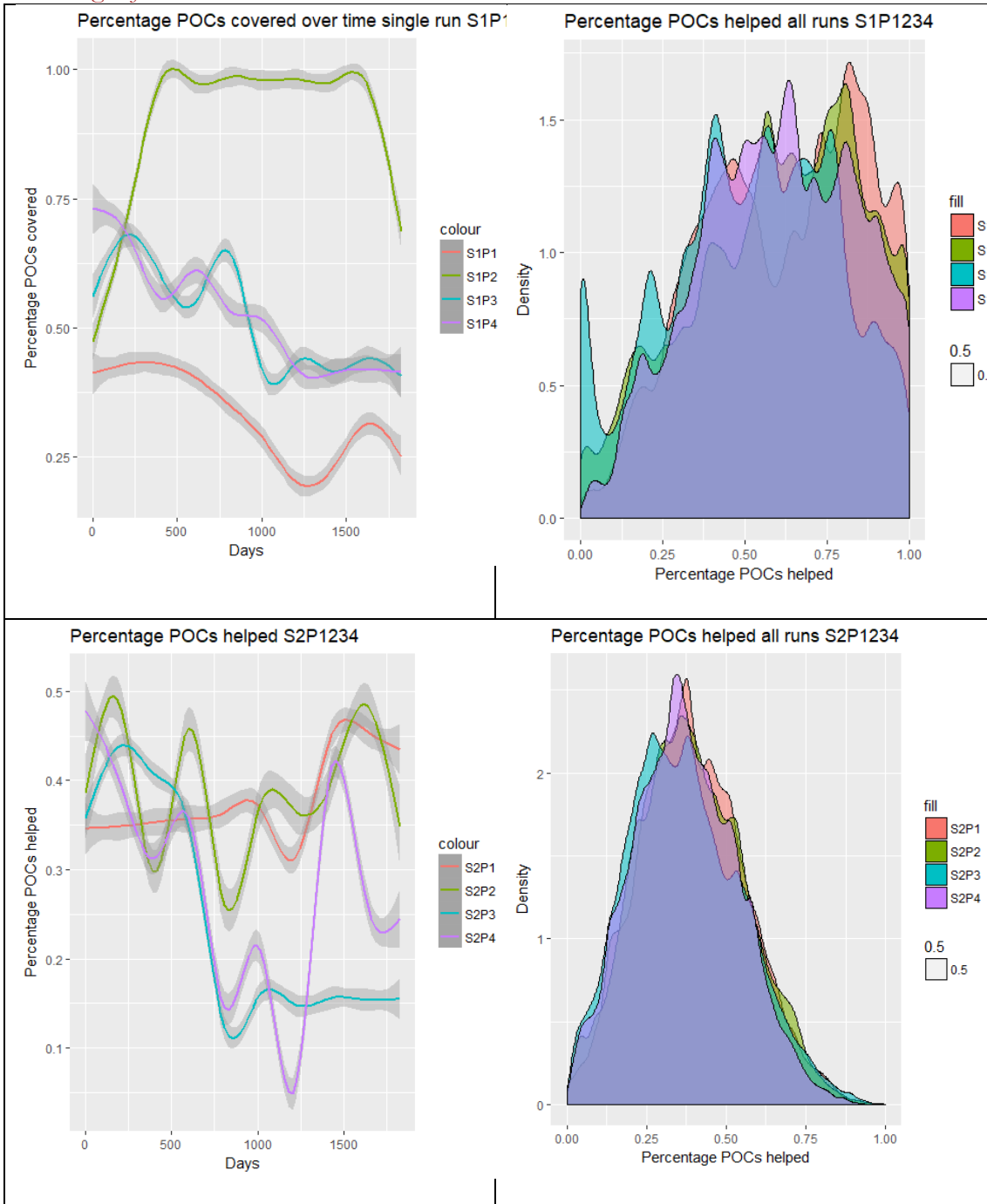
*Total funding available*

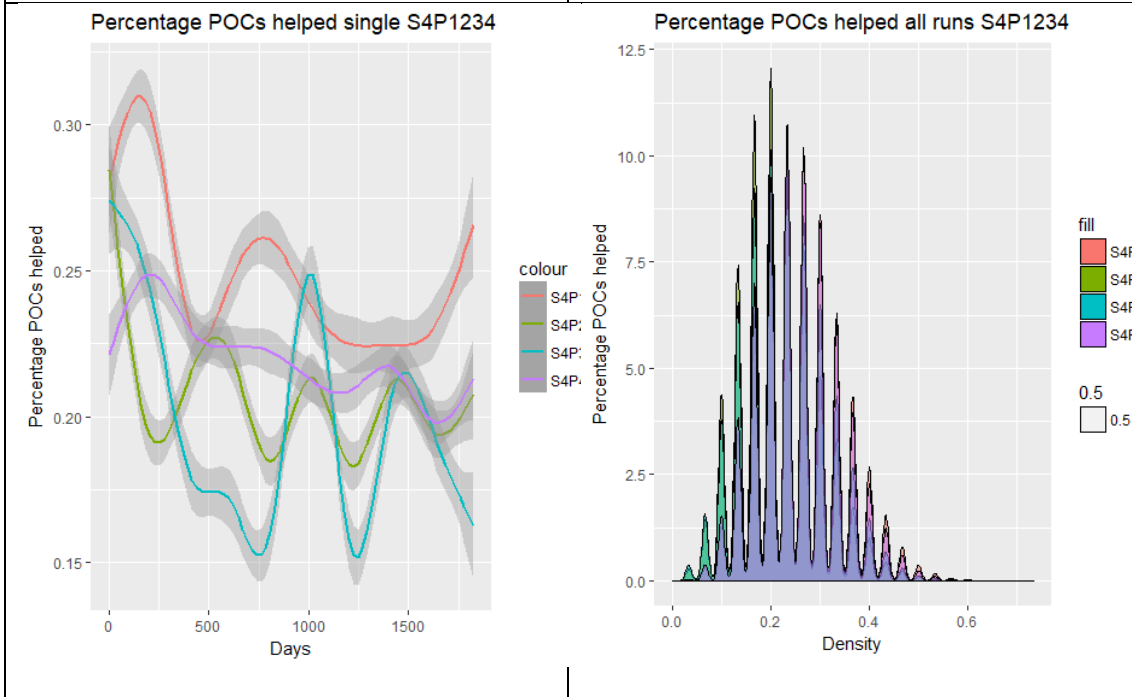
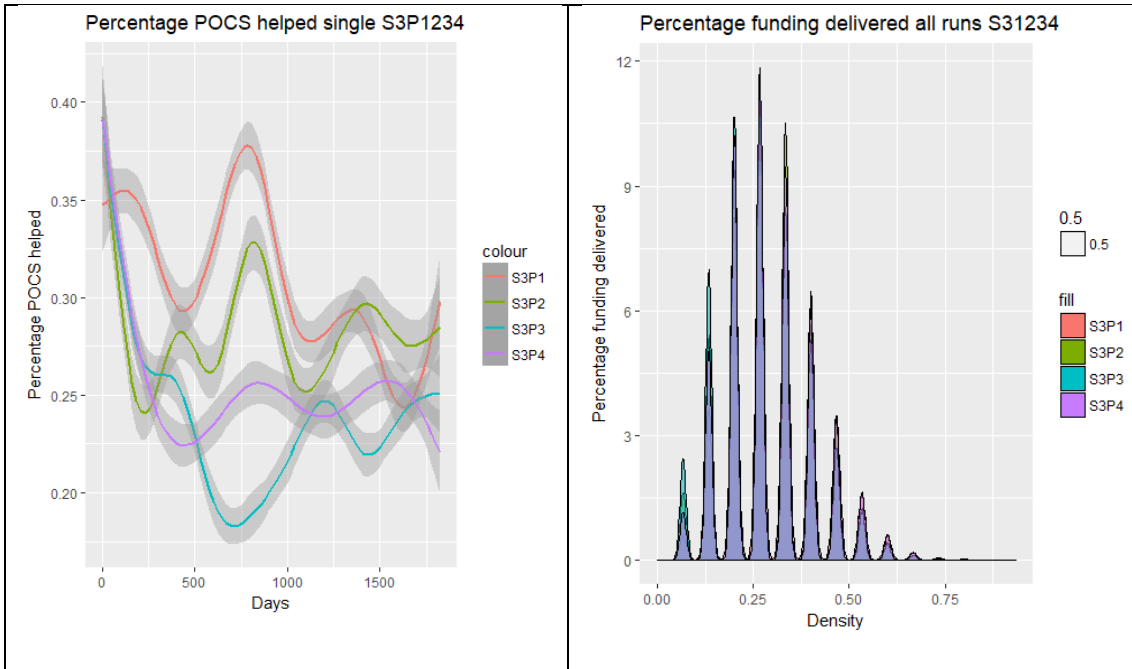




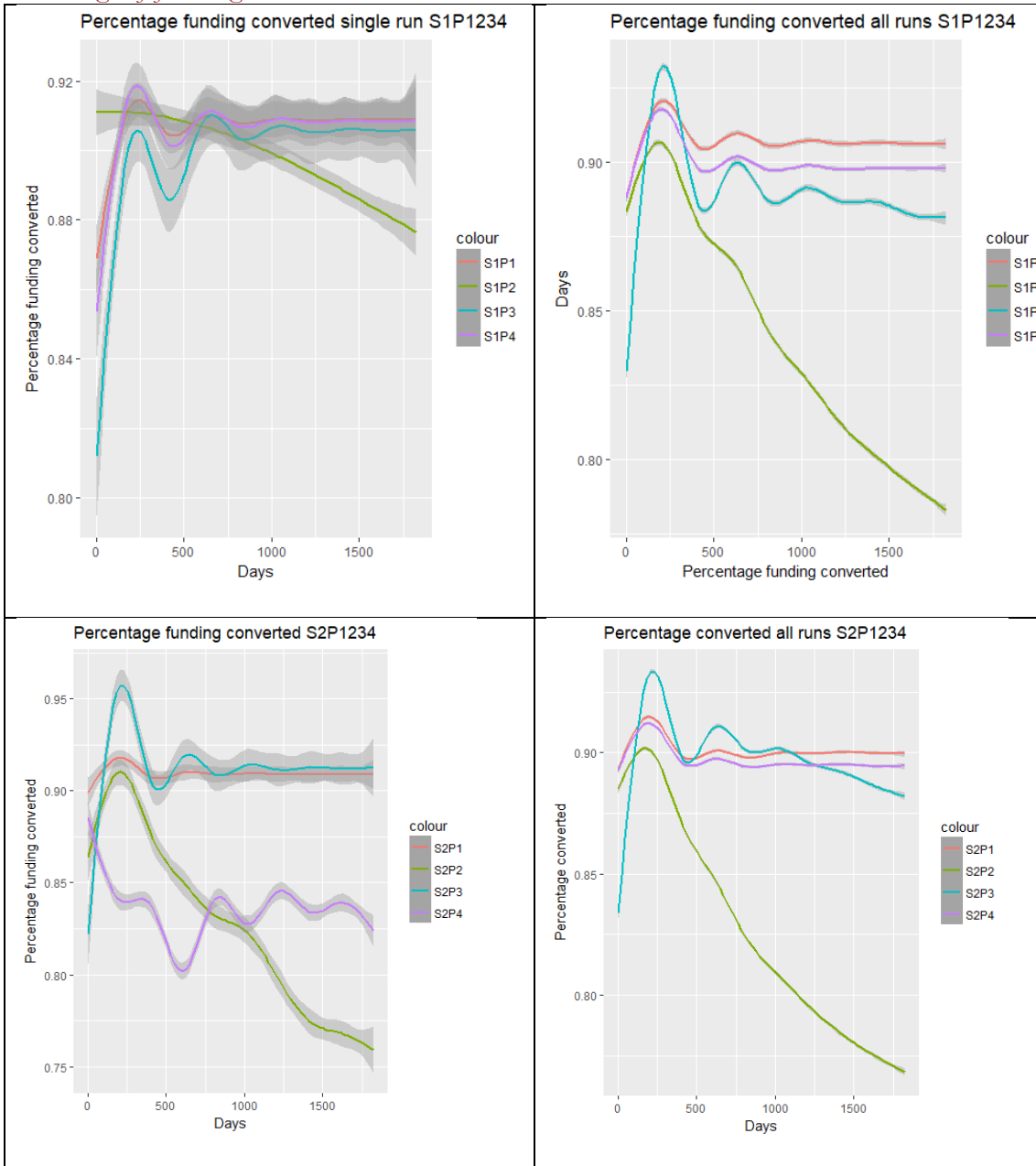
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
<b>Policy 1</b>	$2.75 * 10^{12}$	2.88	3.92	5.24
<b>Policy 2</b>	$1.52 * 10^{12}$	2.00	1.69	0.62
<b>Policy 3</b>	$1.69 * 10^{12}$	1.470	1.49	1.97
<b>Policy 4</b>	$4.37 * 10^{12}$	2.94	2.95	4.85

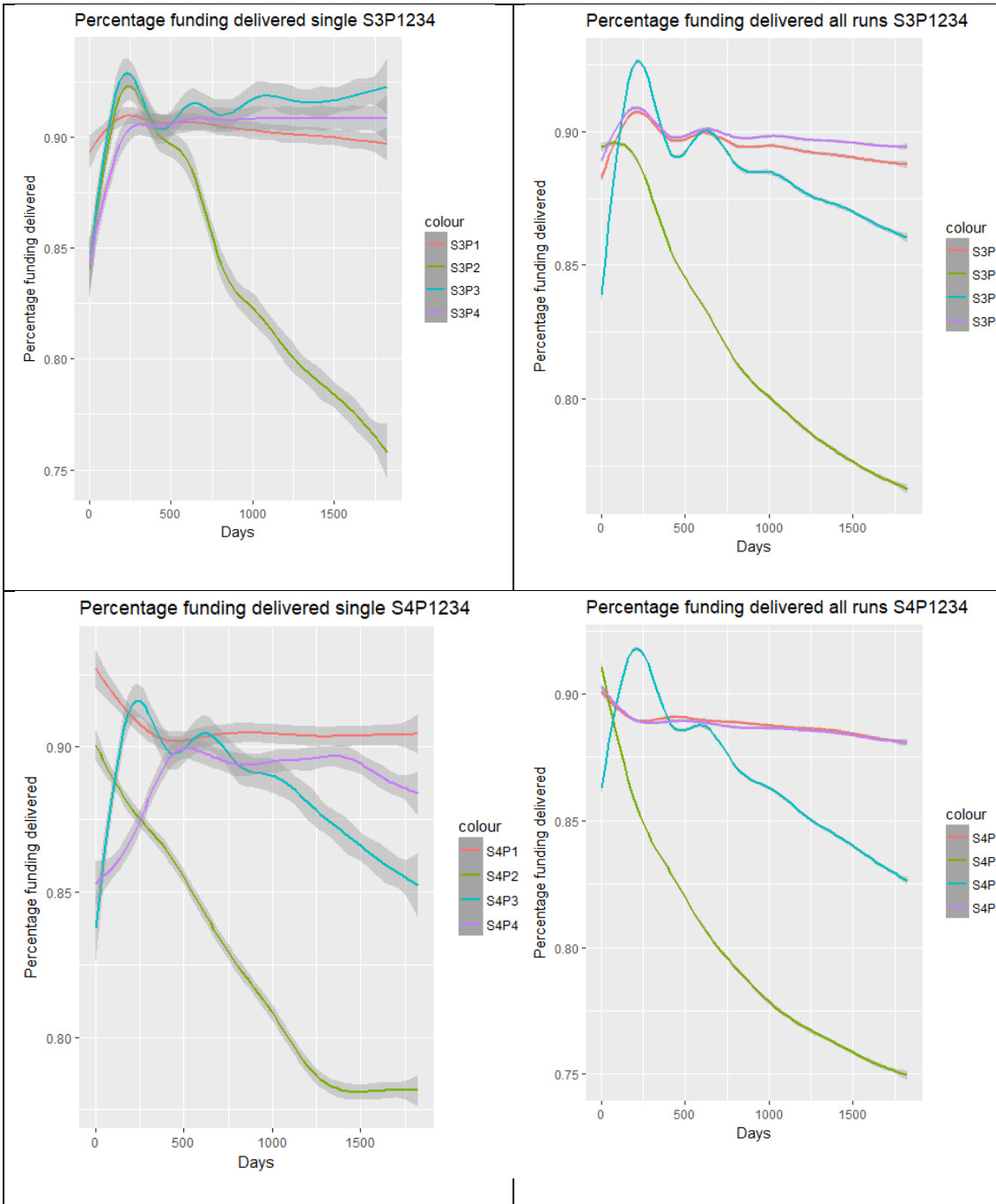
Percentage of POCs covered



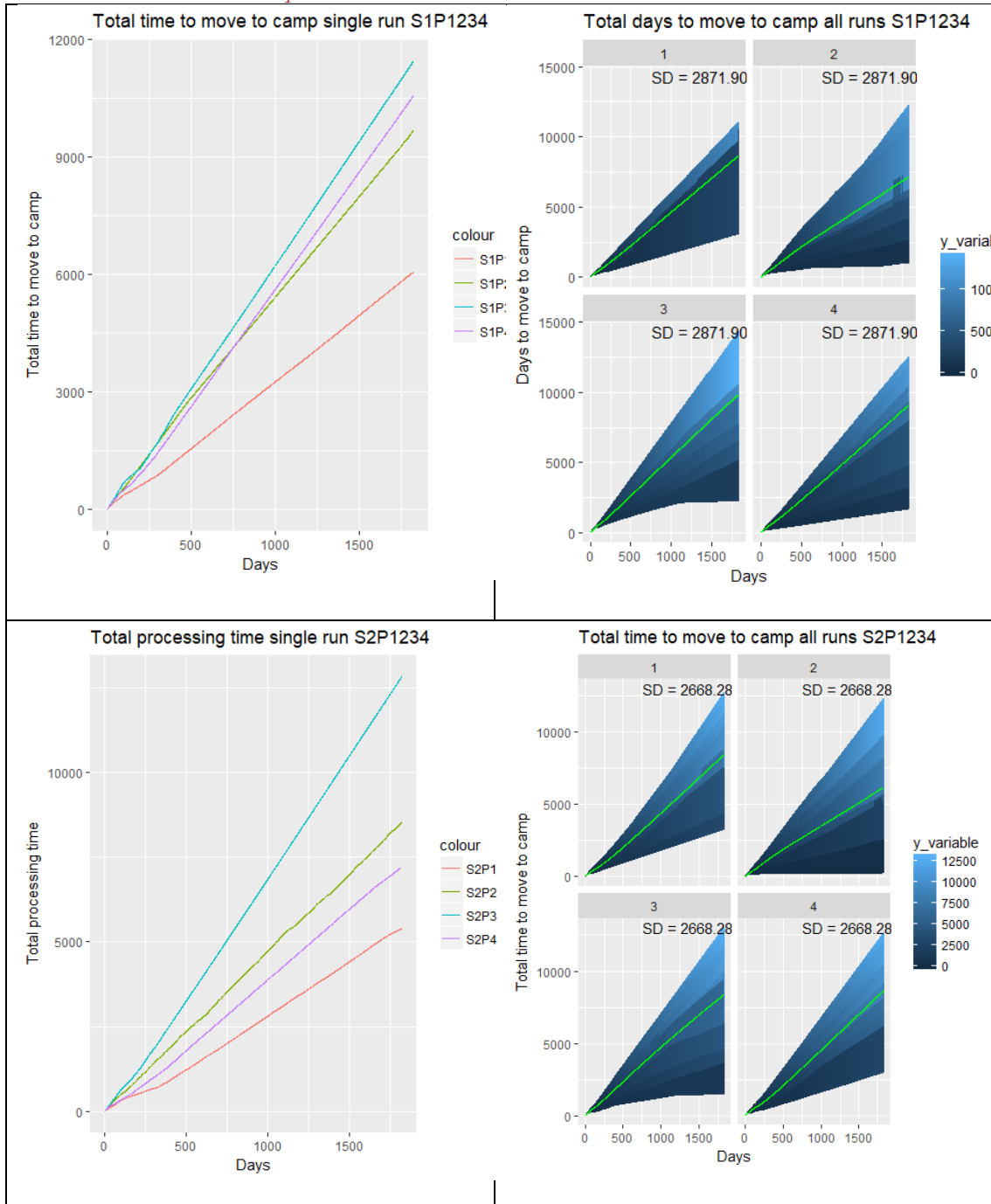


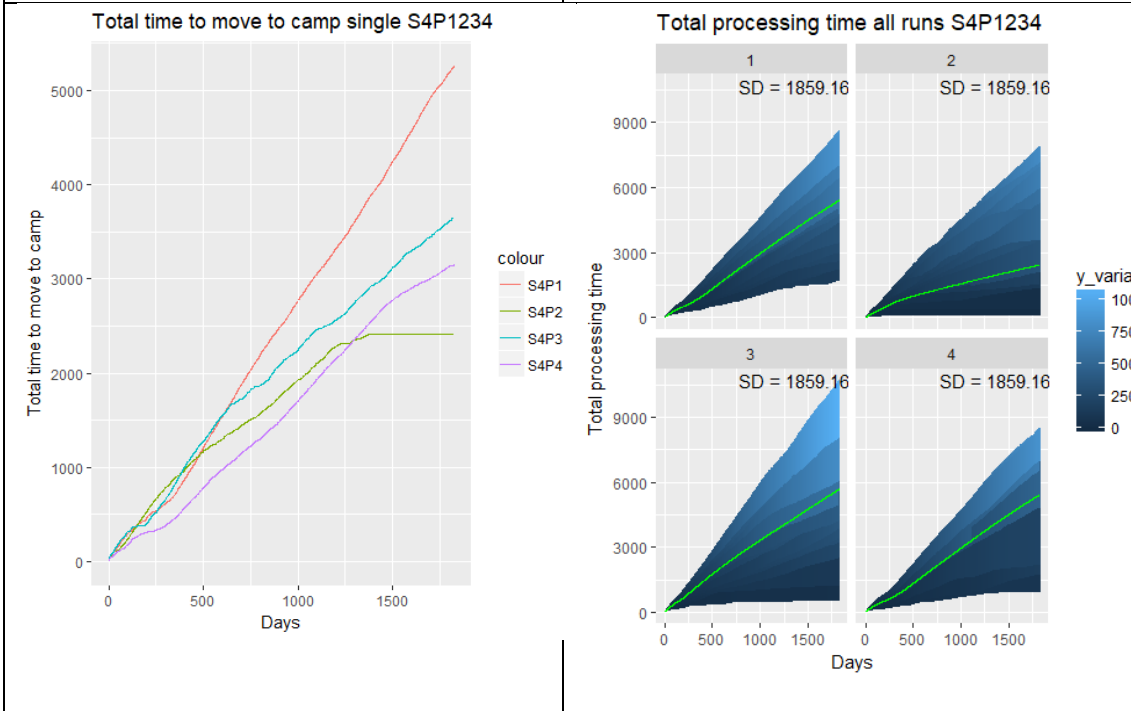
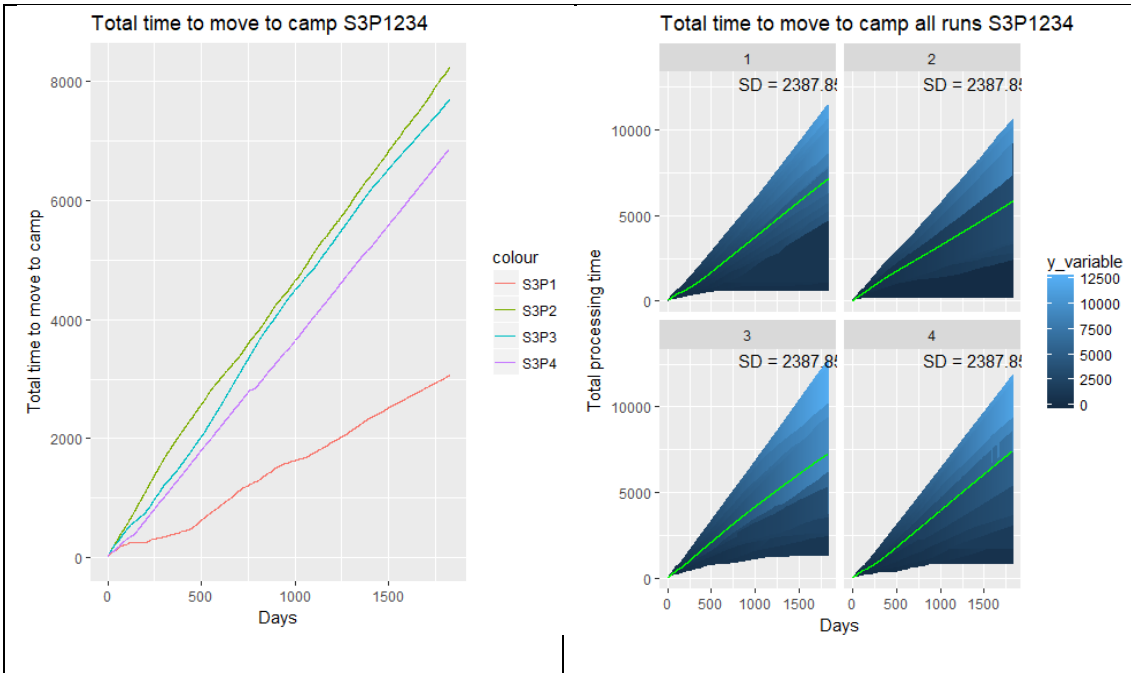
*Percentage of funding converted*





Total time to move to camp

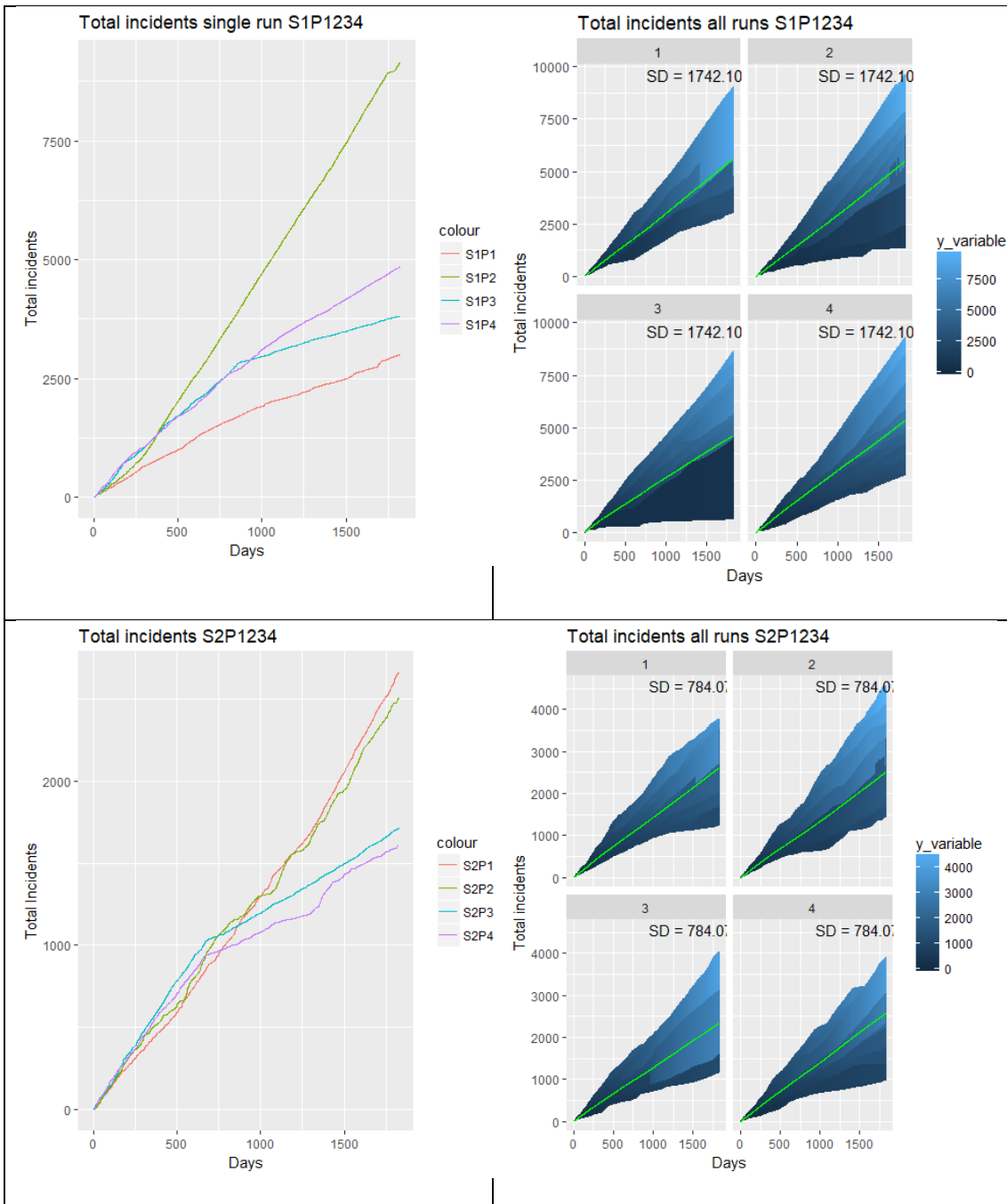


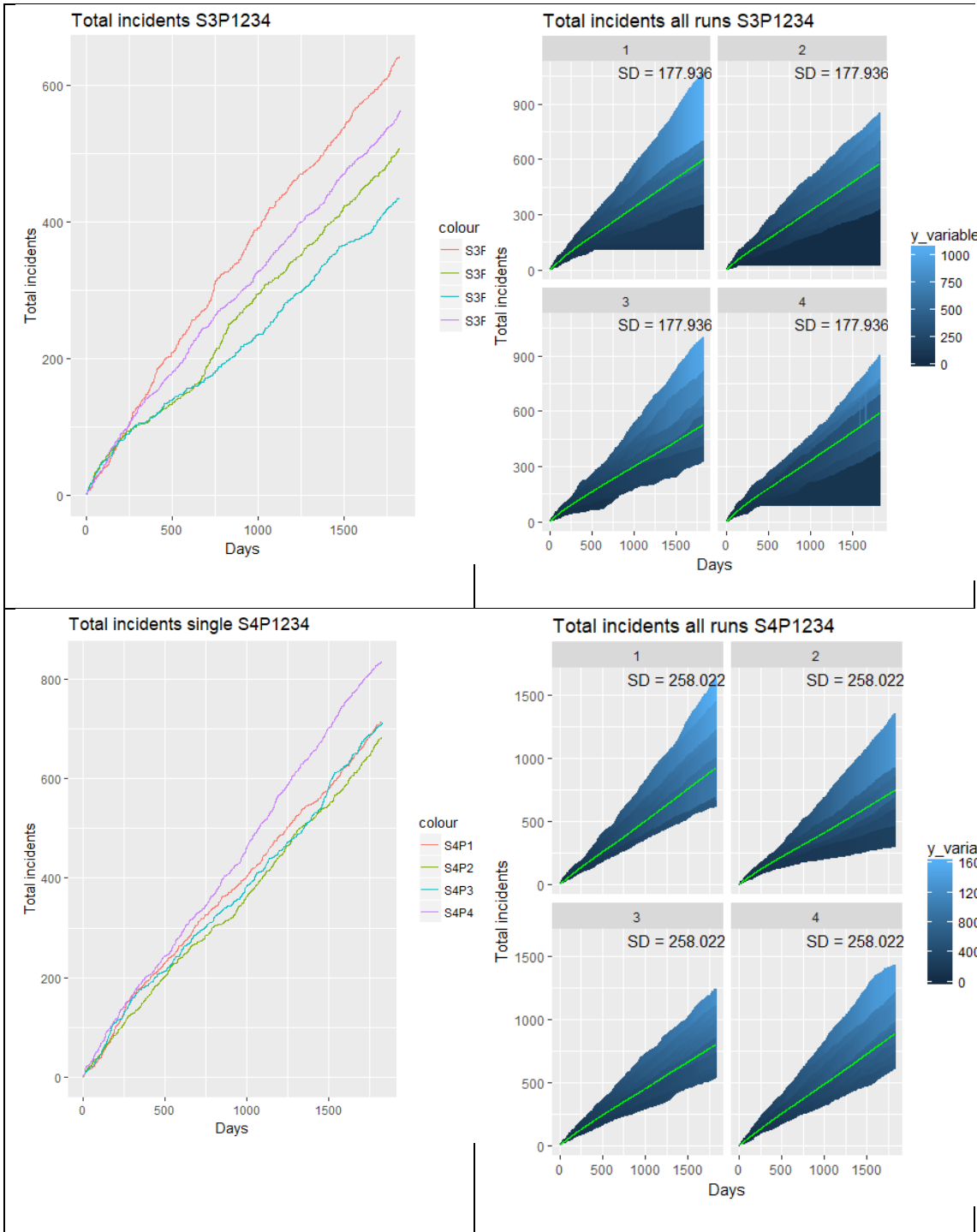




	Scenario 1	Scenario 2	Scenario 3	Scenario 4
<b>Policy 1</b>	8450510	7379774	6548657	4491099
<b>Policy 2</b>	5715219	4809872	6821540	1981571
<b>Policy 3</b>	8663635	8925220	5141022	5270775
<b>Policy 4</b>	9092989	7324564	7661413	5463163

Total incidents

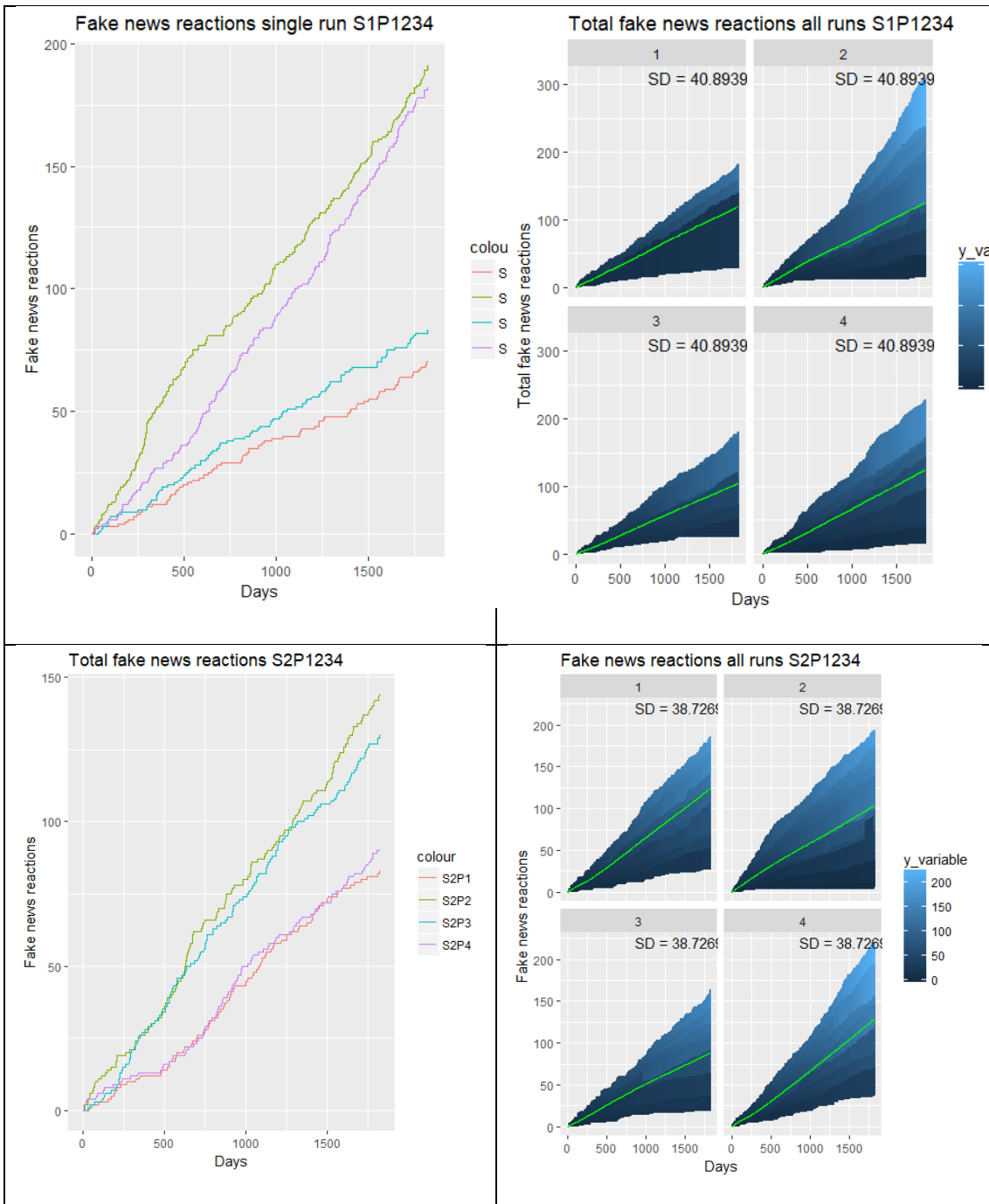


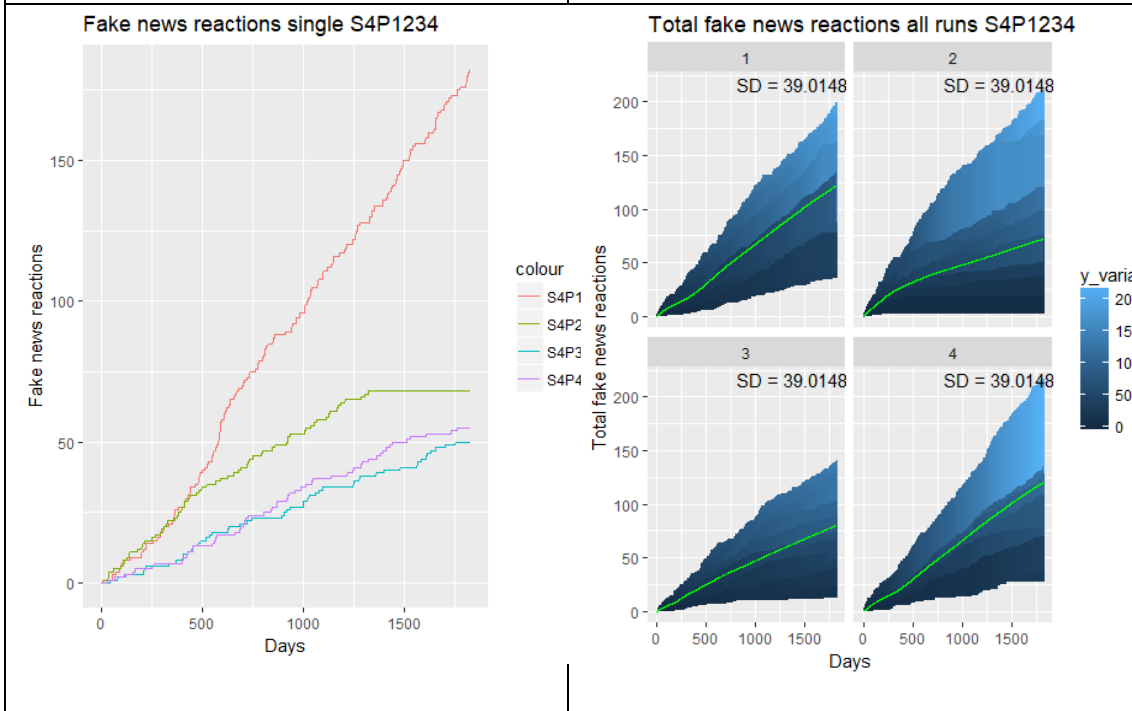
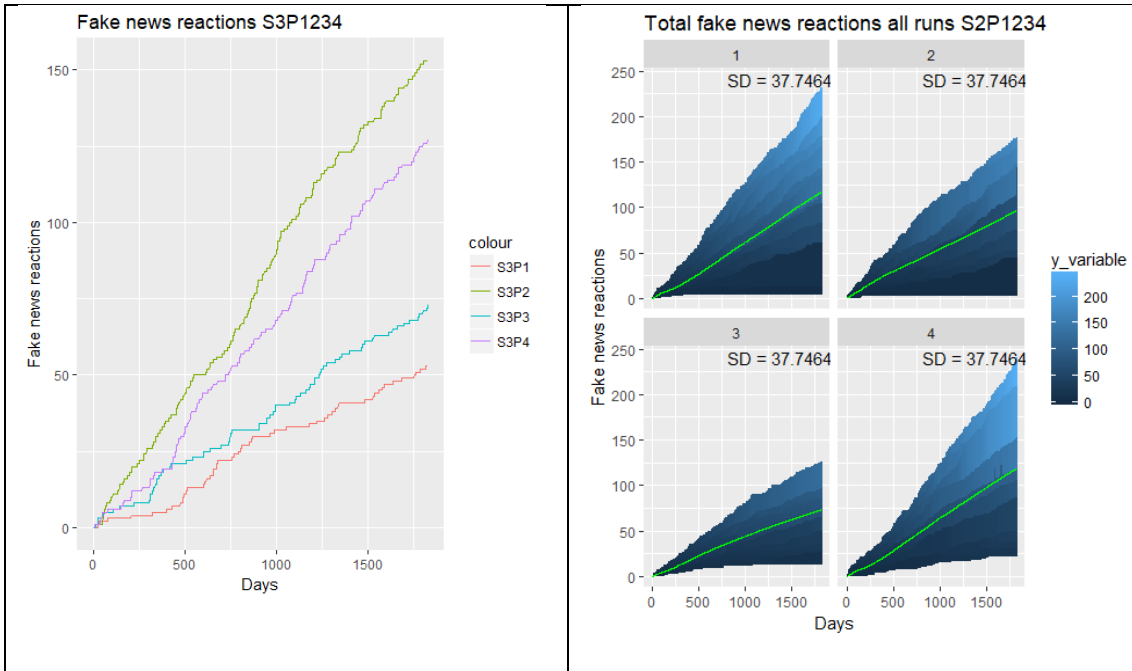


*Areas under curve for total incidents*

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
<b>Policy 1</b>	4695195	2515704	560287	667934
<b>Policy 2</b>	4301837	2416568	559060	611288
<b>Policy 3</b>	4206525	1652104	536907	801379
<b>Policy 4</b>	4627039	2133499	684414	829488

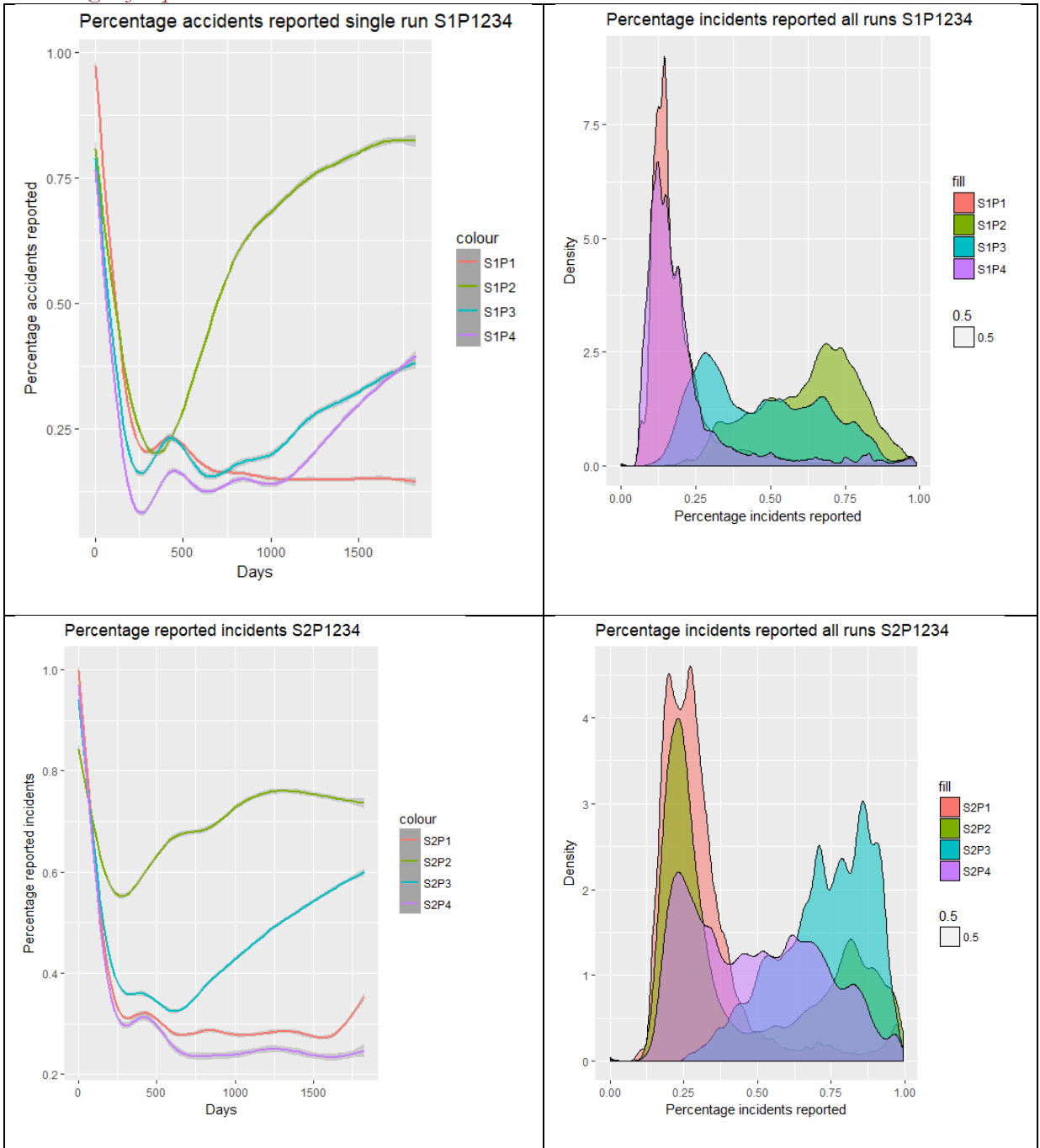
Total fake news reactions



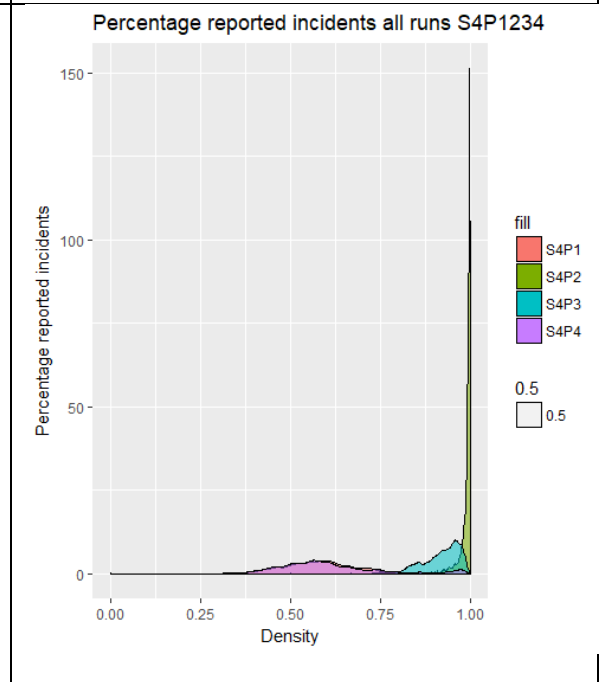
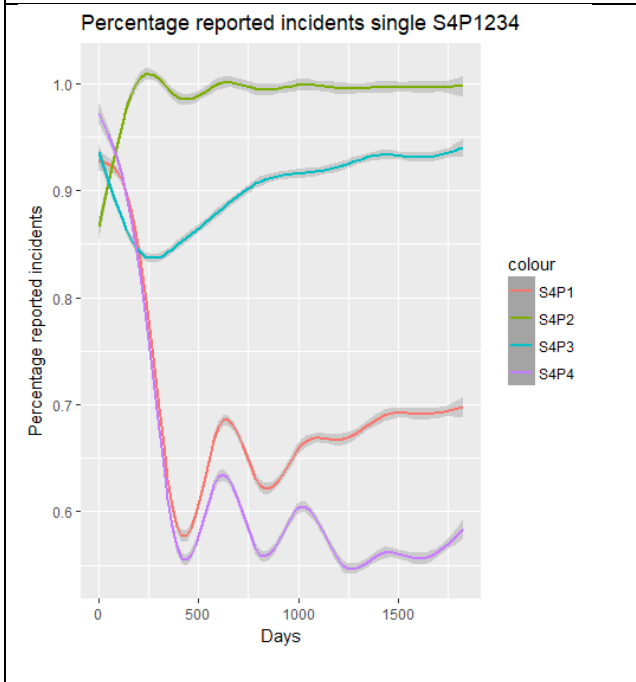
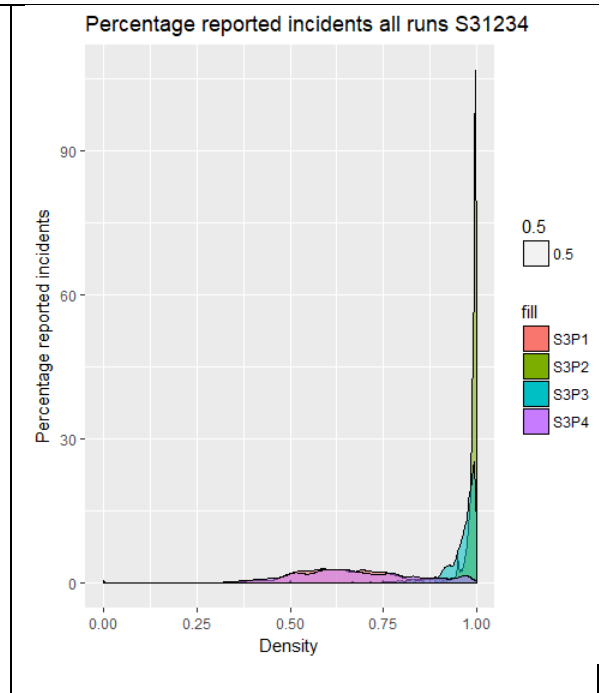
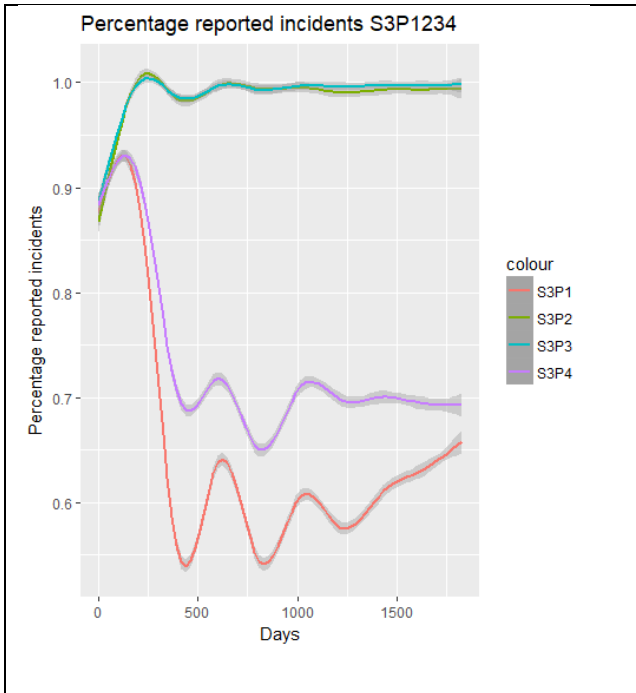


	Scenario 1	Scenario 2	Scenario 3	Scenario 4
<b>Policy 1</b>	142138.5	126005	94292	117833
<b>Policy 2</b>	103828.5	67007	100585	64704
<b>Policy 3</b>	104930	91364	60529	82198
<b>Policy 4</b>	140186	101367	112905	115572

Percentage of reported accidents







# XII. APPENDIX E TOWARDS HIGH- AGGREGATION POLICY TABLE

To arrive to the most high-level depiction of performance of policies in different scenarios, three steps have been made:

1. From graphic and numerical depiction to color code. Every color code in the first four graphs shown below represent a value for KPIs of a policy. Green means it performs better than average, yellow/orange means it performs approximately average and red means it performs worse than average.
2. The second step is from the first group of graphs to the second group of graphs. This combines the color codes of KPIs for one category into one color code.
3. The last step is to combine all four categories into one color code, which represents the overall performance of the policy.

Scenario	Total aid delivered		Efficiency		Safety		Transparency
	Funding available	Percentage covered	Percentage converted	Total processing time	Total incidents	Fake news reactions	Percentage reported incidents
<b>Scenario 1</b>							
Policy 1							
Policy 2							
Policy 3							
Policy 4							
<b>Scenario 2</b>							
Policy 1							
Policy 2							
Policy 3							
Policy 4							
<b>Scenario 3</b>							
Policy 1							
Policy 2							
Policy 3							
Policy 4							
<b>Scenario 4</b>							
Policy 1							
Policy 2							
Policy 3							
Policy 4							

Scenario 1	Total aid delivered	Efficiency	Safety	Transparency
Policy 1				
Policy 2				
Policy 3				
Policy 4				

Scenario 2	Total aid delivered	Efficiency	Safety	Transparency
Policy 1				
Policy 2				
Policy 3				
Policy 4				

Scenario 3	Total aid delivered	Efficiency	Safety	Transparency
Policy 1				
Policy 2				
Policy 3				
Policy 4				

Scenario 4	Total aid delivered	Efficiency	Safety	Transparency
Policy 1				
Policy 2				
Policy 3				
Policy 4				

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Policy 1	Red	Yellow	Light Yellow	Light Yellow
Policy 2	Light Yellow	Yellow	Red	Light Yellow
Policy 3	Light Yellow	Light Yellow	Light Yellow	Red
Policy 4	Red	Light Yellow	Red	Red

# XIII. APPENDIX F

## NETLOGO MODEL

The NetLogo model can be found in the GitHub Repository:

<https://github.com/laurensdekok/ThesisLdK>