MSc thesis in Engineering and Policy Analysis

# INFORMATION DIFFUSION IN COMPLEX EMERGENCIES

## A model-based evaluation of information sharing strategies

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TU Delft

510 AN INITIATIVE OF THE NETHERLANDS RED CROSS

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TU Delft

# PREFACE

Before you lies the master thesis "Information diffusion in complex emergencies". The product of 6 months of hard work. I would like to thank my supervisors for their excellent guidance and support during all the phases of my graduation project.

Thank you Bartel Van de Walle, for sparking my initial interest for humanitarian aid. I find it inspiring how you commit yourself to safeguarding and increasing the quality of research and education at our faculty. I also like to tell you how much I enjoyed our trip to Geneva.

Marc van den Homberg, I appreciated the perspective your brought to the committee: deep in the literature and with a steady eye for the relevance for 510 and humanitarians in the field. It was great to receive new articles, useful ideas and constructive feedback, no matter what moment of the day.

Tina Comes, I must confess that, in conversations with friends, I sometimes referred to you as my precious resource. Your comments were spot-on and enabled me multiple times to lift the project to the next level. I also very much appreciated your kind and encouraging words at the end of our meetings.

Martijn Warnier, I never doubted whether it would be a good idea to have you as first supervisor in my committee. Never could I have imagined how supportive, educational and just enjoyable it was to have you involved in this project. Thank you for all the times you received me, read my drafts and provided me with new insights while drawing figures on the whiteboard in your office. You need a statue!

I would also like to thank everyone at 510. It is great to have seen the team and its products evolve in the 1.5 years that I was part of it. Of course, also a big thanks for all my friends in Delft. You know who you are and you are awesome!

The journey that brought me to this point did not start 5 months ago, nor did it start when I set foot to the campus of the TU Delft. It started with the love and support of my family and especially my parents. Riekje and Marina, thank you for the endless spellings checks and wise words you provided. Also a word of gratitude to Wessel, Niels, Ton and Machteld, you made me to what I am. Then of course, dear Joep, sorry for all the times I brought up my thesis in our conversations the last months. Thank you for all your help. I am very happy that you are by my side.

I know my close family and friends like to remind me of the letter that I planned to write to prime minister Kok. As my 7 year old self was convinced, learning was just not something for me. The prime minster should exempt me from ever going to school again. Luckily, because of your support, that attitude changed and now, almost 20 years later, I am handing in this master thesis. I'm a happy man!

Please enjoy reading this rapport.

Jasper Meijering

# EXECUTIVE SUMMARY

Since World War II the number of people forcibly displaced from their homes has not been as high as it is today (UNHCR, 2017). The refugee crises that emerge from these displacements are examples of 'slow-onset, man-made emergencies', also known as complex emergencies. As humanitarian responses last longer and aim to relief suffering of communities whose needs are greater, the system's operations continue to take place under constant pressure (Alnap, 2015; Ashdown, 2011).

In an emergency, humanitarian organisations share information to prevent redundant data collection and avoid gaps and overlap in the relief activities that they commence. Increasing the number of times a piece of information is shared, or in other words, increasing the diffusion of information, can potentially counter these effects.

This research is performed at 510, the data initiative of the Red Cross. Enabling 510 and other humanitarian organisations that produce information to better understand how information diffuses in a disaster can help them to make humanitarian response more efficient. In addition, humanitarian organisations that use information for strategy, planning or operations can benefit from a better understanding of information diffusion. These humanitarians are often confronted with information gaps and information overloads at the same time. Moreover, they could rely on wrong, outdated or skewed information. Understanding how choices in relief operations effect the diffusion of information can help them to address these problems.

Earlier studies evaluate strategies to increase the diffusion of information (Altay & Pal, 2014; Bateman & Gralla, 2018). It is, however, still largely unknown what the effects of these and various other strategies are on the diffusion of information in complex emergencies. This is especially unknown if one considers that information needs in disasters constantly change and that social networks play a prominent role in the spread of information.

This research uses a model-based approach to evaluate strategies aiming to increase information diffusion in complex emergencies. This approach is used to answer the main research question, that reads as follows:

**"What are the effects of information sharing strategies on the diffusion of information in complex emergencies?**

An analysis of hygiene kit distribution in the Bangladesh-Myanmar displacement crisis and consultation of both literature and numerous humanitarian professionals led to the construction of a model on information diffusion in complex emergencies. Analysis of the results of the experiments conducted with this agent based model shows that there are multiple options to increase the diffusion of information. Five of the six individual information sharing strategies, shown in figure 0.1, increase information diffusion significantly.

Based on analysis of the results, it is also concluded that replacing assessment methods that are highly accurate but slow, by less accurate assessments that are created in near-real time, is the most effective individual strategy. It enables fewer responders to diffuse more information, while the gap between the needs and the relief activities remains constant. The effect of this strategy on the diffusion of information is shown in the top left plot in 0.1.

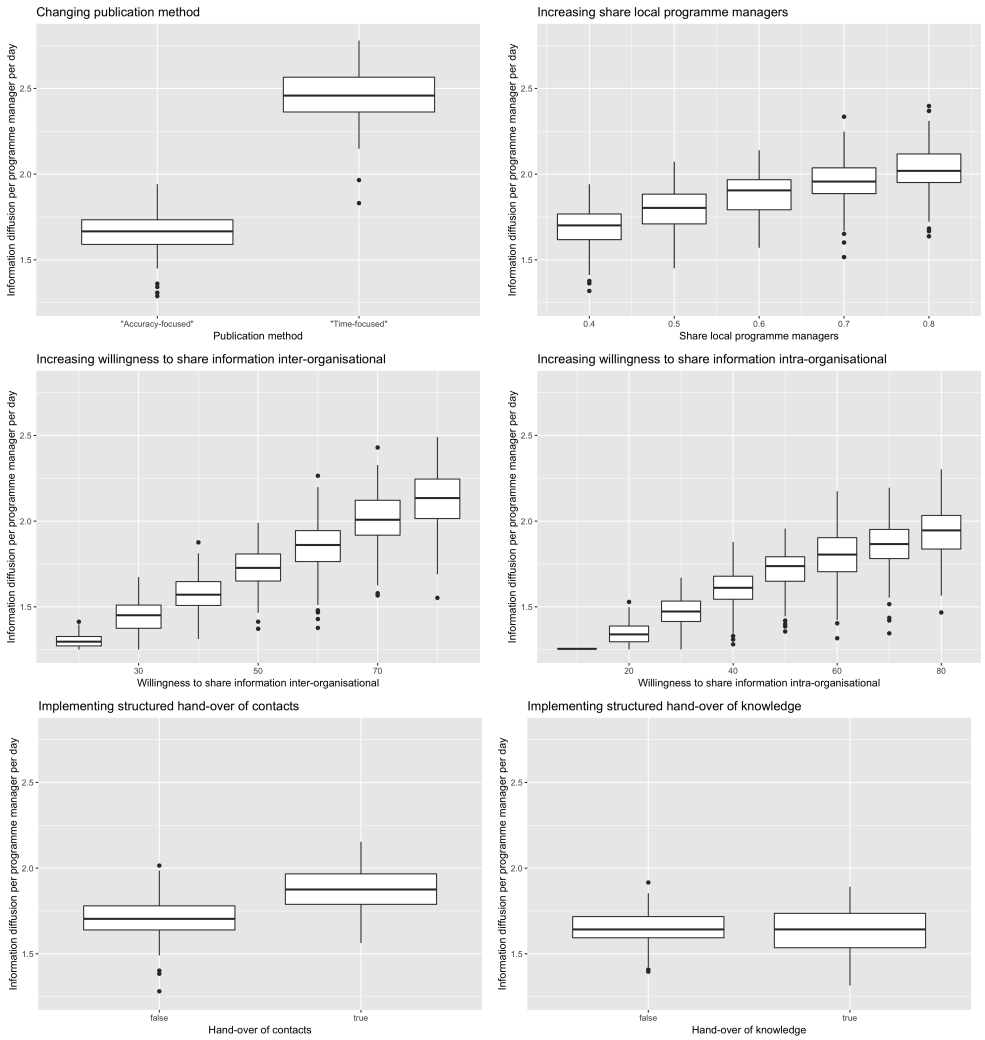


**Figure 0.1:** The behaviour of the effect of six information sharing strategies on the information diffused per person per day. The plot shown in the top left of the figure shows the behaviour of the strategy that is most effective: changing from accuracy-focused to time-focused assessments. The plot in the bottom right shows the effect of implementing structured hand-overs of knowledge, this strategy is not effective in increasing information diffusion.

Figure 0.1 furthermore shows that *Increasing the share of local responders* in a disaster is the second most effective strategy to increase the diffusion of information. In addition, analysis shows that increasing *inter-organisational willingness to share information* is more effective once compared to *increasing intra-organisational willingness to share*. Lastly, the study into the effects of the individuals information sharing strategies shows that *handing-over knowledge* is not an effective strategy to increase information diffusion. In this regard, handing over contacts is more effective.

In addition to the analysis of the effects of the individual strategies, this study also examines the effects of implementing combinations of strategies. The effects of eight comprehensive strategies on the diffusion of information are displayed in figure 0.2. Analysis shows that there is no enforcing or dampening effect between the individual strategies. The results of this study suggest that implementation of combinations of strategies will not lead to effects that are stronger than the sum of the individual strategies nor will the effect be weaker than this sum. As a result, it is concluded that a locally sourced team, with an outward focused organisation that produces near real-time information products, is the most effective comprehensive strategy to diffuse information. It remains unclear what the effect of this strategy

is on the observed total relief gap and the number of days worked in a disaster, as none of the comprehensive strategies change these indicators significantly.

It must be emphasised that the model used to obtain these results is parameterised for the Bangladesh-Myanmar displacement crisis. As the effectiveness of the strategies is context dependent, the results cannot be generalised to other disasters directly. If one were to conclude on the effects of the information sharing strategies in another context one should reflect on the differences between information on hygiene kit distribution and the nature of the information to which the generalisation is made. In addition, one is advised to consider using the model and changing the parametrisation to reflect the disaster at hand. Lastly, it is emphasised that the process by which information leads to planning of relief activities and, as a result, effects the observed relief gap and days needed for the response, is an important direction for future research and extension of the model.

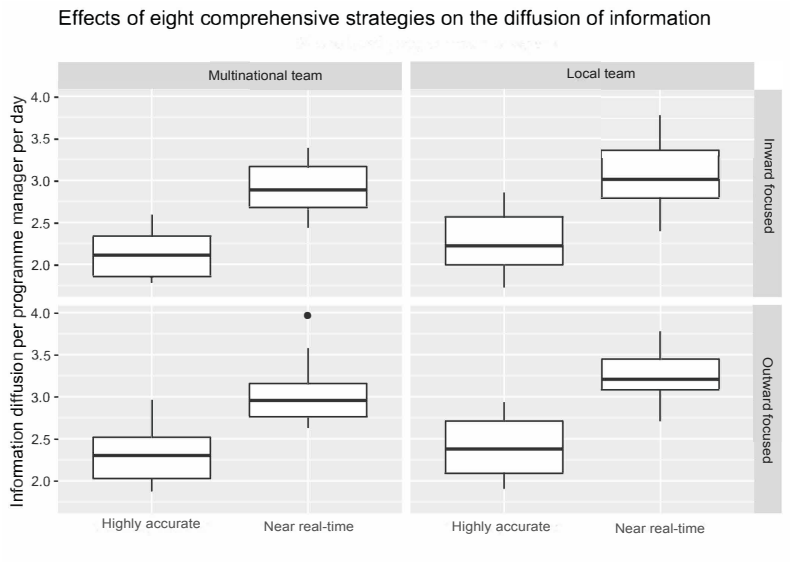


**Figure 0.2:** The behaviour of the effect of the eight comprehensive strategies on the information diffused per person per day. This figure shows that a locally sourced team, with an outward focused organisation that produces near real-time information products is most effective in diffusing information.

The findings of this study suggest that chasing high accuracy levels at the cost of time is not beneficial for information diffusion, closing the relief gap or decreasing the hours that people work in a disaster. Humanitarians are recommended to thoroughly reflect on the rational behind their current choices for assessment and publication methods. The findings also indicate that information diffusion profits from a higher share of local staff. Therefore, they provide support for those that are trying to improve safety of responders belonging to the local community. In this light, humanitarians are encouraged to distinguish reasons from excuses in the discussion about the number of locals versus internationals in a response. Furthermore, this study shows that, from an information diffusion perspective, increasing willingness to share information can be beneficial. The study supports the statement that irrational incentives to not share data should be removed and recommends considering further alignment of the formats that are used to share information. Moreover, this study provides potential alternatives to enhance information diffusion once increasing willingness to share is not desirable. Lastly, humanitarians are recommended to reflect on their hand-overs. If the reason behind a hand-over is to share information so the successor will share it with the rest of the community, it could be wise to use the energy on one of the strategies that showed more effective.

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# 1 INTRODUCTION

## 1.1 INFORMATION IN COMPLEX EMERGENCIES

Since World War II the number of people forcibly displaced from their homes has not been as high as it is today. According to the United Nations Refugee Agency 2017, as many as 65.6 million people are living as refugees or as displaced persons inside their own countries. These individuals are forcibly displaced as a result of persecution, conflict, violence, or human rights violations in amongst others the Syrian Arab Republic, Afghanistan, South Sudan and Myanmar (UNHCR, 2017). A disaster can be natural or man-made (Van Wassenhove, 2006). Refugee crises are examples of 'slow-onset, man-made emergencies', also known as complex emergencies. The effects of these crises are not limited to the refugees themselves. With 84 percent of all refugees living in low- and middle-income countries, developing regions are disproportionately affected by hosting refugees. These countries already face structural barriers to economic growth and development, and usually have limited resources to respond to the needs of people seeking refuge (UNHCR, 2017).

According to a sector-wide review, the international humanitarian system that evolved to respond to the described disasters, is larger than it has ever been in terms of financial and human resources (Alnap, 2015). Yet, as humanitarian responses last longer and aim to relief suffering of communities whose needs are greater, the system's operations continue to take place under constant pressure (Alnap, 2015; Ashdown, 2011).

One of the areas where this pressure can be observed is in information management. All actors in a disaster need information to determine their strategy, planning and operations. Obtaining information for decision-making is challenging (Gralla, Goentzel & Van de Walle, 2015; Comes, Vybornova & Van de Walle, 2015; van den Homberg, Monné & Spruit, 2018b). In most humanitarian organisations, information management officers work to collect relevant data and convert these into information products. One of their most important challenges is to create products that are useful in dynamic and uncertain contexts within a very short time (Comes et al., 2015). Humanitarian decision-makers that use these products are working in stressful, high-pressure conditions where information is often lacking, distorted or uncertain. These conditions are known to introduce or enforce biases (Comes, 2016).

In an emergency, humanitarian organisations share information to prevent redundant data collection and avoid gaps and overlap in the relief activities that they commence. Increasing the number of times a piece of information is shared, or in other words, increasing the diffusion of information, can potentially counter these effects.

## 1.2 SOCIETAL CONTRIBUTIONS: WHY IMPROVE INFORMATION SHARING?

It is claimed that, the fast increase in the availability of data, as observed in recent years, has led to a shift towards more evidence-based humanitarian decision-making, offering humanitarian actors ways to become more effective and efficient (Haak, Ubacht, van den Homberg, Cunningham & Van de Walle, 2018). Although this illusion might prevail in the meeting rooms of some humanitarian head quarters, the arrival of new techniques and the abundance of data does not mean that knowledge is ubiquitous. Nevertheless, a growing number of studies is dedicated to data-analytic techniques and mathematical models that support humanitarian decision-making in the preparation for, or response to the consequences of a disaster (Ortuño et al., 2013). These include data-driven priority indices and numerous data and machine learning tools to prioritise aid (Benini, 2015). These methods, however, all rely on data that must be accessible, timely available and of the appropriate quality.

Today, the information landscape is more volatile and more dynamically evolving than ever before (Comes et al., 2015). Information needs of responders are highly context-specific (Gralla et al., 2015). Moreover, information gaps and information overloads are observed simultaneously, as information needs and quality of the required data depend on the decision at hand. Decision makers in the field are constantly confronted with different levels and scales of uncertainty surrounding these decision (Comes et al., 2015).

### 1.2.1 Three perspectives on what knowledge humanitarians need to improve their response

What knowledge humanitarians miss to improve their response, can be described from the perspective of the information user, from the perspective of the information producer, but also from looking to the system as a whole. Humanitarians, as user of information could be affected by the earlier mentioned information gaps and information overload. It could also be possible that they rely on wrong, outdated or skewed information. This leads to so-called cognitive or motivational biases in their decision making. These biases potentially decrease the effectiveness of a relief operation. For the humanitarian, as users of information, it is often unclear what they can do about this.

For a producer of information, on the other hand, it is currently often unknown by whom, how and when its data products are used. They have difficulty assessing whether their products are of the right quality, at which point in time they should share their analysis and to whom they can best send it. As Andrej Verity set out in his blog post, it is difficult to proof what the impact is of one information product on the effectiveness of a response (Verity, 2014a). Enabling humanitarian organisation to improve their information sharing strategies by gaining a better understanding of how information diffuses in a disaster can, however, potentially increase the impact of the information they produce. It can also help to identify gaps, bottlenecks and critical nodes. Moreover, it enables the organisation to reflect on whether it produces right product and uses the right methods and channels.

In 2005, Markku Niskala, IFRC Secretary General, called upon aid organisations to recognise that accurate, timely information is a form of disaster response in its own right. *Information alone can save lives but, there are gaps in the way we gather and share this powerful resource*, he argued (International Federation of Red Cross and Red Crescent Societies, 2005). Looking to the system as a whole, one could

argue that duplication of information producing efforts coupled with prevailing gaps, potentially makes the relief operation less efficient. How this happens and, at least as important, how this could be altered is less clear.

### 1.2.2 Information sharing at 510, an initiative of The Netherlands Red Cross

This research project is performed at 510, the data initiative of the Red Cross. 510 is both a producer and user of humanitarian data. The team assists national societies of the Red Cross in developing countries in their data related projects and the interventions they are doing. In some cases partnering national societies also make use of the 510 information products. On request, 510 produces information products and shares these with the requester. In some cases, disseminates of information is more indirect and information products are placed on geospatial data sharing platforms.

One of the tools that is developed in cooperation of other national societies is the '*Community Risk Assessment dashboard*'. This is a data-driven tool for which relevant data on risk components is gathered and combined to provide a detailed risk assessment for areas and communities in a country. The tool is currently not being used for support in complex crises. The goal of the Community Risk Assessment dashboard is to quickly identify the geographic areas that are most affected by a natural disaster and, within those areas, the people that are most affected. It forms a solution to help reach those affected and most vulnerable faster and more efficiently (510, 2018). 510 aims to retrieve data at the lowest possible granular level. Detailed data improves the value of the model predictions. The philosophy behind the Community Risk Assessment dashboard and a number of other products and services is that field assessment teams need less time for identification and prioritisation of affected people, time they can spend on bringing aid. Understanding how information products diffuse in a disasters and knowing how information diffusion can be increased supports 510 in reaching this goal.

To be able to apply these data-analytic techniques and mathematical models, a certain level of 'data preparedness' is required (van den Homberg, Visser & van der Veen, 2017). In their article on data ecosystems in Malawi, van den Homberg and Susha (2018) observe that: *"Incentives to share and use data are not well aligned and user selection differs among actors whereby some open their data, others only on demand or not at all"*. Currently data sharing is mainly driven by the expectation of reciprocity (van den Homberg & Susha, 2018).

To share the information that has been produced by these techniques an understanding of how information diffuses under individuals and organisations is desirable. As other humanitarian organisation do, 510 has a number of choices in how, when and to whom it shares its information products. The effects of these choices are largely unknown.

## 1.3 RESEARCH OBJECTIVE: EVALUATING INFORMATION SHARING STRATEGIES

As will be elaborated on in the following chapters, this study aims to evaluate the effects of various information sharing strategies on the diffusion of information in complex emergencies. To support the humanitarian community, scholars investigated the effects of various strategies for information sharing. Amongst others Tatham and Kovács (2010), Altay and Labonte (2014) and Papadopoulos et al. (2017) used mainly qualitative approaches to further our understanding of how informa-

tion sharing can be increased. Altay and Pal (2014) and Bateman and Gralla (2018) were the first researchers that used an agent-based modelling approach to evaluate strategies that aim to increase information sharing between and within organisations. The latter scholars looked amongst others into the role of the cluster leads in the cluster approach, the effect of increasing trust and willingness to share information and implementing regular team meetings to exchange information. The effects of various other strategies for information sharing, for example the effect of hand-overs on the diffusion of information are, however, still ill understood as will be substantiated in the following chapter.

## 1.4 RESEARCH SCOPE: SHARING STRATEGIES AND DIFFUSION AMONGST INDIVIDUALS AND ORGANISATIONS

This study focuses on the effects of information sharing strategies on the diffusion of information in complex emergencies. The study does not consider the political, financial or cultural motives to implement these strategies. Neither is it focused on answering questions related to data responsibility. Moreover, it does not aim to answer the question of whether and how the diffusion of information increases the effectiveness or efficiency of a response. The study does focus on diffusion of operational information in complex, level 3 emergencies. The demarcation of the research scope will receive more attention in the chapters that follow.

## 1.5 STRUCTURE OF THIS STUDY

This first chapter of this thesis aims to introduce the subject of this study along with its societal relevance and context in which it is performed. The following chapter, chapter 2 consist of a literature review that explores existing research on information sharing in complex emergencies. this chapter aims to identify the knowledge gap that shapes the ensuing direction of the study. Chapter 3 formulates the main research question, sub-questions and the research design. The sub-questions are answered in the chapters 4 to 9. Subsequently, the outcomes of the study are discussed and reflected on in chapter 10. Finally, chapter 11 synthesises the findings, societal and academic contributions and the recommendations discussed in this study.

# 2 LITERATURE REVIEW ON INFORMATION SHARING IN COMPLEX EMERGENCIES

This chapter consists of a literature review that explores existing research on information sharing in complex emergencies. By exploring established research and discussing the core concepts of information sharing in complex emergencies, this chapter aims to identify a knowledge gap that shapes the ensuing direction of the study. By identifying this study's knowledge gap this chapter also discusses the demarcation of the project.

## 2.1 HUMANITARIAN RESPONSE AS COMPLEX SYSTEM

As described by Einarsson and Rausand (1998), communities or societies can be seen as complex systems that are characterised by dynamic behaviour, non-linearity and emergence. Although this study sees complex emergencies as complex systems, the concept complex system should not be confused with the concept complex emergency. A complex emergency is a humanitarian crisis that is often the result of a combination of political instability, conflict and violence, social inequities and underlying poverty. Complex systems or complex adaptive systems are systems in which a perfect understanding of the individual parts does not automatically convey a perfect understanding of the whole system's behaviour (Miller & Page, 2007). In the line with Comes et al. (2015), this study sees emergencies as phenomena that can be understood as shocks that drastically change a system's behaviour. This study defines a emergency as a complex system with a behaviour that is drastically changed as the result of a shock.

**Concept 2.1.1: Humanitarian response as complex adaptive system**

This study defines a disaster as a complex adaptive system with a behaviour that is drastically changed as the result of a shock.

## 2.2 HUMANITARIAN RESPONSE AS MULTI-ACTOR SYSTEM

Humanitarian response can be characterised by the multitude of actors that are simultaneously trying to react to the disaster. Efficient disaster response requires well-aligned information flows, decision processes and coordination structures (Quarantelli, 1988). Over the past decades, there have been many developments in improving the coordination in humanitarian relief operations. In 2005, the Humanitarian Reform process was initiated by the Emergency Relief Coordinator, together with the Inter-Agency Standing Committee to improve the effectiveness of humanitarian response through greater predictability, accountability, responsibility and partnerships Inter-Agency Standing Committee, 2011. In addition, with the United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) and the Emergency Response Coordination Centre (ERCC), the UN and EU established their own bodies coordinating humanitarian aid. There are, however, still

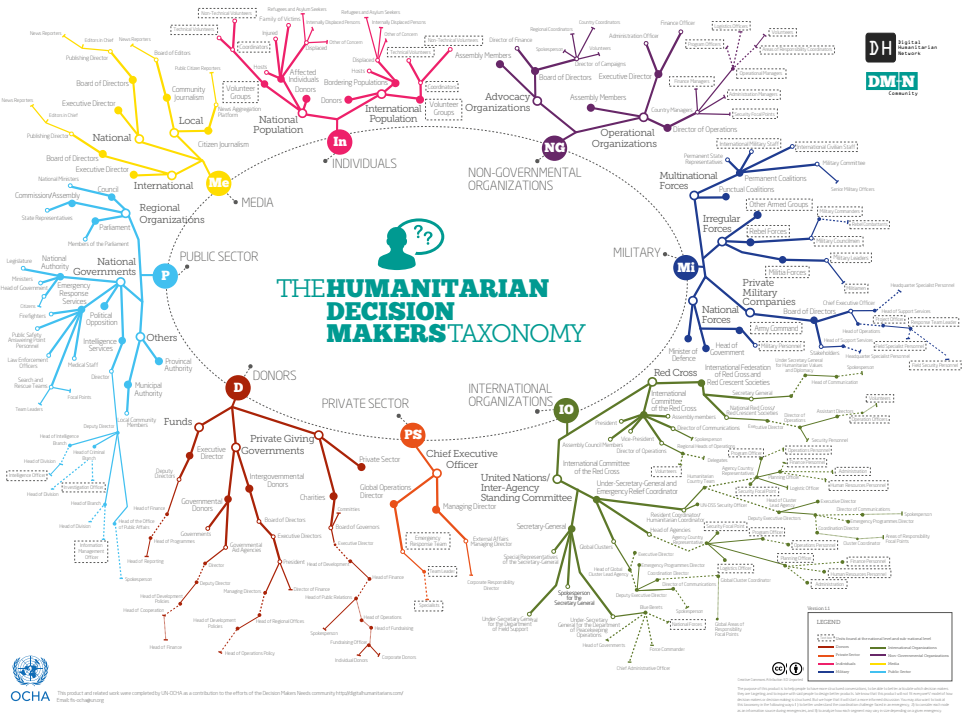


**Figure 2.1:** The Humanitarian Decision Makers Taxonomy adopted from Verity 2013.

many challenges facing effective coordination in humanitarian relief.

According to the Decision-Makers Taxonomy of Verity (2013) the decision makers in disaster management of sudden-onset emergencies are a wide variety of organisations and individuals that can be grouped into individuals, non-governmental organisations, military, international organisations, the private sector, donors, the public sector and the media. The decision-makers taxonomy is illustrated in Figure 2.1.

Slow-onset emergencies generally receive less attention then sudden-onset disasters. In addition, while complex emergencies are generally characterised by the stronger role for the actors that cause the disaster, their multi-actor nature is evident.

**Concept 2.2.1: Humanitarian response as multi-actor system**

This study sees humanitarian response as multi-actor system, consisting of various individuals and organisations.

## 2.3 HUMANITARIAN RESPONSE AS VIRTUOUS CIRCLE

**??** Decision-making and sense-making can be seen as two related but distinct concepts. Decision-making is traditionally viewed as a sequential process of problem classification and definition, alternative generation, alternative evaluation, and selection of the best course of action (Simon, 1976). Sense-making, on the other hand is concerned with making things that have already happened meaningful (Boland, 2008). Muhren (2011) first presented a distinction between decision and sense making regarding the processing of information. This study follows his distinction that, *decision-making is about coping with information processing challenges of uncertainty and complexity by dealing with information, whereas sense making is about coping with informa-*

*tion processing challenges of ambiguity and equivocality by dealing with frames of reference.*

In order to be insightful for decision or sense making, data needs to be collected and transformed into information. Because decision-making constantly influences the disaster, this process is a "virtuous circle". Data on the disaster is collected and transformed into information for decision- and sense-making. Based on information, decisions are made. These decisions influence and change the disaster Comes (2016). The process starts over again. The virtuous circle between disaster, information, decision-making and sense making is illustrated in figure 2.2.

In addition to sense-making and decision making on an individual level, groups of people also make decisions and sense of information. The Collection Coordination and Information Requirements Management cycle described by Brouwer and Scholten (n.d.), provides a example of how organisations, amongst others those in the intelligence community, make sense and base decision on information that is continuously changing. In this cycle, first requirements for data collection are defined, then, data is collected and processed. subsequently, information is disseminated. Other bodies use the information to make decisions, the system changes and the cycle repeats itself.

**Concept 2.3.1: Disaster, information & decision-making, a virtuous circle**

This study sees information processing, sense- and decision-making in humanitarian disasters as continuing processes that are part of a virtuous circle.

## 2.4 HUMANITARIAN RESPONSE IN A DATA ECOSYSTEM

Haak et al. (2018) analysed the complex, fragmented humanitarian decision makers context from a data ecosystems perspective. Previous to Haak et al. (2018), academics in information intensive, socio-technical contexts have applied the ecosystems perspective to get an idea of the diverse interrelationships between data users, data providers, data itself, institutions and material infrastructure (Harrison, Pardo & Cook, 2012). According to Harrison et al. (2012) data ecosystems can be used as a means for decision-making and planning, to locate the relative positions of the actors in the ecosystem, and to facilitate access to sharing and using data.

Haak et al. (2018) describe the humanitarian data ecosystem as a *"data ecosystem that is in an emerging phase of development whereby it links to other sub-data ecosystems*

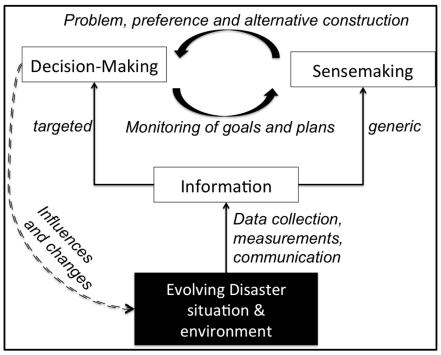


**Figure 2.2:** The virtuous circle of sense making and decision-making in humanitarian disasters and the role of information adopted from Comes 2016.

*or in some cases data collaboratives, that collect, handle and use data*". They derived a general framework of criteria for a successful data ecosystem from literature and discussion with a group of open data researchers. This framework is displayed in figure 2.3. In their article Haak et al. (2018) argue that*"[t]o stimulate its development, the special point of attention in the humanitarian data ecosystem appeared to be the governance part of the framework*".

In a paper that characterises data ecosystems to support official statistics with open mapping data, van den Homberg and Susha (2018) introduce an integrated framework to characterise data ecosystems. This framework goes beyond the one introduced by Haak et al. (2018) as it characterises data ecosystems by five dimensions instead of three: actors, data supply, data infrastructure, data demand and data ecosystem governance. The first, actor and role dimension, describes the actors and the roles they can have as producer, consumer and/or intermediary. Homberg and Susha argue that in a mature data ecosystem that a data producer has relationships with other actors including users. In immature data ecosystems, such as the humanitarian ecosystem, data producers might be not well networked.

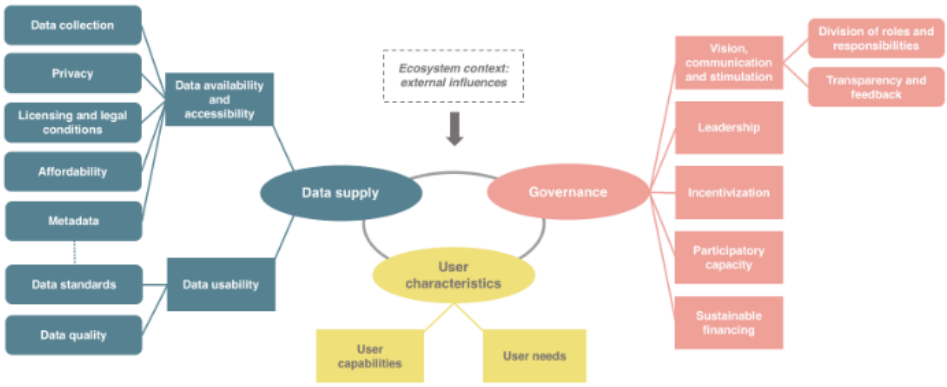


**Figure 2.3:** General framework of criteria for a successful data ecosystem adopted from Haak 2017

**Concept 2.4.1: Humanitarian response as emerging data ecosystem**

- This study underlines that humanitarian response can be seen as a data ecosystem, in an emerging phase of development.
- This study characterises this data ecosystem, where needed, on five dimensions with corresponding characteristics: actors, data supply, data infrastructure, data demand and data ecosystem governance.
- This study acknowledge that actors in the ecosystem can take the role of producers, users and/or governing intermediaries.

## 2.5 EXPLAINING INFORMATION SHARING IN HUMANITARIAN RESPONSE

The previous paragraphs elaborated on the challenges that surround the coordinating relief operations in the complex and fragmented humanitarian ecosystem. The next sub-paragraphs aim to discuss the when, what, with whom and how of information sharing in order to set the stage for a description of the knowledge that

is currently missing. The description of this knowledge gap will follow in this subsequent parts of this chapter.

### 2.5.1 When information sharing?

Emergency response occurs on three levels: local, national and international (Vitoriano, Montero & Ruan, 2013). When a disaster strikes, local people are first to respond. These people are often also victims of the disaster themselves. In addition to local people, state agencies might assist in, or take responsibility for, relief operations. Depending on the size of the disaster, government agencies could also be overwhelmed by the impact of a disaster or lack the capacity or specific knowledge to take care of the response operations. As nations are sovereign, international relief organisations cannot single-handedly decide to start deploying relief teams. Nations can, in these cases, request or agree to receive international assistance. When the Inter Agency Standing Committee (IASC) declares a *Level 3 disaster*, international humanitarian teams will be directly deployed to support the national and local teams. Another classification of emergencies are *corporate emergencies*. OCHA defines corporate emergencies as rapid-onset or rapidly escalating crises requiring OCHA's highest level of response (OCHA, 2017).

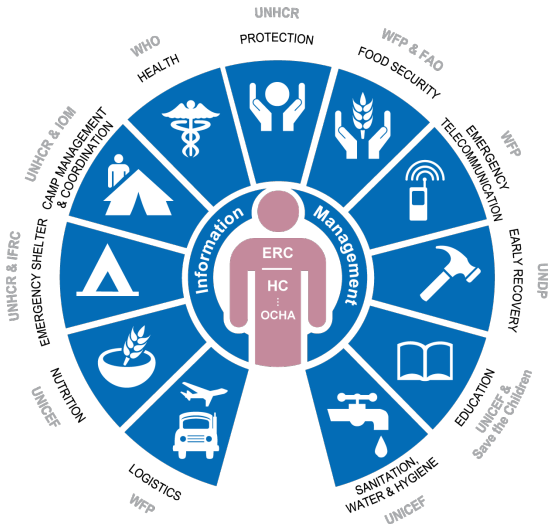


**Figure 2.4:** Inter-Agency Standing Committee's Cluster Approach adopted from UN OCHA (n.d.).

When a level 3 disaster is declared, system-wide mobilisation is requested and the humanitarian cluster system is activated. Clusters are groups of humanitarian organisations, both UN and non-UN, in each of the main sectors of humanitarian action, e.g. shelter, health and logistics. They are designated by the IASC and have dedicated responsibilities for coordination of the relief operation.

The amount of information that is shared vastly varies between local (level 1), national (level 2) and disasters with international assistance (level 3). While lower level disasters might be very difficult to manage, the number of stakeholders and procedures that challenge level three disasters make effective coordination especially complex. This research is performed at the Netherlands Red Cross, an organisation amongst others offering remote and in the field support for international disasters. Specifically, this study focuses on level 3 disasters and corporate emergencies.

Disaster management could be divided in four sequential phases; mitigation, preparedness, response and recovery (Crisis Preparedness Response and Recovery Resource Center, n.d.) In the mitigation phase, risk-reducing measures are taken in

case a disaster strikes. In the preparedness phases personnel, equipment and organisational capabilities are identified for a potential incident. This phase also involves preparing communities for a potential disaster. The response is the phase where a disaster has taken place and actions need to be undertaken to help victims of a disaster in order to reduce the suffering for as much as possible. Response activities are focused on the short-term need, but also seek to reduce the probability of secondary damage resulting from the emergency situation. Recovery consists of the recovery of a community and reconstructing society (Crisis Preparedness Response and Recovery Resource Center, n.d.).

**Scoping decision 2.5.1: When information sharing**

This study focuses on level 3 disasters and corporate emergencies

### 2.5.2 What information sharing?

One of the first steps in any emergency response is to assess the extent and impact of the damage caused by the disaster. Another first priority is to determine the capacity of the affected population and whether these meet immediate survival needs. A third example of an important first step in a disaster is assessing the operational presence of organisation that aim to bring relief.

Needs assessments identify and measure the humanitarian needs of a disaster-affected community. A coordinated needs assessment consists either of a single assessment exercise including various sectors, or of the combination of various sectoral assessments analysed together. Needs assessments form the basis for needs-based strategic planning and system-wide monitoring. They constitute the first of five phases of actions undertaken in in the management of international humanitarian response operations, also known as the Humanitarian Programme Cycle (Humanitarianresponse.info, n.d.-b).

Assessing the operational presence of humanitarian organisations is done by conducting *who does what where* or *3W* assessments. The assessment are often extended with 'for Whom', 'When' and 'why' questions, extending the assessment to a *6W*. The main purpose of a basic 3W is to show the operational presence of humanitarian organisations by sector and location within an emergency. An operational presence 3W can enable organisations to help identify potential partners, quickly give a very rough understanding of an on going response, and superficially identify potential overlaps or gaps in response (Humanitarianresponse.info, n.d.-a).

3W's and needs assessments provide insight in how the situation in the emergencies evolves as both the hazard and the relief operation change the system. These situational information products are complemented by baseline information post disaster information. Baseline and post disaster information is collected and controlled by many autonomous actors, including national authorities. Common operational datasets are core sets of data needed to support operations and decision-making for all actors in a humanitarian response. Some of these data-sets, such as data on the affected population and damage to infrastructure, will change during the disaster. This study is focused on situational information.

In addition to needs assessments and 3Ws, various organisations, including remote responders, conduct analysis with the aim of facilitating decision makers to gain an overview of the damage, needs, priorities and the activities planned and being executed in the continuous chancing disaster context. The *community risk assessment dashboard*, discussed in paragraph 1.2 is an example of an information

product aimed at facilitating prioritising needs of communities affected by a disaster.

Information that is collected during disaster often relates to physical object that can be represented by numerical values in a geographic coordinate system. These geospatial data represent the location, size and shape of objects such as buildings, lakes, villages or people. Spatial data may also include attributes that provide more information about the entity that is being represented. Geographic Information Systems (GIS) or other software applications can be used to access, visualise, manipulate and analyse geospatial data Rouse, 2013. Information and data produced and shared in disaster are of different quality and are often specific to the disaster, geographical location, cluster and/or intended use. Level of aggregation, recency, reliability, accuracy, novelty, interoperability can all be sees as aspects of data quality.

Paring information on needs and response can help responders to ask more informed questions and to identify a variety of overlaps and gaps (Humanitarianresponse.info, n.d.-a). A gap analysis forms the critical link between humanitarian needs and humanitarian response actions that have been taken. As the name suggests, it attempt to identity a difference between the desired state and the actual state in a disaster. Gap analyses are conducted at both sector and inter-sector level. Once the gaps have been identified, organisations or communities can determine if corrective actions need to be taken (Verity, 2014b). This study is focused on the diffusion of information in 3Ws, needs assessments and gap analysis.

**Scoping decision 2.5.2: What information sharing**

This study is focused on the diffusion of situational information in 3Ws, needs assessments and gap analyses.

### 2.5.3 How information sharing?

In order to make information management activities predictable and to reduce the amount of ad-hoc requests in level 3 disasters, OCHA or the Information Managmenet Working Group (IMWG) set up a standard IM reporting and product cycle. By using this formal approach, clusters are able do their work between reporting periods. To increase predictability of when to expect certain information products, cluster coordinators and cluster members can also choose to set up a IM reporting and product cycle for inter-cluster coordination. Given that there may be a geographical spread of the emergency and thus multiple coordination hubs, OCHA advice to agree upon an IM data flow, early in the emergency. In order to provide clarity, it should be proactively decided that the field clusters are responsible for collecting their own local data, sharing it with their clusters at the national level to compile, and then share the data with OCHA (Humanitarianresponse.info, n.d.-c). OCHA or a cluster-coordinator may also decide to publish a product catalogue that indicates when, which information products are shared with whom. The information products should be linked to the information needs expressed or anticipated by partners in the response.

Field observations made by Comes et al. (2015) during the response to typhoon Haiyan, draft an image that differs from the formal reality just described. They indicated that low technology or no-technology tools such as contact information lists, paper surveys, questionnaires, printed in humanitarian operations, maps, and whiteboards with updated information are frequently used, even if there are more sophisticated technological-based tools available. Collaborative technology-based

communication platforms that were most commonly used for information and data sharing were shared Dropbox folders and Skype chat groups (Comes et al., 2015). Comes et al. (2015) also describe that the intra-organisational coordination between decision-makers was found to be particularly difficult between the field staff and headquarters. For long, early phase, in-field information sharing seemed to predominantly take place on an ad-hoc bases, among humanitarians in the field that had similar interest or might know each other from earlier deployments.

Within information sharing, two general type of sharing can be distinguished. The first is dedicated sharing. Dedicated information sharing pertains to information that is shared between two individuals. Dedicated information sharing can be unidirectional or bidirectional. During a disaster a great number of meetings is organised. These meetings expand the social networks of humanitarian professionals. Some of these meetings are standard practise e.g. inter-cluster meetings or IM working group meetings. Others might be held on a need-to-have bases or as a result of individual action.

The second form of information sharing is broadcasting or one to many sharing. There is a multitude of platforms, initiatives and procedures that aim to encourage this form of sharing. Once reading 'encouraged and transparent information sharing', an experienced humanitarian might immediately think of the International Aid Transparency Initiative or IATI. This is a standard by which humanitarian donors try to push their recipients to open their data. Specifically, IATI tries to increase transparency about how aid money is spent (IATI, n.d.). However, because these data are submitted, far after relief operations have started, IATI data is not or barley of use in the early phase of disaster response.

Three OCHA-led initiatives that facilitate data and information sharing, can be of more use in early phase of disaster response. These are Virtual On-Site Operations Coordination Centre (Virtual OSOCC), the Humanitarian Data Exchange (HDX) and Humanitarian ID. Virtual OSOCC is part of the Alert and Coordination System (GDACS). A joint initiative of OCHA and the European Commission to improve alerts, information exchange and coordination in the first phase after major sudden-onset disasters. The GDACS database contains links to sources of scientific data, model results or services related to this specific event (GDACS, n.d.).

HDX is another open platform for sharing humanitarian data across crises and organisations. The 2014 Ebola outbreak seemed to be turning point for HDX (Griliopoulos, 2014). The data exchange now contains over 7,688 data sets, on over 248 locations from over 1,046 sources (OCHA, n.d.).

Besides initiatives as Vritual OSOCC and HDX, that are all led by professionals of OCHA, there are also data sharing initatives that are run by (online) communities of volunteers. The Humanitarian OpenStreetMap Team (HOT) is such an online community and international NGO that aims to add content to OpenStreetMap, a community-driven free and editable map of the world. When disaster strikes, HOT's thousands of volunteers come together online and on the ground to create open map data that enables disaster responders to reach those in need (Humanitarian OpenStreetMap Team, n.d.). In addition, there are initiative such as MissingMaps, the Ushahidi project and the StandBy Task Force. These initiative are partly self-organised and partly organised by governing bodies and aim to facilitate large scale analysis of amongst others drone and satellite imagery and monitoring of elections and social media networks. While these initiatives offer the wisdom of the crowd, challenges remain in terms of valuation and integration in existing systems.

HDX, Virtual OSOCC and HOT are all global platforms. There are also many national level data sharing platforms. GeoNode is such a collaborative geospatial platform. Geodash is in iniative that uses the GeoNode platform. It is part of the Open Data for Resilience Initiative (OpenDRI) that was initiated by the World Bank and is now taking over by the Government of Bangladesh (GeoDASH, n.d.). OpenDRI, aims to use open data practices to improve data collection, use and sharing to help reduce vulnerability to natural hazards (Worldbank, n.d.). GeoNode is the backbone of multiple other services, for example of those provided by MASDAP in Malawi.

In their paper van den Homberg and Susha (2018) distinguish six forms of data infrastructure: data holder, data archive, catalogue, single-site repository, multi-site repository or cyber-infrastructure. The simplest data infrastructure is a data holding, where a data provider has an informal collection of data files on a personal computer. Next step is when an organisation creates a data archive, catalogue, repository or portal, followed by a single-site or multiple-site repository up to cyber-infrastructures. Van den Homberg and Susha note that institutional characteristics of data holders are very basic but that these institutional characteristics become more complex when looking towards the multiple-site repositories.

By no means, do the previous paragraphs aim to provide an extensive overview of available information sharing tools. These paragraphs merely describe the various forms in which the tools and initiatives come. These tools and initiatives can either be low technology or high technology, open or protected, local or international, simple or complex. In addition, these tools can all be used because they are prescribed in formal, possibly predefined, procedures or because they naturally evolved into informal, possibly improvised, practises. The difference between formal and informal information sharing is not always obvious as formal procedures can welcome informal practises or successful, informal practises can be formalised in procedures. In addition, formally predefined information products such as 3Ws could be shared informally. These study sees formal and informal information sharing as concept that both have their specific characteristics. It also sees these concepts as interrelated. This study focuses on formal and informal information sharing, as it sees these processes as interrelated.

**Scoping decision 2.5.3: How information sharing**

This study focuses on both formal and informal, dedicated information sharing.

**Responsible information sharing**

With the growing number of data initiatives, the benefits of data tend to overshadow the potential harm that comes with data. Inadequate data management increases the potential of data to harm the same people humanitarians are trying to help (Sandvik & Raymond, 2017). Depending on amongst others the nature of the disaster, its geographical context and the cluster of the response the level of sensitivity of data differs. An example of an information sharing tool that lets users decide on which of their data is shared with whom is Humanitarian ID. Humanitarian ID is a contact management tool that lets humanitarian responders 'check-in' to a crisis. Keeping an accurate contact list is critical but also nearly impossible in the hectic response phase of a disaster. The self-managed' approach of Humanitarian ID aims to decrease the number of outdated contact lists being send back and forth. Humanitarian ID tries to lower data sharing risks by only letting users access each others contact information in disaster where security risk is high. Today about

18.000 responders are connected to the platform (Humanitarian ID, n.d.).

How these responders in their turn share data in a responsible manner that is not only in line with privacy agreements, but also considers the wider implications of sharing information, is another question. Implementing responsible information security is a complex practice that most practitioners, fieldworkers, project designers and technologists have little expertise in (Antin et al., 2016). This could potentially put people in need of aid in danger, due to the possibility that their data ends up in the hands of the people they are trying to escape from.

Data responsibility can be described as *"the responsible processing of data with respect to ethical standards and principles in the humanitarian context, bearing in mind potential consequences and taking measures to avoid putting individuals or communities at risk"*. Data Responsibility encapsulates both data protection, the local and humanitarian context, as well as the ethical standards and principles. Some organisation, including the 510, developed data responsibility policy. How data responsibility is addressed in the wider humanitarian sector remains, however, for large parts an open question or work in progress. This study is not directly focused on answering these questions. It, however, underlines that responsible use of information is a theme that is too important to ignore.

**Scoping decision 2.5.4: How information sharing**

This study is not directly focused on answering questions related to data responsibility.

### 2.5.4 With whom information sharing?

Paragraph 2.2 discussed the wide variety of organisations and individuals that make decisions in humanitarian response operations. A distinction can be made between types of information sharing. Information sharing can take across organisational boundaries, this is considered as horizontal or inter-organisational information sharing. Information sharing can occur within organisations, this is referred to as intra-organisational. Where improved intra-organisational information sharing could better facilitate effective response to disasters by a single organisation. Inter-organisational could potentially facilitate a more effective response by the humanitarian system as a whole. This study focuses on both inter-organisational and intra-organisational information sharing of organisations and individuals. In figure 2.1 these organisations and individuals can be found in the top right corner, in the non-governmental organisations branch, and in the bottom right corner, in the international organisations branch.

In addition to humanitarian organisations and their employees, the affected communities play an important role in deciding which aid receives the community in what manner. To understand communities' needs, humanitarian organisations carry out surveys, and hold focus group discussions with affected men and women. To give an example derived from the Bangladesh-Myanmar displacement crisis, BBC Media Action, Internews and Translators without Borders have evaluated strategies to improve access to information for Rohingya communities. According to their study, Mahjis (Rohingya community leaders) are the main and most trusted source of information for Rohingya people. They also concluded that in this disaster, the people affected, are giving feedback and are satisfied with how feedback is being handled. A quarter of them said that they had given feedback or made a complaint, 82% of these people said they were satisfied with what happened next (Bailey, Hoque, Michie & Rabbi, 2018). This example illustrates, that communities can play

an important role in disaster response and information sharing.

This study focuses on information sharing between and within humanitarian organisation performed by individuals that belong to these organisations. Organisations and individuals that can take the role of both information user, information provider and/or intermediary. In this study the needs, activities and interest of communities are and represented by humanitarian organisation and individuals. This study is also focused on the role of teams that, on request, provide remote support to the humanitarians in the field by analysing drone and satellite imagery. As described in chapter 1 510 is an organisation that provides remote support in disasters through its Community Risk Assessment, Impact database and priority index.

**Scoping decision 2.5.5: With whom information sharing**

- This study focuses on both inter-organisational and intra-organisational information sharing.
- In this study the needs, activities and interest of communities are and represented by humanitarian organisation and individuals.
- This study is also focused on the role of teams that, on request, provide remote support to the humanitarians in the field by analysing drone and satellite imagery.

## 2.6 KNOWLEDGE GAP

To support the humanitarian community, scholars analysed the effects of various strategies on information sharing and humanitarian logistics. This paragraph aims to explore established research in these areas in order to substantiate what information is missing to enable more effective information sharing.

In their 2010 article, Tatham and Kovács discuss the fundamental role that 'swift trust' plays in the hastily formed networks of humanitarian supply chains. They argue that third party information about humanitarian organisations and the individuals they send to the disaster are crucial to develop trust in the networks that are formed after a disaster struck. Humanitarian organisations themselves can benefit from sending more information about the individuals they send to a particular disaster (Tatham & Kovács, 2010).

Altay and Labonte (2014) analysed 27 evaluations, lessons learnt reports and mission reports using an analytical framework to study the challenges to information flow in the the humanitarian response to the 2010 Haiti earthquake. According to their analysis, many Haitians felt that their local knowledge, initiatives and capacities were largely ignored by the international community. They highlight that OCHA should remain agile and adaptive to changes on the ground as one of the paths forward to overcome this challenge in the future. They also stress that humanitarian information management and exchange should be designed specifically to deal with incompatible and unverifiable data (Altay & Labonte, 2014).

Papadopoulos et al. (2017) used a more quantitative approach to understand how humanitarian supply chains are affected by disasters. Their big unstructured data analysis revealed a framework which attempts to explain resilience in supply chain networks. This framework was subsequently tested using data from 205 responses

to a survey by people who were involved in disaster relief operations after the 2015 Nepal earthquake. The results of their analysis suggest that swift trust, information sharing and public-private partnership are critical enablers of resilience in supply chain networks.

Altay and Pal (2014) and Bateman and Gralla (2018) evaluated strategies for intra-organisational and inter-organisational information sharing. Building on the work of the scholars previously mentioned, Altay and Pal conducted research into the effects of employing an information hub and improving inter-organisational trust. Their findings support the statement that clusters can help diffuse information more quickly, but they found that the willingness to share information between organisations was the greater determinant of rapid information spread Altay and Pal, 2014.

Bateman and Gralla (2018) assessed the effects of implementing regular team meetings, deploying IM specialists, varying the frequency of meetings and increasing willingness to exchange information with other organisations. One of their findings suggest that holding regular meetings or deploying an IM specialist make the largest difference in the time it takes to collect sufficient information for decision-making. Surprisingly, willingness to share information did not, in their model, make a significant impact on information acquisition. This could have been caused by the fact that their model focused primarily on a single organisation, rather than the humanitarian system as a whole (Bateman & Gralla, 2018).

The previous paragraphs were aimed at exploring established research and discussing the core concepts of information sharing in complex emergencies. They discussed existing literature in order to set the stage for the for a description of the knowledge gap. The next sub-paragraphs present this knowledge gap in three steps.

### 2.6.1 Disasters as series of shocks

The the fast increase in the availability of information, observed in recent years, changes humanitarian decision making. While, this claim has been made for a number of times in the writing, the way in which the increase in information affects decision making has remained largely implicit. Van de Walle, Comes, Meesters, van den Homberg et al. (2013) describe how thinking about information management's main challenges changed over the years. In the past, they argue, information management's main challenge was considered to be overcoming the lack, uncertainty or vagueness of information. At that time, the core assumption used to be that more information and a complete overview of the situation enable decision-makers to make better decisions. It was assumed that, not only more information becomes available while time progressed, but also that the uncertainty and vagueness inherent in the information can be reduced to make well informed, analysed and justified decisions a few weeks into the disaster. This past paradigm is illustrated in figure 2.5.

In their 2013 report Van de Walle et al. bring forward a different perspective. They argue that in this day and age, humanitarians face situations where decision problems and the information that is required to address them evolve highly dynamically in an information landscape that is more volatile than ever before. The complexity of disasters in interconnected systems implies that one has to deal with different levels and scales of uncertainty all at the same time.

This goes beyond the definition brought forward in paragraph 2.1. Not only can disasters be seen as a complex system with a behaviour that is drastically changed as the result of an unexpected shock. Disasters can be seen as complex systems

with a behaviour that is drastically changed as the result of series of shocks. After the initial shock the system and especially the diffusion of information within this system, continues to be affected by consecutive, interconnected shocks. After an earthquake multiple aftershocks could follow, moreover parts of cities could flood, disease could break and as a result there could be an outbreak of violence. As a result the collection and exchange of information is never completely finished.

The existing knowledge base on information diffusion in humanitarian disaster does not reflect this postulated change in thinking. Existing literature and related modelling efforts, including those of Altay & Pal and Bateman & Gralla, assume that there will be continuously better information and that humanitarian decision makers will get a clearer picture over time. The already limited number of research projects that have tried to unravel information diffusion in humanitarian disasters do not see the humanitarian information landscape as continuously evolving but more as a continuously improving path. The contrasts the observation stated in paragraph **??** that information is the link between the disasters, which physical, governance and social properties are continuously evolving and the decision-making efforts that aim to react to that. It is unclear what the effect is of the discrepancy in approaching information diffusion in humanitarian disasters. The effect of these contradicting views is both unclear for the context of sudden-onset disasters, the focus of the study conducted by Bateman and Gralla, 2018, as for the context of slow-onset disasters, the focus of this study. It is also unknown what the effects of information sharing strategies is on the diffusion of information under the assumption of continuously evolving instead of ending information diffusion processes. This void forms the first aspect of the knowledge gap that this study aims to close.

**Knowledge gap 2.6.1: Non-monotonous behaviour of information needs**

It is unknown what the effects of information sharing strategies are on the diffusion of information, under the assumption of non-monotonous behaviour of information needs.

### 2.6.2 Information sharing in social networks

Per definition a model is a simplified formalisation of real world system. Following this philosophy, Altay and Pal and Bateman and Gralla did not attempt to mimic a specific scenario such as Haiti earthquake or typhoon Haiyan. Rather, they developed an abstraction of what happens during an international humanitarian

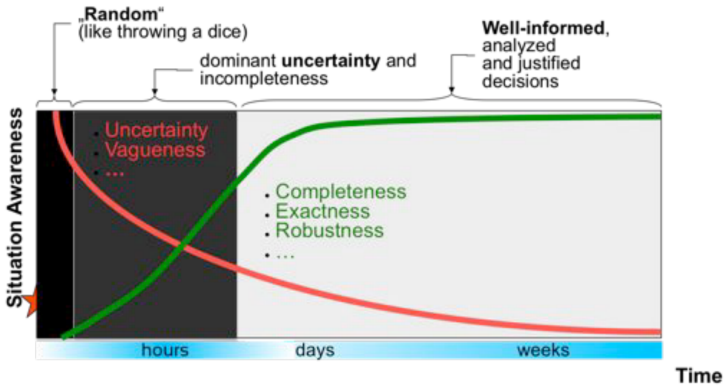


Figure 2.5: The past paradigm: the ideal of information completeness adopted from Van de Walle, Comes, Meesters, van den Homberg et al. (2013).

response. As is common in modelling and simulation research they made various assumptions about how the international humanitarian response system works.

To model the dynamics of an international response both Altay and Pal and Bateman and Gralla assume that searching for information may be represented by a random search. Altay and Pal (2014) argue that *"considering the lack of clear communication channels due to the chaotic nature of the initial response phase, the random search assumptions are not far from reality"*. They, however, also note that *"humanitarian agencies may have prior knowledge on whether/where to attend a cluster meeting and/or which peer agencies to approach for information. Thus, humanitarian agencies may be more effective in gathering information than the random search assumptions used in the simulation model, which would possibly worsen the seekers' performance"*. They also suggest to utilise social network theory in further research: *"a network topology could be used to model social connectivity of agents, rather than an agent randomly roaming"*.

In a paper published in 2015, Van de Walle and Comes (2015) contrast the information management challenges observed in humanitarian response operations for a complex disaster to those observed during a natural sudden-onset disaster. Their findings are based on a research visit in Amman, Jordan, in May 2014 to study the response to the Syria crisis and an comparison between their observations and findings derived from earlier field work conducted during the response to Typhoon Haiyan in the Philippines in December 2013. Their findings provide support for where Altay & Pal and Bateman & Gralla random search assumption may hold and may not hold.

Van de Walle and Comes findings suggest that the humanitarian community must work in a very fragmented information landscape, which is characterised by mistrust, secrecy and a strong role of individual networks. During one of their interviews, a donor stated that the issues of confidentiality and security concerns are not new, and they are common for all complex crises, and should definitely not come as a surprise in the Middle East.

The atmosphere of mistrust is ubiquitous, and hampers exchange even of such information that is common knowledge between all actors, they argue. At the same time, trusted individual relations and networks for information sharing have become ever more important. These networks are so strong and important that they may undermine all attempts of structuring information flows or establishing protocols for sharing in future.

This observation is supported by earlier work done by Van de Walle, Comes, Meesters, Van den Homberg, Chan and Brugghemans in 2013 that states that early information sharing greatly relies on direct bilateral exchange, either in person or via radios and satellite phones. Even when connectivity became better, people they spoke with reported to rely on their social networks rather than on products provided online.

Besides the observation that trusted individual relations and networks for information sharing seem to especially important in complex crises Van de Walle and Comes report on a number of other findings. Two observations about the social networks in which information is shared are especially relevant for earlier mentioned random search assumptions. First, they note that regularly, information and knowledge are lost when people leave the disaster. Particularly in a crisis that is so difficult to manage as the situation in Syria, and in which information management rely so much on individual social network, this comes down to an organisational form "designed to forget" – instead of the ideal of a learning organisation, they plead. This study argues that this aspect of 'social network based learning and

forgetting' is not explicitly reflected in a model that sees information sharing as a random search.

The second observation about the role of social networks is the direction of the information flows. Van de Walle and Comes (2015) argue that their observation that much sharing happens "under the table", gives rise to two networks and channels of information sharing: the official reporting network, communicating mostly upwards to headquarters, and a largely uncontrolled information sharing network that support operational decision making, but make the official system almost obsolete. A model that sees information sharing as random search ignores the observation that information flows can have a direction.

Both Altay & Pal's and Bateman & Gralla argue that their random search assumption is not far from reality. Given that their work is the only available reference on information diffusion in humanitarian response, it is unclear what the effect is of this modelling assumption. Specifically, it is unknown what the effects of information sharing strategies is on the diffusion of information under the assumption that information sharing should be represented by social networks instead of random searches. This void forms the second aspect of the knowledge gap that this study aims to close.

**Knowledge gap 2.6.2: Information sharing in social networks**

It is unknown what the effects of information sharing strategies are on the diffusion of information, under the assumption that information is shared in social networks.

### 2.6.3 Effects of information sharing strategies

According to Whipkey and Verity (2015) and Nissen (2015), the humanitarian information management community seems to be predominantly focused on collecting, analysing, and visualising data quicker and better - the supply side - and less with understanding how the outcomes of their efforts are used for decision-making - the demand side of information management. As mentioned in the previous sub-paragraphs, the literature on model-based evaluation on information diffusion thanks its existence to the work of only a small group of researches. Altay & Pal and Bateman & Gralla pioneered modelling research into diffusion of humanitarian information. Increasing willingness to share information is the only strategy evaluated by both modelling studies. Though, what kind of willingness to share information is evaluated differs between the two studies. Altay and Pal mention the following: *[Given there are also inter-agency exchanges of information,] this article investigates how information diffuses in a cluster-oriented system and how it could be improved to enhance effectiveness of response.* Altay and Pal's willingness to share information strategy can be seen as inter-organisational information sharing. In contrast, Bateman and Gralla's study *uses an agent-based model to analyze various strategies for intra-organizational information management*.

The results obtained by Altay and Pal suggest that *"willingness to exchange information has more of an impact on information diffusion than the existence of an information hub"*. In fact, it is the most effective strategy to increase information diffusion in their model. Bateman and Gralla conclude the following: *[Surprisingly,] "willingness to share information does not, in this model, make a significant impact on information acquisition in the focal organization. However, this model focuses primarily on a single organization, rather than the humanitarian system as a whole in a response. Both in practice and in research [...], information sharing is emphasized for the impact it can have across or-*

*ganizations, when every actor in the system opts to increase their willingness to share. The results from this model should not be taken as justification for refusing to share information in a response. Instead, the results simply show that increasing willingness to share does not increase willingness to share does not increase a single organization's own information-seeking capabilities in the environment we modeled"*. As Altay and Pal and Bateman and Gralla evaluate different forms of willingness to share strategies and produced different findings it is unclear which form is more effective in diffusing information.

In addition, it is unclear what the relative effects are of a number of other information sharing strategies. The first of these strategies is increasing the share of local delegates active in the response. Decreasing the number of international delegates that are send to a disaster is a frequently suggested strategy to increase the efficiency of relief operations. While the Red Cross is one of the few humanitarian organisations that works with a national society system, these calls are not solely address to organisations to more heavily rely on their international delegates. Nor is it clear what the effect of the strategy is on information diffusion.

The second information sharing strategy is provided by Van de Walle, Comes, Meesters, van den Homberg et al. (2013) as they suggest a new paradigm for information management. An aspect of this paradigm is the near-real time creation and publication of assessments. While this idea sounds promising, it is unclear what the effect is on the information diffusion, especially because shorter publication time could come at a cost of accuracy of the assessments. This study both uses 'changing publication method' and 'changing assessment method' to refer to this strategy.

The third strategy is implementing structure hand-overs. As performing hand-overs could relate to handing of knowledge or handing of contacts this strategy is split into. While hand-overs are common practise in humanitarian response it is unclear what the effect is on the information diffusion, especially because some knowledge might be tacit and relations difficult to transfer.

**Knowledge gap 2.6.3: Additional aspects knowledge gap**

- As Altay and Pal and Bateman and Gralla both evaluated different forms of willingness to share strategies and produced different findings, it is unclear which form is more effective in diffusing information.
- It is unclear what the effect is of increasing the share of local delegates on the diffusion of information.
- It is unclear what the effect is of changing assessment and publication method from accuracy-focused to time-focused on the diffusion of information.
- It is unclear what the effect is of implementing structured handing-over of knowledge on the diffusion of information.
- It is unclear what the effect is of implementing structured handing-over of contacts on the diffusion of information.

### 2.6.4 Conclusion knowledge gap

It is currently unknown what the effects of information sharing strategies are the diffusion of information in complex emergencies. This is specifically unknown if one considers the non-monotonous, social-network-based nature of the diffusion processes. In addition, the effects of six information sharing strategies on the dif-

fusion of information are unclear. This study aims to bridge this knowledge gap by evaluating the effects of these strategies with an approach that recognises the effects of the non-monotonous behaviour of information needs and the role of social networks in information sharing. The next chapter discusses how.

# 3 RESEARCH FORMULATION

The knowledge gap identified in the previous chapter shows that there is currently insufficient knowledge about what the effects of information sharing strategies are on continuously evolving, social-network-based information diffusion processes observed in complex emergencies. This study aims to evaluate the effects of six information sharing strategies on the diffusion of information.

This chapter discusses the main research questions, the associated sub-research questions and the research design of this study. Paragraph 3.1 first discusses the main research. This paragraph is followed by description of the general research methodology in paragraph 3.2. The third paragraph discusses the four sub-questions that aim to answer the main research question along with the specific methods that correspond to these questions.The chapter ends with a conclusion.

## 3.1 MAIN RESEARCH QUESTION

This research revolves around one main research question that addresses the identified knowledge gap and is motivated by the research objective discussed in the previous chapters. This research question is formulated as:

**"What are the effects of information sharing strategies on the diffusion of information in complex emergencies?**

The main research questions of this study is based on the hypothesis that diffusion of information in complex emergencies can be improved by information sharing strategies. Whether this hypothesis holds and - if it holds - what the effects of various information sharing strategies are on the diffusion of data are, is analysed in this study.

## 3.2 RESEARCH METHODOLOGY

To answer the main research question this study uses different combination of research methods. The research design is visualised in the research flow diagram displayed in figure 3.1. This diagram shows how the various aspects of the research design are connected. The diagram also indicates how the report is structured, as the grey block correspondent to chapters in the final report.

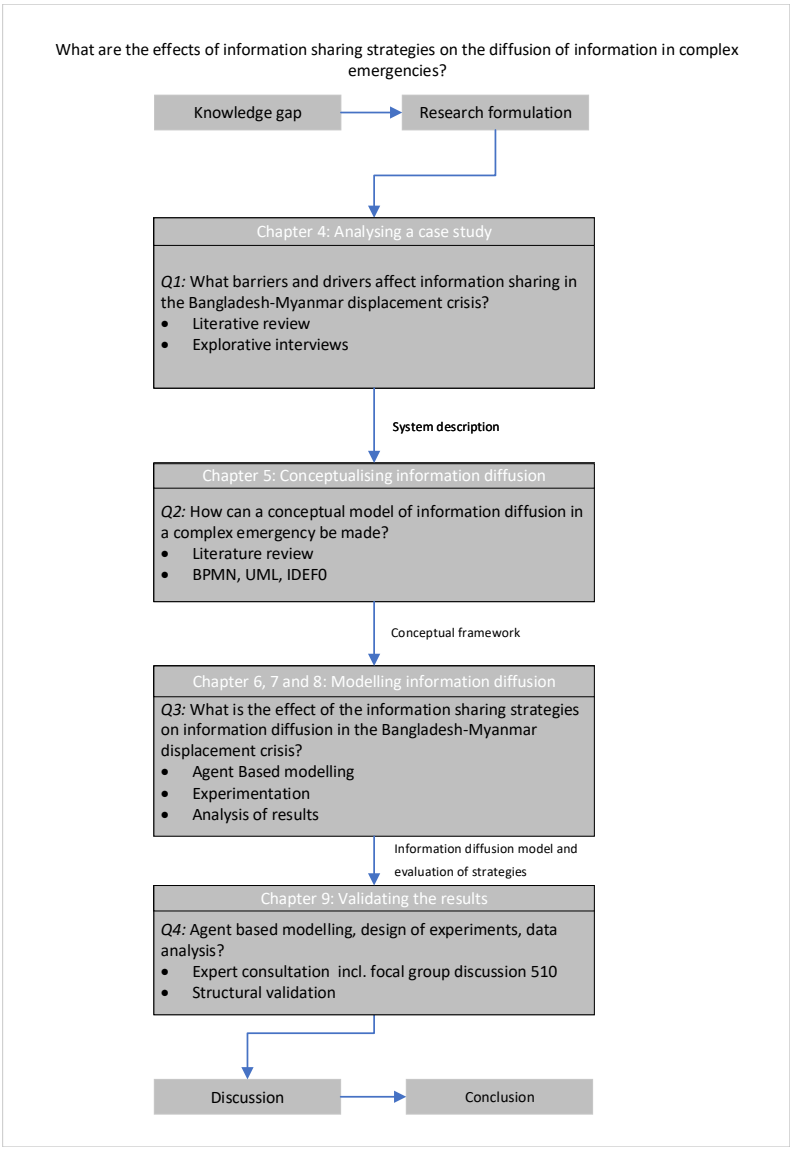


**Figure 3.1**: Research flow diagram

### 3.2.1 An exploratory, sequential model based research design

The chosen research approach aims to describe the information diffusion system in complex emergencies based on a case-study. It deduces a conceptual model on information diffusion in complex emergencies from the available theory on disaster management, information diffusion, data ecosystems and intelligence processing and from experience expressed by professionals active in complex emergencies. Thereafter, it implements this conceptual model in an agent based modelling environment. Experiments are preformed to analyse the effects of various information sharing strategies on the diffusion of information. The objective of this modelling study is to induce findings from the model to a generic conclusion. Reflecting on this research design through the lens of Creswell and Clark 2011, one could argue that this is an exploratory sequential research design.

The model-based research approach is chosen over data analytically approaches that explore information diffusion patterns in social media or beacon data and qualitative research approaches that involve extensive interview series with responders in the field. At the one hand this approach is motivated by the limited options to conduct field research in available time for this study. At the other hand, this approach is chosen because its exploratory nature can complement the existing research efforts in this field of study. While among others **??** mention selection of empirical evidence for model validation as one of the limitations of agent based modelling, a more thorough understanding of the suitability of agent based modelling research in this domain especially given the limited number of studies that use this approach in the context of information diffusion in humanitarian disasters. A better understanding the suitability of modelling research in this domain can provides us with better comprehension of the available research tools to evaluate information sharing strategies.

## 3.3 SUB-QUESTIONS AND CORRESPONDING RESEARCH METHODS

The following paragraphs discuss the four sub-questions that aim to answer the main research question along with the specific methods that correspond to these questions.

### 3.3.1 Sub-question 1: What barriers and drivers affect information sharing in the Bangladesh-Myanmar displacement crisis?

By providing the drives and barriers to information sharing one case study, this sub-question aims to provide a system description of information sharing in a complex emergency. For the selection process of the case study two types of criteria were used. The first set of criteria revolved around the question whether the disaster was inline with the scope of the research project. The second set of criteria were concerned with practical matters, such as in-field connections and data availability. Based on the selection process the Bangladesh-Myanmar displacement crisis is selected as case study.

According to OCHA (2017) more than 128 million people needed humanitarian assistance in 33 countries at the beginning of 2017. That year, the organisation appealed for US$22.2 billion—the largest humanitarian appeal ever launched. In 2017, the humanitarian aid system dealt with four Level 3 emergencies: DRC, Iraq, Syria and Yemen and was present in four corporate emergencies: the Rohingya crisis,

Ethiopia, Nigeria and Somalia.

An Inter-Agency Standing Committee (IASC) Humanitarian System-Wide Emergency Response, more commonly referred to as an L3 emergency response, is activated when a humanitarian situation suddenly and significantly changes and the required capacity to lead, coordinate and deliver humanitarian assistance and protection is not available on the ground. Corporate emergencies are rapid-onset or rapidly escalating crises requiring OCHA's highest level of response (OCHA, 2017). Based on the selection process the Bangladesh-Myanmar displacement crisis is selected as case study. The first sub-question to provide a system description of information sharing in a complex emergency by analysing the barriers and drivers and other properties of information diffusion in this system.

### 3.3.2 Research methods 1: Analysis of information diffusion based on a literature review and semi-structured interviews

To answer the first sub-question, information sharing processes in a specific case study are analysed. To come up with a system description and to derive properties that characterise information in a complex emergency, publications of a multitude of non-governmental organisations, inter-governmental organisations and research institutes are analysed. These publications range from policy plans to news articles and scientific articles.

In addition, a number of humanitarian professionals that work or worked in the Bangladesh-Myanmar displacement crisis is approached to participate in a semi-structured interview. The semi-structured interviewing method is an explorative and open method, that allows new ideas to be brought up during the interview as a result of what the interviewee says. Appendix A provides an overview of all the professionals that are invited to take part in the interviewing exercise. The interviewees are asked for their consent to digitally record the sessions. Based on the recordings a structured summary of the interviews is created. In this summary the answers are grouped together to facilitate easier comprehension and comparison of the answers. To make sure the summary reflects the actual content of the meeting, the summary is shared and agreed upon by the participant. Appendix A provides a more elaborate discussion of the approach used for the interviews. In this appendix one can also find the interview guide and invitation letter used for the interviews.

Based on the interviews, the literature review and operational presence data, a suitable sector and focal-decision in the Bangladesh-Myanmar displacement crises is selected to be able produce a more detailed system description that serves as the bases for the conceptualisation of information of information diffusion that is addressed by the next sub-question.

### 3.3.3 Sub-question 2: How can a conceptual model of information diffusion in a complex emergency be made?

The second sub-question is devoted to finding a way to transfer the dynamics found in literature, interviews and by answering the first sub-question into a conceptual model. By answering this question a conceptualisation is provided of information diffusion as well as a conceptualisation of information sharing strategies. This conceptual model in turn forms the basis of the simulations model that is developed in the next step. It explains the assumptions and abstractions that are needed to construct this model.

### 3.3.4 Research methods 2: Conceptional model construction based on interviews and literature

The thesis goes through a modelling cycle that, as described by van Dam, Nikolic and Lukszo (2013), contains the steps conceptualisation, specification, experimentation and validation. The methods used to answer the second sub-question revolve around the first step in this modelling cycle.

The conceptualisation is aided by the utilisation of three modelling languages to capture procedures in a graphical notation. It is not the aim of this step to capture the system strictly using all the conventions. Instead, the research will choose function over form and design conceptual diagrams with methods inspired on the modelling languages BPMN, IDEFo and UML. With this flexible interpretation on the modelling conventions the study aims optimally facilitate the understanding and discussion of the simulation model.

### 3.3.5 Sub-question 3: What is the effect of the information sharing strategies on information diffusion in the Bangladesh-Myanmar displacement crisis?

Once there is more insight around information diffusion surrounding the specific decision and a way is found to conceptualised these dynamics, a model can be constructed to test the effects of the various information sharing strategies. This sub-question forms a fundamental part of the study as it aims to understand the effects of the strategies that have been identified by answering sub-question one and have been conceptualised in by answering sub-question two.

### 3.3.6 Research methods 3: Agent based modelling, design of experiments, data analysis

The research methods used to answer sub question 3 amount to the specification and experimentation step of the earlier described modelling cycle. Construction and verification of the model form the building blocks of the model specification. Design of experiments and analysis of the results are the building blocks of the experimentation step.

Based on the characteristics of the problem, Agent Based Modelling is chosen as suitable computational modelling school. Rand and Rust (2011) identify six properties of a system that make it useful to model using Agent Based Model or ABM: (1) a medium number of agents, (2) local and potentially complex interactions among agents, (3) agents' heterogeneity, (4) rich environments, (5) temporal aspects, and (6) agents' adaptability. Information diffusion features all six of these properties to an extent, making ABM a suitable method for this study.

Based on Ashby's Law of Requisite Variety (Ashby, 1968) van Dam et al. (2013) state that *"to be a successful model of a complex adaptive systems, the model must also be a complex adaptive systems"*. Van Dam et al. found that every complex adaptive systems model should contain the following three main properties: multi-domain & multi-disciplinary knowledge, generative and bottom up capacity and adaptivity. A (well developed) complex adaptive systems model made for this study captures multiple formalisms, can be described in terms of interconnected networks and has a capacity to evolve over time. Chapter 2 described the core concepts of information diffusion in complex emergencies. The argumentation brought forward in this chapter, affirms the suitability of this method.

During and after model developed, various verification methods are used. These include recording and tracking agent behaviour, extreme values verification, extens-

ive code walk through and interaction testing in a minimal model. An experimental design is constructed to determine the effects of non-monotonous behaviour of information needs, the effect of information sharing in social networks and the effect of individual and combined information sharing strategies that can be executed on one machine in less then one week time. The results of the conducted experiments are analysed using various packages developed for the R software environment for statistical computing.

### 3.3.7 Sub-question 4: How could the outcomes of this study be generalised to other complex emergencies?

This sub-question tries to assess how valid the observed behaviour in the model is in relation to the multitude of disaster that can be observed in reality. Given that it is impossible to conduct experiments on all existing humanitarian projects worldwide the results for this study will be induced from specific observations, the Bangladesh-Myanmar displacement crisis. The fourth sub-question asks the question of how to validate the system description, conceptualisation, critical assumptions and outcomes of this study.

### 3.3.8 Research methods 4: Expert consultation, focus group discussion and structural validation

In the fourth phase of the projects, the generalisability of the results is assessed using three validation methods. The fist method is validation by expert consultation. For the interviews two humanitarian professionals are approached through the professional network of the research team.

The interviewees are asked to reflect on the system description, conceptualisation and outcomes of the study. Specifically, they are asked whether they recognise the barriers and driver and how the description of the case study differs from other complex emergencies. In addition, the researcher explains the BPMN conceptual diagram and asks questions on its suitability to capture the important concepts of information sharing in a complex disaster. The entire interviews are recorded digitally. Based on the recordings a structured story line is created. In this story line the discussion points, comments and remarks are grouped in three categories: system description, conceptualisation and outcomes of this study.

The second method is validation by focus group discussion. The about 100 team member of the 510 data team of the Red Cross are approached to structurally reflect on the critical assumptions and main findings of the modelling study. Also the content of this session is recorded. Based on the recordings a structured story line is created. To make sure the story line reflects the actual content of the meeting and to prevent cherry picking, the story line is discussed with one of the participants. More details on the set-up and approach used for the focus group discussion, including an overview of the participants and the questions that are asked can be found in appendix K

The third validation method is structural validation. Sensitivity analysis is executed to assess the robustness on variables relating to the strategies and critical assumptions of the model. Boundary testing is performed to assess the behaviour of the model using extreme values. Which key variables will be analysed is based on the analysis of the results and the response of the focus group.

The different validation methods have their specific limitations. For example, face-validation is limited because experts may fully understand what has happened but might not know what will happen. Moreover, a common seen limitation of this validation method is that experts do not fully understand the model but make assumptions of how they think it works. To address the limitations of the different methods, a combination of methods is used to assess whether the model satisfies the intended use. In addition, suggestions for future execution of validation studies are provided.

## 3.4 CONCLUSION

This chapter discusses the main research question that addresses the identified knowledge gap and is motivated by the research objective discussed in the previous chapters. It also discusses the four sub-questions that aim to answer the main research question along with the specific methods that correspond to these questions. The chosen research approach aims to describe the information diffusion system in complex emergencies based on a case-study. It deduces a conceptual model on information diffusion in complex emergencies from the available theory on disaster management, information diffusion, data ecosystems and intelligence processing and from experience expressed by professionals active in complex emergencies. Thereafter, it implements this conceptual model in an agent based modelling environment. Experiments are preformed to analyse the effects of various information sharing strategies on the diffusion of information. The objective of this modelling study is to induce findings from the model to a generic conclusion.

# 4 BARRIERS AND DRIVERS TO INFORMATION SHARING

The previous chapters discussed the knowledge gap that is central to this study. They also presented the approach that will be used to fill this gap. This chapter revolves around the first sub-question out of a set of four that aim to evaluate the effects of various information sharing strategies on the diffusion of information in complex emergencies. By providing the drives and barriers to information sharing in the Bangladesh-Myanmar displacement crisis, this chapter aims to provide a system description of information sharing in a complex emergency. A number of interviews are conducted with humanitarian professionals currently present of just returned from a deployment. Subsequently, a suitable sector and focal-decision in the Bangladesh-Myanmar displacement crises is selected based on the findings from the literature review, interviews and operational presence data to provide a more detailed version of the system description, that serves as the bases for the conceptualisation of information of information diffusion that is addressed in the next chapter.

**What barriers and drivers affect information sharing in the Bangladesh-Myanmar displacement crisis?**

## 4.1 INFORMATION SHARING IN THE BANGLADESH–MYANMAR DISPLACEMENT CRISIS

The Bangladesh-Myanmar displacement crisis has become one of the fastest growing refugee crises in the world. This paragraph aims to provide the reader with a better understanding of the information sharing processes in this crisis. For this reflection, publications of multitude of non-governmental organisations, intergovernmental organisations and research institutes was analysis. This publications range from policy plans to news articles and scientific articles. In addition, a number of interviews has been conducted with humanitarian professionals currently present at, or just returned from a deployment in Bangladesh. The professionals hold the following functions:

| Function | Organisation | Base | Length deployment (Approx) |
|---|---|---|---|
| Information Management Officer WASH Sector | Unicef | Cox's Bazar | 3 months |
| Acting Head of Programme Support Unit | IOM | Cox's Bazar and The Hague | 3 weeks |
| Monitoring and Evaluation Officer | IOM | Cox's Bazar | 9 months |
| Programme Support Officer | IOM | Cox's Bazar | 9 months |
| Information Management Officer | IOM | Cox's Bazar | 9 months |

**Table 4.1:** Overview interviewed professionals

Appendix A provides a more elaborate discussion of the approach used for the interviews. This appendix also contains the interview guide used to structure the interviews and the answers provided by the participants. This paragraph contains a number of quotes shared by the participants. These quotes facilitate easy reference and aim to add more context to the system description. Readers interested in the complete summaries of the interviews are advised to consult appendix B.

Paragraph 2.5 in chapter 2 provides an elaborate discussion on how, what, when and with whom information is shared in humanitarian disasters. This paragraph does not aim to reiterate all points that are brought forward in that section. Instead, the following paragraphs serves two proposes. They aim to shed light on how information sharing processes in the Bangladesh differ from general processes seen in other disasters and, secondly, they aim to describe the observed drivers and barriers to information sharing in this crisis.

> *"During the 2017 influx, assistance was focused on pushing as much volume as possible. Now, we can we can focus more efforts on quality of relief, as this pressure has lessened."*
>
> *Interview NGO staff member*

The 2017 influx marks s critical point in the Bangladesh Myanmar refugee crisis. Not only has the influx of arrivals around 25 August made this the fastest growing refugee crisis in the world, the concentration of refugees in Cox's Bazar is amongst the densest in the world. Refugees arriving in Bangladesh, mostly women and children, are traumatised, and some have arrived with injuries caused by gunshots, shrapnel, fire and landmines. The 2017 influx does, however, not mark the start of the refugee camps near Cox's Bazar. People have been fleeing to Bangladesh for decades. While this only stresses the tragicness of the situation, longer presence of humanitarian organisations in the region added to the availability of data. This point is seen as a driver of information sharing. After the peak in influx, more and more information management actors came to Cox's Bazar, bringing more information management projects and generating more data activities. The need for data gathering, the number of deployed data-gathering methods, and the amount of data gathered only increased.

> *"Before the 2017 influx, the environment was already data-rich. Also, there was a structured information sharing mechanism."*
>
> *Interview NGO staff member*

When looking at the Bangladesh Myanmar refugee crisis, an experienced humanitarian would notice a dissimilarity in formal coordination structure. As described in paragraph 2.5, the humanitarian cluster system provides a framework for cooperation between organisation in large scale disasters. The organisations active in Bangladesh do not cooperate under the cluster system. Instead, the related but slightly different sector system is used. The primary difference between the sector and cluster system relates to accountability and responsibility. In countries the national government has the responsibility for coordination, one refers to sectors instead of clusters. The ISCG coordination structure is shown in figure 4.1. Due to various reasons, the Bangladeshi government considers national responsibility in this crisis as highly important.

While one could argue that Bangladesh only holds on to its rights as sovereign nation, multiple interviewee mention the negative effects the current system has on the effectiveness of relief operations. The different role that is allocated for UN

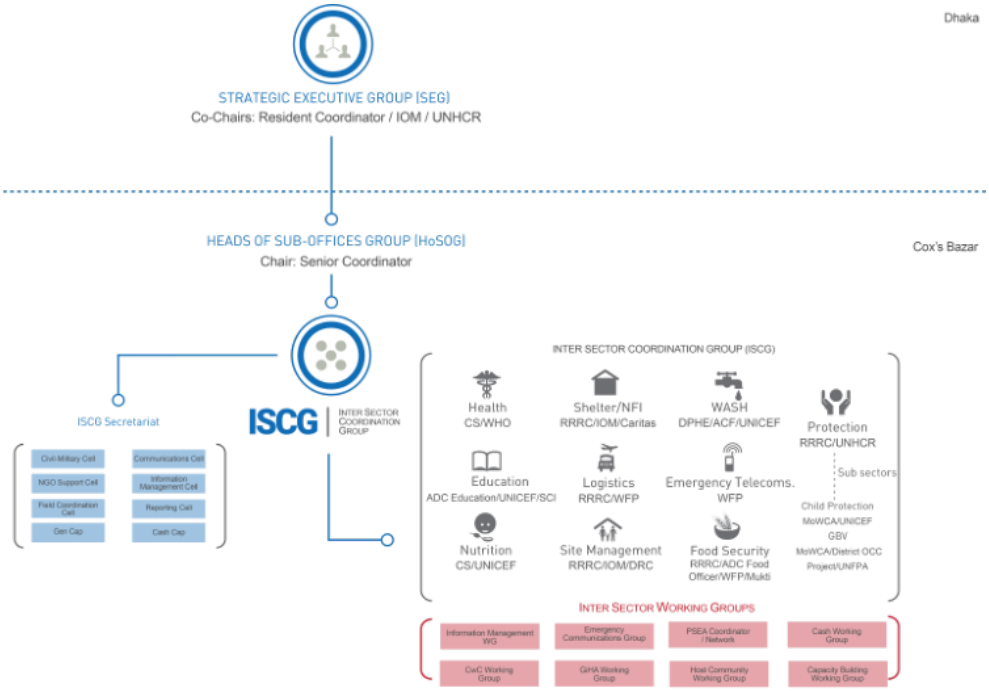


**Figure 4.1:** ISCG Coordination Structure adopted from HumanitarianResponse.info (2018b)

OCHA is seen as one these negative effects. In Cox's Bazar, Bangladesh, the humanitarian response is coordinated by the Inter-Sector Coordination Group (ISCG) which is led by the International Organization for Migration (IOM) and the UN Refugee Agency (UNHCR). While ISCG acts as a driver for information sharing, the potential of OCHA's experience and its neutral role in information sharing is not fully used. Instead, the organisations present in Bangladesh have to set up the whole infrastructure themselves. While none of the interviewees wanted to comment on this, political tensions about the role of the government in the relief project seem present.

> *"It is not clear how other organisations come to their findings. As an example, there are three official refugee numbers. If one would ask a partner how they come to their numbers, they probably won't explain their exact method. There are various reasons for this, including inter-agency competition. As a result, you have to live with the numbers you get. It is, therefore, really difficult to say what information is correct and what is wrong. Internally, everyone uses their own numbers but if it is shared with other agencies it is up to them which number they use".*
>
> *Interview NGO staff member*

According to humanitarian professionals active in the crises, effective coordination to channel information needs and field data collection is currently present and acts as a driver for information sharing. Unwillingness to share information completely, or in a specific data format, however, remains an impediment to information sharing. One of the other barriers that are mentioned, is the difficulty in assessing the reliability of information due to sub-optimal transparency about information sharing methods. One of the interviewees suggested that the introduction of a bilateral screen system to oversee bilateral information sharing requests. A final barrier to information sharing in Bangladesh, is inter-agency competition. Competition for funding and media attention annexes value to information and makes organisations guard it from others.

**Overview 4.1.1: Barriers and drivers to information sharing in Bangladesh**

Drivers:

- The long presence of data collection projects in Bangladesh.
- The 2017 refugee influx, brought more information management partners that generate more data activities.
- The ISCG platform, as it acts as the key advocate for data sharing, pushing all big data owners to share information on public forums.

Barriers:

- Absence of OCHA as neutral and experienced partner in information sharing.
- Unwillingness to share information, completely or in a specific data format.
- Sub-optimal transparency about data collection methods.
- Inter-agency competition.

## 4.2 WASH ACTIVITIES IN THE BANGLADESH–MYANMAR DISPLACEMENT CRISIS

The Water, Hygiene and Sanitation or WASH sector is one of the 11 sectors in the sector and cluster approach. The publicly available WASH 4W data sets provide an indication of how frequent which type of activities are performed by which organisations. In addition, they give an idea of which activities are especially reaching high numbers of beneficiaries. Appendix **??** discusses the methods, data sets and scrips used for the exploratory data analysis on the activities performed by the active humanitarian organisations.

Figure 4.2 shows, the number of times an WASH activity has been performed by the 10 humanitarian organisations that are most active in WASH relief in Bangladesh. Ideally, these activities have been planned according to an apparent gap between needs of refugees and the present relief. In case, enough resources are available, either in Bangladesh on in the pipeline to Bangladesh, this gap could be bridged. Figure 4.2 shows that the only activity that is performed by all 10 most active humanitarian organisation is the distribution of hygiene kits. The decision about when and where to distribute hygiene kits is chosen as the focal decision for the modelling study. This decision is chosen as it affects a high number of beneficiaries and because there is relatively a lot of data available on this activity, which enables better facilitated research. Hygiene kit distribution does not require one single decision. Instead, it requires coordination of many organisations and individuals that need to decide about the location and time of distribution and about the content of kits. The nature of inter connected system implies that all decisions are interrelated. The decision about when and where to distribute hygiene kits based on the apparent gap between needs of refugees and relief activities present in surroundings is seen as a decision that is of attribution level that is low enough to perform meaning full analysis.

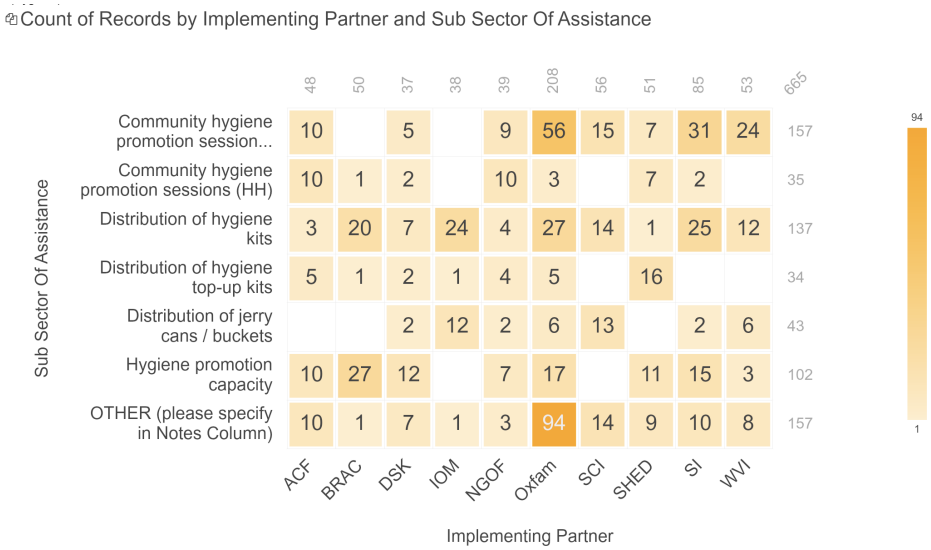


**Figure 4.2:** All major humanitarian organisations distribute hygiene kits. Analysis based on 4W data.

Maps of the ISCG and WASH sector show that area in which refugees reside is divided the into four areas and over 25 camps. The sector appointed area and camp focal agencies to facilitate more efficient communication and coordination among the areas. In addition, focal agencies and persons were appointed for the various host communities. The number of organisations active in the camps chances over time. By the end of October 2018, 20 organisations reported their activities to the sector coordination team WASH Sector Cox's Bazar and ISCG, 2018. The actual number of organisations providing WASH related relief could be higher, as the chance exists that organisations did not report their activities. Figure 4.3 shows the operational presence map. It provides in indication of the local geographic coordination structure, as it indicates which organisations are present in which camp and which organisation are appointed as focal agency.

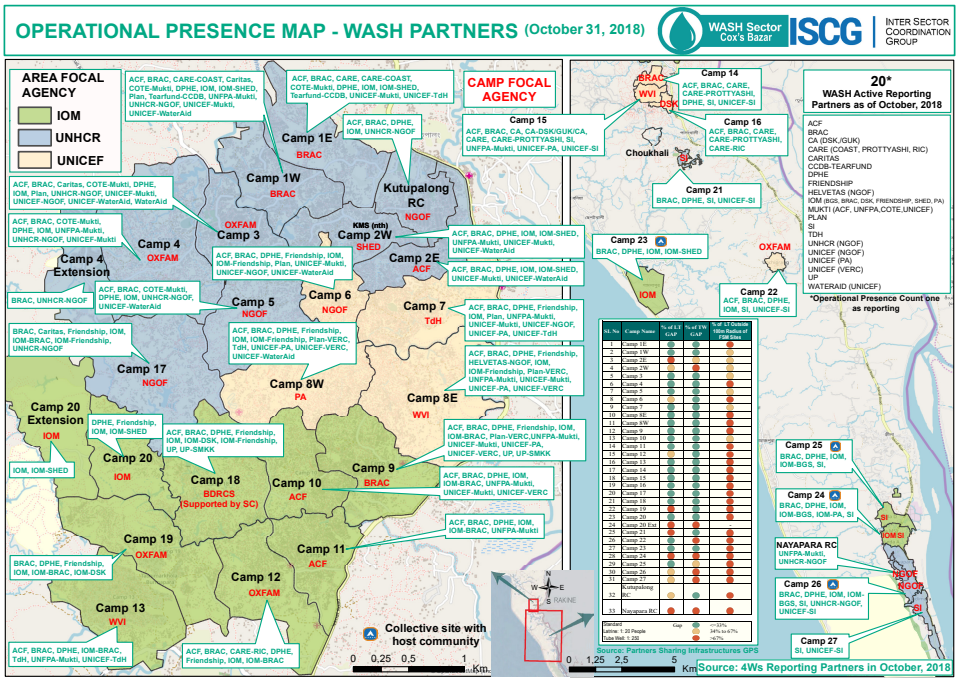


**Figure 4.3:** Area & Camp focal agency presence map adopted from WASH Sector Cox's Bazar and ISCG (2018)

The organisations active in providing WASH related relief to the inhabitants of the refugee camps share information using various formats and via different methods. Figure 9.1 gives an indication of the different information products that are shared in the WASH sector in Bangladesh. In addition to the WASH specific information products, a fast variety of sector wide information products is shared. An example is the Needs and Population Monitoring (NPM) site assessment. This is a multi-sectoral needs assessment that is conducted about every 2 months. Such assessment activities give the big picture of need-based information and satisfy most the advocacy needs. Furthermore, it became clear from the interviews that there are always more agency-wise assessments being performed to obtain more programme orientated information. Some of these assessments are shared, others not.

Strategic response planning is one of the steps in the humanitarian programme cycle. In Bangladesh a joint response plan has been developed for the period from March until December 2018. A new plan is expected soon. The joint response plan consolidates the efforts of all sectors and organisations. The document is used for advocacy and accountability and it tries to prioritise response and make it specific, measurable, attainable, time-bound and results-based. One of the biggest data producers in the refugee camps in IOM. One of the activities that is performed by this agency is analysis of satellite and drone imagery to complement needs assessments conducted in the field.

> *"The District is highly vulnerable to shocks, in an extremely fragile environment which has annual cyclone and monsoon seasons. The humanitarian community has limited time to prepare prior to April 2018, when the season begins.".*
>
> *Joint response plan for Rohingya Humanitarian Crisis March - December 2018 adopted from Strategic Executive Group and partners (2018).*

Comparing these observations with findings from Van de Walle and Comes (2015), gives rise to the impression that the information landscape in Bangladesh is fragmented but less so then the information landscape in Syria. Moreover, this limited

WASH Sector Cox's Bazar

WASH IM Products Catalog

| # | Name | Frequency | *Dissemination* | Format | Data Sources | Distribution |
|---|---|---|---|---|---|---|
| 1 | 4Ws, FTS, Infrastructures GPS update | Bi-weekly | *By e-mail*<br><br>*By WASH Sector Mailing list/Mai chimp* | *Excel* | 4Ws, FTS, Partners Infrastructures GPS datasets | *Upload HR.info*<br><br>*4Ws need to Send to ISCG by e-mail* |
| 2 | UNICEF Sitrep | Bi-weekly | | *Excel* | 4Ws | |
| 3 | ISCG Sitrep | Bi-weekly | | Word | 4Ws<br>FTS | |
| 4 | Operational Presence map *(with Sitrep WASH summary)* | Bi-weekly | *e-mail by WASH Sector Mailing list/Mailchimp to all partners* | PDF | 4WS,<br>ISCG Sitrep summary | *Upload HR.info* |
| 5 | WASH indicators matrix | Bi-weekly or Monthly | *By e-mail to site management* | *Excel* | 4Ws,<br>NPM,<br>REACH,<br>GPS | |
| 6 | GAP Analysis Matrix | Monthly | *By email With WASH Sector team* | *Excel* | 4ws,<br>REACH,<br>GPS,<br>NPM | |
| 7 | Water Quality Testing | Monthly | *By email With WASH Sector team* | *Pdf, kml etc* | UNICEF & WHO WQ test dataset | *Upload HR.info* |
| 8 | Risk mapping | Monthly | | *Pdf, kml etc* | Reach or Partners infrastructures GPS datasets | *Upload HR.info* |

**Figure 4.4:** Example of a WASH IM Products Catalogue adopted from HumanitarianResponse.info (2018a)

set of impressions suggests that mistrust and secrecy seems to be a bit less apparent. At the same time, the views of the interviewees and available documents, strengthen the belief that the direction of the information stream mostly goes up, leading from field to headquarters.

## 4.3 CONCLUSION

This chapter describes information sharing in a specific, complex emergency: the Bangladesh-Myanmar displacement crisis. For the Bangladesh-Myanmar displacement crisis, seven drivers and barriers that effect information sharing were identified. The WASH sector is one of the sectors where these drivers and barriers effect information sharing. Hygiene kit distribution is the only activity in this sector that is performed by all 10 most active humanitarian organisation. Comparing these observations gives rise to the impression that the information landscape in Bangladesh is fragmented but less so then the information landscape in Syria. Moreover, this limited set of impressions suggests that mistrust and secrecy seems to be a bit less apparent.At the same time, the views of the interviewees and available documents, strengthen the belief that direction of the information stream mostly goes up, leading from field to headquarters. The next chapter uses the provided system description to conceptualise information sharing in complex emergencies.

# 5 CONCEPTUALISATION

This chapter describes information sharing in a specific, complex emergency: the Bangladesh-Myanmar displacement crisis. This chapter is devoted to finding a way to transfer the dynamics found in literature, interviews and by answering the first sub-question into a conceptual model. By answering this question a conceptualisation is provided of information diffusion as well as a conceptualisation of information sharing strategies. This conceptual model in turn forms the basis of the simulations model that is developed in the next step. It explains the assumptions and abstractions that are needed to construct this model.

The sub-question belonging to this chapter is formulated as:

**How can a conceptual model of information diffusion in a complex emergency be made?**

The following paragraphs discuss the choices that are made as part of the conceptualisation of information management in complex emergencies. It is not the aim of this step to capture the system strictly using all the conventions. Instead, the research chooses function over form and design conceptual diagrams with methods inspired on the modelling languages BPMN, IDEFo and UML. For matters of readability it is decided to not always add the prefix inspired to BPMN, IDEFo or UML. The BPMN diagram is shown Figure 5.1 and the UML diagram shown in figure 5.2. Appendix D provides a more elaborate description of the conceptualisation based on an IDEFo diagram. Appendix F contains a list of assumptions made for this conceptualisation.

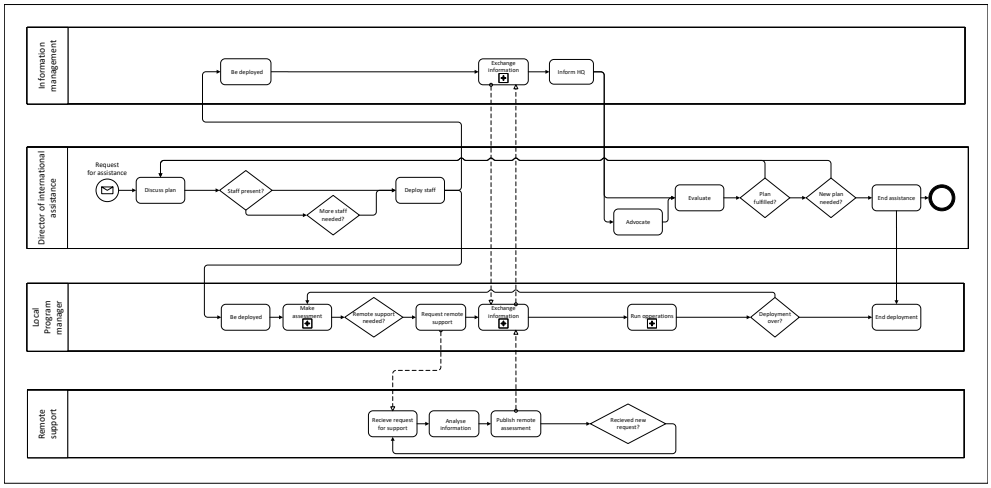


**Figure 5.1:** BPMN inspired diagram (A larger version of this diagram can be found in C.

## 5.1 AGENTS TYPES, PROPERTIES AND INTERACTIONS

Figure 5.1 shows the BPMN diagram that provides an overview of the conceptualisation of information diffusion in complex emergencies. The diagram shows four rectangles, or 'swim lanes'. These swim lanes contain the processes and choices that correspond to four types of agents. These agent types are: Director of international assistance, information management, local programme manager and remote support.

Characterising these agents in terms of the framework provided by van den Homberg and Susha, 2018, information management acts as intermediaries. Information management is deployed and subsequently facilitates the exchange of information, by requesting, consolidating and sending information from and to local programme managers. Information management is also the link with the director of international assistance and periodically shares information with this agent. Information management can decide when they request and share their information. This capability is one of the two of the types of strategies that will be evaluated. Information management can either share their information after a fixed time interval, the standard or periodic strategy. The can also share their information if the perceive information needs to be high, the adaptive strategy. Finally, they can share their information needs when they perceive the quality of information to be high.

The local programme manager is deployed, makes assessments, exchanges information, runs operations and subsequently either continues to stay deployed or end their deployment and leave the disaster. For a local programme manager, exchanging information means receiving information from information management and remote support and sending information to fellow programme managers in their social network and to information management of their organisation. The combination of having a social network and continuously arriving and departing

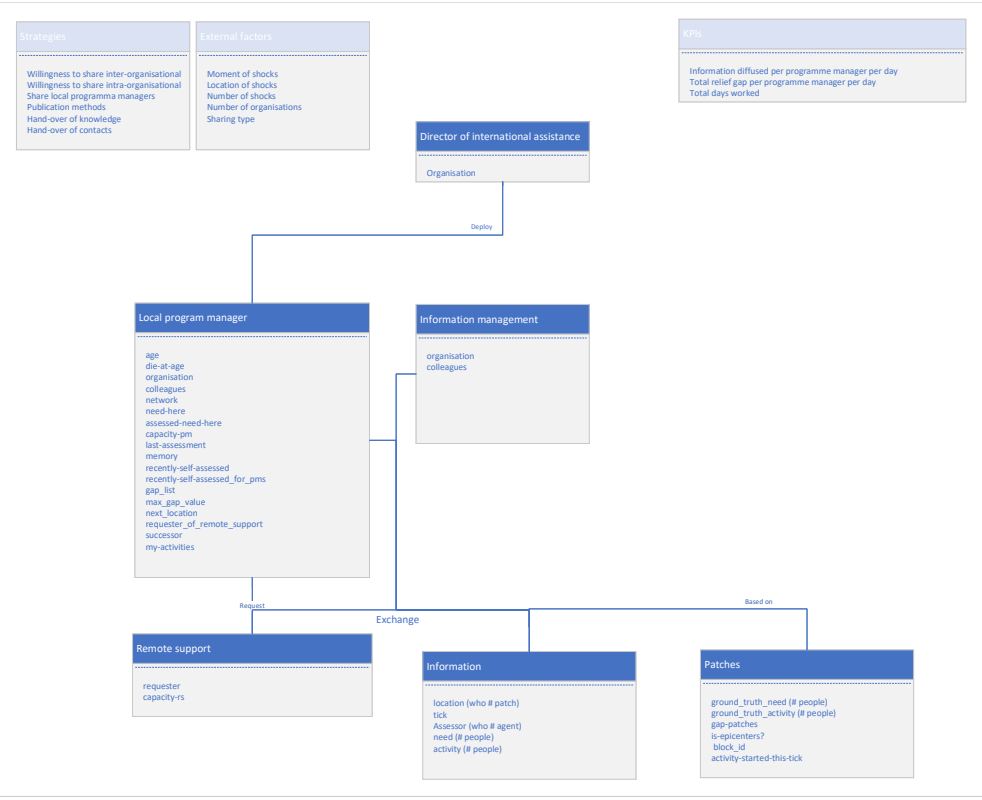


**Figure 5.2:** UML class inspired diagram (A larger version of this diagram can be found in E.

programme managers gives rise to the information landscape where information is forgotten. Information that is shared directly with fellow programme managers is shared in a social network. Hence, this form of information sharing is not random. Instead, information sharing through information management is random. As result, the model can be analysed under the assumption of social network based sharing, random sharing or a hybrid form of sharing which is a combination of the previously named types of sharing.

This dynamic contrasts to dyanamics models developed by Altay and Pal (2014) and Bateman and Gralla (2018) that model the information gather as random search. The social network and (un)deploying dynamic is only implemented in the local programme manager agent and not the information management. The motivation behind this simplification is that in case information management would have the same dynamic the model would likely be overloaded with uncertainty. This would evaluation of specific strategies very challenging.

After a fixed time interval, local programme managers can extend their social networks. These social networks are modelled as scale free networks. This means that the distribution of connections is exponential. As a result, few local programme managers have many links and many programme managers have a few. If they leave a disaster these social networks are only partly handed over. Local programme managers also have a willingness to share information. This value can be specified for inter-organisational information sharing and intra-organisational information sharing. This capability is the other of the types of strategies that will be evaluated.

The local programme manager moves from site to site in a disaster. By performing an assessment it measures the need for hygiene kits at that time for that location. The accuracy of the programme manager determines whether the assessed need is high or lower than the ground truth need at that location. The accuracy of the individual programme manager is pulled from a normal distribution. The mean and standard deviation of this distribution can be changed by the user. Local programme managers can request and receive the assistance of remote support. Local programme managers are also decision makers. A local programme manager decides where and when hygiene kits are distributes and shares information about these activities with other programme managers and with information management, which helps diffusing this information. A local programme manager can only move to, assess and provide relieve on a limited number of places. As all these activities take time they rely on other agents for assistance. Characterising these agent in terms of the framework provided by van den Homberg and Susha, 2018, this agent is both a producer and consumer of data.

Remote support agents are producers of data. They become available after they received an request from an local programme manager. In contrast to local programme managers, remote support agents can assess needs on high number of places at the same time. As is the case for local programme managers this assessment is not 100% accurate, instead the accuracy is based on the capacity of the remote support agent. As information management, can decided when they share their assessment. They have the same strategies as information management.

The final agent is the director of international assistance. This agent decided how many local programme managers will be deployed. It furthermore, receives information from information management. The behaviour of this agent is relatively simple. One of the function of this agents is to make the model easier relatable for the users.

## 5.2 KEY PERFORMANCE INDICATORS

The performance of the system is evaluated based on three KPIs. The main KPI is the number of information items shared per programme manager per day. An information item relates to information about one needs assessments or activity at one specific block in a refugee camp at one specific day. The other KPIs are the total relief gap and the number of days worked by all programme managers. The total relief gap reflects the summation of the number of days a person was not able to meet its needs for all persons in an emergency. The days worked relates to the summation of days worked in an emergency for all programme managers deployed to the disaster. The latter two KPIs are variables that reflect the efficiency by which information is used to close the relief gap and diffuse information. To increase readability the KPIs are occasionally expressed in their shorter forms: information diffused, relief gap and days worked.

This study recognises that a prominent reason to share information in a disaster is to lower the number of people that do not have access to relief. In addition, information can be shared to prevent overlap and inefficient allocation on (human) resources. This study aims to model information diffusion in a more realistic way than is done in the studies by Altay and Pal and Bateman and Gralla. As is the case in the later studies and as stated in the research scope in chapter 1, this study does not aim to answer the question of whether and how the diffusion of information increases the effectiveness or efficiency of a response.

The studies by Altay and Pal and Bateman and Gralla measure the performance of the system based on the 'total time' and 'seeker count'. The total time and seeker count indicators cannot be used in this study, as a result of the non-monotonous behaviour of information needs, the system never reaches a point where (all) agents are finished with their work of providing relief. Therefore, this study measures the performance of the system by three other KPIs, information diffusion, relief gap and days worked.

The reason that the information diffusion KPI weighs heavier in the evaluation of the system's performance is that, as a result of the objective of this study, the information diffusion dynamics is more realistic than the dynamics that effect the other KPIs. The relief gap and days worked variables are theoretical constructs that are included to enable modelling of diffusion of information. It is partly unclear how these theoretical constructs relate to reality.

There is a growing body of research focused on answering the question of how information leads to decision making in humanitarian response. The conceptualisation of the model can be extended by including more research from this research area into the model. Klein (2009) argues that experts typically use 5 cues to make a decision. As set out by Verity (2014a) experience helps responders develop patterns that let them size up situations quickly, therefore enabling them to judge what to pay attention to and what to ignore. They reserve their attention for the most important cues and aspects of a situation. It is, however, also these patterns or reservations that can lead to biases in decision making. The dynamics that are used in the model do not fully include this reality. Based on all the information a programme has in his memory, the programme manager chooses the location with the highest need as the location where to start an activity.

As the dynamics that underlie the relief gap and days worked KPIs are less well rooted in literature and potentially have a greater distance to reality, the effects on these KPI are weighted less heavily in the evaluation of the performance of the system. The effect of the information diffusion KPI is, in this regard, leading. The

other KPIs are checked for clear, significant effects that strengthen or weaken the overall performance of the system. In case such an effect is observed, it is reported in the analysis and findings of this study. The KPIs and other variables used in the model and their relations are displayed in the UML class inspired diagram shown in figure 5.2.

## 5.3 THE MODEL ENVIRONMENT

The model environment is characterised by two main concepts that define the disaster. The first concept is time. In the model time is represented by ticks. One tick corresponds to one day in the disaster. The length of the disaster can be defined by the user. The second concept is location, and especially the needs of and relief activities for (potential) beneficiaries at that location.

The needs of (potential) beneficiaries at a location chances in shocks. The location of these chocks changes over time. This in contrast to the models developed by Altay and Pal (2014) and Bateman and Gralla (2018) that assume the (information about the) needs to be constant.

## 5.4 CONCLUSION

This chapter discussed the conceptualisation of information sharing in complex emergencies. It explained the assumptions and abstractions that are needed to construct this model. The conceptualisation consists of four different agent types with their own specific behaviour. The information management, local programme managers, directors of international assistance and remote support agents use different strategies to share information. The social network and (un)deploy dynamic belonging to local programme manager agents make this conceptualisation fundamentally different from conceptualisations used by other scholars. This is also the case for the way in which needs of (potential) beneficiaries are conceptualised. In contrast to the concepts used in other conceptualisations the needs change over time, leading to an continuous instead of monotonous chancing information landscape. The next chapter will implement the conceptualisation into an agent based model.

# 6 MODEL CONSTRUCTION AND VERIFICATION

In this chapter the process of implementing the conceptual model in an Agent Based Model is described. In chapter 4 and 5 the conceptualisation of the information diffusion in complex emergencies is described. Paragraph 6.1 discusses the implementation of this concepts into the ABM by amongst others discussing the model interface and its input and output. The second paragraph is devoted to model verification. This paragraph provides points that aim to prove that the implementation of the conceptual model of information diffusion in the ABM is correct. The final paragraph concludes the chapter.

This chapter is the first of three that aim to answer the following sub-question:

**What is the effect of the information sharing strategies on information diffusion in the Bangladesh-Myanmar displacement crisis?**

## 6.1 MODEL IMPLEMENTATION

The thesis uses a modelling cycle that, as described by van Dam et al. (2013), contains the steps conceptualisation, specification, experimentation and validation. Model implementation belongs to the specification step. In this step the concepts

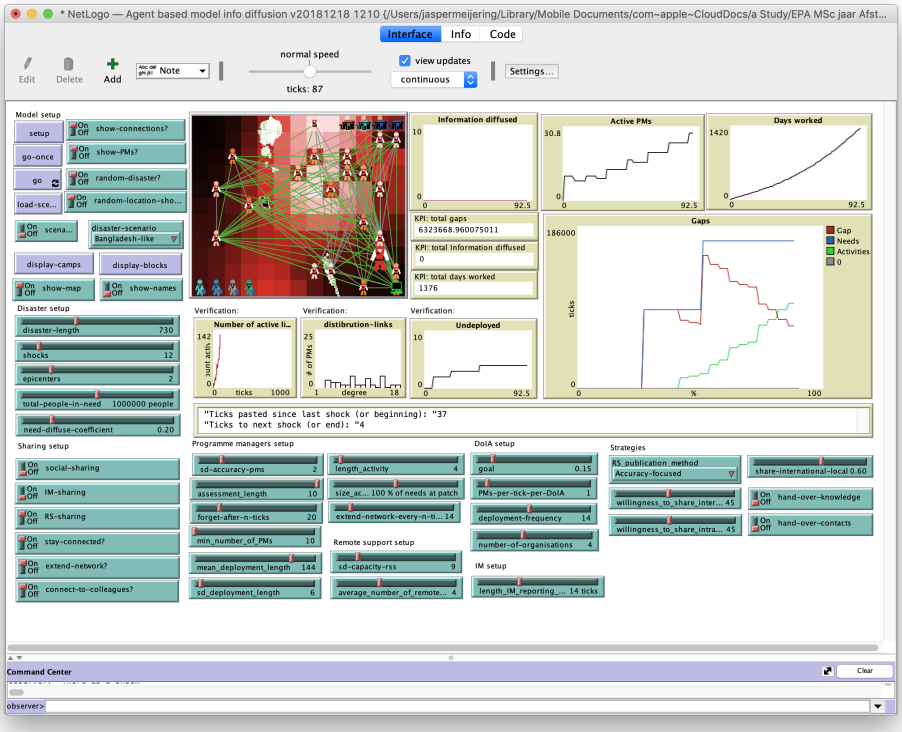


**Figure 6.1**: The interface of the agent based model

defined in the conceptualisation are transformed into an ABM. This transformation requires the modeller to make choices. The following paragraphs describes the constructed ABM and the choices made for the model implementation in three steps. First the input and interface of the model are discussed. These sub-paragraphs aim to give the reader an understanding how the model variables can be changed to simulate a specific disaster, evaluate different strategies or change conceptual choices. Subsequently, the model output and visualisations are discussed in the second sub-paragraph. These sub-paragraphs aim to provide the reader with an understanding of how the various parameters, plots and other visualisation should be interpreted. The last sub-paragraph considers the parametrisation of the model. It discusses what values are set as default for the various inputs. This chapter does not discuss the code of the ABM. Readers interested in the model code can consult the model documentation that is published on this Github page: https://github.com/JasperCM/information-diffusion

Figure 6.1 shows the interface of the ABM. The agent based model is implemented in Netlogo. The interface is a feature of Netlogo to improve the user experience of the modeller and its audience. While the model interface facilitates easier experimentation, verification and communication of results, the multitude of sliders, switches and visualisation may come over as intimidating. This is the reason that the model interface is discussed in a step-by-step manner in this and the following sub-paragraphs. The first sub-paragraph focuses on the model input, the buttons, switches, sliders and selectors that are displayed in purple and green in the left and bottom parts of the interface. The next sub-paragraph focuses on the model output and its visualisation by discussing the grid, shown in the centre of the interface, together with the monitors, plots and output fields displayed in sand colour.

### 6.1.1 Input and model interface

It is a deliberate choice to try to include all variables in the model interface. The alternative is to hide the variables in the code. While the number of buttons, sliders and switches may discourage the user at first, this disadvantage is chosen as the lesser of two evils. Refraining user access to the variables not only limits its use of the model, it also refrains the user from getting an understanding of the multitude of dependencies and assumptions the model is subject to.

The input variables can be grouped in 5 functional categories. These categories are model setup, disaster setup, sharing setup, agent setup and strategy setup. The first category, model setup allows the user to start and stop the model. It also gives the user control over the visualisation options as users can select to show or hide agents, connections or map projections. Furthermore, it enables the user to load in a disaster. By loading in a disaster variables in other categories are set to a prespecified value. The ABM is constructed based on a Bangladesh case study. If the Bangladesh-like scenario is loaded all variables are set to values that, according to the researcher, represent the situation in Bangladesh.

In the disaster setup section, the user can specify the *length* and the *number of shocks in the disaster*. The variable *epicentres* defines the number of places at which a shock hits. If this number is set to two, a shock hits in two places simultaneously. This represents a monsoon storm, landslide or sudden refugee influx changing needs in two places at once. By changing the *total people in need* slider one changes the number of people that are hit over the entire disaster length. Dividing the *total people in need* by the *number of shocks* and the number of *epicentres* gives the number of people that are hit in one epicentre of one shock. Every day a part of the needs and relief activities diffuse from one camp to another. This can be seen as

refugees looking for relief in neighbouring camps or hygiene kits being shared of camp borders. If *diffuse needs* variable is set to 0.20, 20% of all needs and activities at one camp transfer to all neighbouring camps at the end of each day.

The sharing setup section gives the user control over a number of conceptual choices. As an example, s/he can switch off *social sharing*, as a result all information is shared only through information management and not through social networks. If *RS-sharing* is switched off, there is no remote support in the disaster. In case *stay connected* is switched off, programme managers may have zero connections and, or new, not connected social networks might emerge. Switching off *extend network* replicates a scenario where social networks are not extended but stay constant over time. This represents a situation where no meetings are organised, communication might be impossible and there is no possibility to get to other programme managers. When *connect-to-colleagues* is switched on programme managers connect to other programme managers from their own organisation in addition to their 'normal' network extension that is independent of their organisation.

The agent setup section sets the values for variables that are agent specific. Examples are the *standard deviation of the normal distribution of the accuracy of assessments* carried out by programme managers or remote support. There are also variables that relate to the time it takes to do activities or assessments and to the moment at which activities or assessments will be started. Another variable sets the frequency at which directors of international assistance decide to send more programme managers to the field. The *number of programme managers* they send at the specified frequency is also a variable. Another variable belonging to the director of international assistance agent class is *goal*. This variable sets a target for the programme managers, if this target is reached, no additional programme managers are send to the field. Some of the agent specific variables can be influence by strategies. An example is the *mean deployment length*. This can be set by the user but it is overwritten if the strategy increase share of local programme managers is deployed by changing the strategy lever *share international local*.

The 5th and last section with variables is the strategies setup section. The variables *willingness to share information inter-organisational*, *willingness to share information intra-organisational* and *share international local* are also referred to as strategy levers. These sliders, shown at the right side of the interface, form the nuts and bolts of the specific strategies and can be set to a multitude of different values. Setting *willingness to share information intra-organisational* to 45% means that at each moment that information is shared with a other programme managers of the same organisation, 45% of all information items known to the programme manager are shared. Increasing the *share of local programme managers* increases the *mean deployment length* because, as by default, the deployment length of local programme managers is longer then that of international programme managers.

*Publication method*, *hand-over knowledge* and *hand-over contracts* are strategy selectors. These variables can take binary values. These are *on* or *off* in the case of the hand-over strategies and *accuracy-focused* or *time-focused* in the case of publication method. Setting publication method to *time-focused* means the time needed to perform an assessment is short but the accuracy of the assessment is low. *Accuracy-focused* represents the opposite, assessments are accurate but take long to perform. If a hand-over strategy is set to *on*, programme managers transfer a share of the information(items) or contacts they have with someone from their organisation (their successor). How much the programme manager and successor are able to share depends on the deployment length of the successor. The hand-over of programme managers that stay longer is more effective if the programme managers stays longer, as was concluded based on interviews.

### 6.1.2 Output and visualisations

The model output can be grouped in 4 categories that all have their specific visualisation. These are the grid or model world, the verification plots and outputs, the model behaviour plots and the KPI values.

The model world is a graphical representation of the place where the agents interact which each other and with the environment. In this world, the programme manager is represented as a person with a red vest. If programme managers are connected by a green line, they are in contacts with each other. The group of programme managers that is connected to a specific programme manager is the social network of that programme manager. In the world, information management is represented as an office building, remote support as a computer and the director of international assistance has a briefcase to store important documents. The pixels or patches in the grid are a specific type of agent. Patches with a relatively high relief gap light up.

The three plots below the grid are verification plots. These plots can be used to see whether the model behaves as expected. The other plots in the model interface can be used to interpret the model behaviour. As an example, the gap plot shows the total needs, activities and gaps of all patches combined. Another example is the days worked plot, this plot shows the sum of the number of programme manager for each day. In other words, the plot shows the total number of working days programme managers spend in the disaster.

An important aspect of the interface are the Key Performance Indicator (KPI) values, shown to the right of the grid in the middle of the model interface. In the model interface, these values are used the evaluate the model behaviour and hence the effects of the strategies. The three KPIs are *total relief gap per programme manager per day*, *total information diffused per programme manager per day* and *total days worked*. As is common for models of complex socio-technical systems, the behaviour of the systems can only be interpreted by looking at multiple variables at once. As an example, once information diffusion increases and the relief gap decreases one should also look at the days worked variable to check whether the effects caused by an efficiency gain or simply by the fact that more programme managers where active in the disaster.

### 6.1.3 Parametrisation

Parametrisation the model involves finding appropriate values for the model variables. For this study the model parametrisation has been based on the Bangladesh case study. The parameter values are set to values that are derived from literature or based on consultation with information managers in the field. the larges part of the model variables are set to constant variable. The variables of external factors, such as the number of shocks and the number of active organisations are sampled between two values. Some external factors that relate to model switches are binary, for example the random shock and social sharing variables. Table 6.1 shows the parametrisation of the strategy variables. The bottom three variables in table 6.1 are binary. In contrast, the top three the variables in table 6.1 are continuous. While their behaviour will be analysed for a wide range of values, the evaluation of the strategies is based on values that are deemed reasonable to reach in the Bangladesh-Myanmar displacement crisis. An overview of the parametrisation can be found in appendix G.

| | Reference scenario | Evaluation scenario |
|---|---|---|
| Willingness to share information inter-organisational | 40% | 50% |
| Willingness to share information intra-organisational | 50% | 70% |
| Share local programme managers | 0.5 | 0.8 |
| Publication method | Accuracy-focused | Time-focused |
| Hand-over knowledge | No | Yes |
| Hand-over contacts | No | Yes |

**Table 6.1:** Reference and evaluation values for the strategy variables.

## 6.2 MODEL VERIFICATION

During and after model developed, various verification tests are executed. The verification process consists of four steps. The first step is extensive code walk-through. The second step is recording and tracking agent behaviour. The third step is interaction testing in a minimal model and the last step is extreme values verification. Example of the latter is setting all values to 0 or a relative very high number. In some cases setting a value to 0 formed a problem as variables where divided by this number in this case a very low number is chosen. A more elaborate description of the verification methods used can be found in appendix H. After performing and analysing the verification tests, the modeller is confident that there are no errors in the code. It is concluded that the model works as expected.

## 6.3 CONCLUSION

In this chapter the implementation of the conceptual model in an Agent Based Model is described. The input variables can be grouped in 5 functional categories. This categories are model setup, disaster setup, sharing setup, agent setup and strategy setup. The model variables can be changed to simulate a specific disaster, evaluate different strategies or change conceptual choices. The model output can be grouped in 4 categories that all have their specific visualisation. These are the grid or model world, the verification plots and outputs, the model behaviour plots and the KPI values.Discussing the model output aims to provide the reader with an understanding of how the various parameters, plots and other visualisation should be interpreted. For this study the model parametrisation has been based on the Bangladesh case study. The parameter values are set to values that are derived from literature. Consultation with information managers in the field also showed an important source for the parametrisation. After conduction all verification tests, it is concluded that the model works as expected. The next chapter discusses the process of using the developed ABM for experimentation.

# 7 MODEL RESULTS

This chapter discusses the process of using the ABM for experimentation. The chapter is divided in two parts. A section on the effects of the core assumptions and general model behaviour and a section on the effects of individual strategies. Both sections first describe the design of experiments that is used to obtain results. They subsequently present the results of the experiments. Although avoiding any interpretation of results is difficult, this chapter aims to limit interpretation and discussion of the results to extend that is needed to explain the setup of experiments. Table 7.1 provides an overview of all experiments.

The data generated using the Netlogo behaviour space feature is analysed using various packages developed for the R software environment for statistical computing. The data files and R markdown file containing the code, plots and documentation are published on this Github page: https://github.com/JasperCM/information-diffusion. Readers interested in the interpretation of the results are advised to also consult the next chapter, as interpretation is the main objective for the chapter that follows. That chapter also discusses a set of additional experiments that are conducted to evaluate the effect of combinations of individual strategies, the so called comprehensive strategies.

A box plot is a standardised way of displaying the distribution of data based on a five number summary. The boxplot shows the 'minimum', first quartile, median, third quartile, and 'maximum'. The white box includes the lower and upper quartile of the data. The distance ranging from the bottom to the top of the box is referred to as the inter-quartile range. The upper whisker extends from the box to the largest value no further than 1.5 times inter-quartile range from the box. The lower whisker ranges from the box to the smallest value at most 1.5 times the inter-quartile range. Data beyond the end of the whiskers are called outliers and are plotted individually as black dots. If the boxes in the box plots do not overlap, one can conclude that with 95% confidence, the true medians do differ. While interpreting the results both the behaviour of the effect and significant differences of and between the strategies are reported.

## 7.1 CORE ASSUMPTIONS AND GENERAL MODEL BEHAVIOUR

Altay and Pal (2014) and Bateman and Gralla (2018) were the first researchers to use agent-based modelling and simulations to model information diffusion and evaluate information sharing strategies in humanitarian disasters. The model developed for this study uses assumptions that are more realistic than the assumptions used by these researchers. The first fundamentally different, more complex, assumption is that this study assumes that information landscapes are continuously evolving instead of behaving monotonously. The second assumptions is that information is gathered amongst others through information sharing in social networks. Altay and Pal (2014) and Bateman and Gralla (2018) assumed that, *considering the lack of clear communication channels due to the chaotic nature of the initial response phase, the random search assumptions are not far from reality*, and modelled it as such. This study

| Experiment | Variable | Value | Number of replications per scenario |
|---|---|---|---|
| Assumption A1 | Random moment shocks<br>Random location shocks | True / False<br>True / False | 100 |
| Assumption A2 | Number of shocks | 2 2 40 | 50 |
| Assumption B | Social sharing<br>IM sharing | True / False<br>True / False | 200 |
| Strategy 1 | Inter-organisational willingness to share | 0 10 80 | 100 |
| Strategy 2 | Inter-organisational willingness to share | 0 10 80 | 100 |
| Sensitivity 1 | Inter-organisational willingness<br>Intra-organisational willingness<br>Number of organisations | 0 10 80<br>0 10 80<br>4 / 8 | 50 |
| Strategy 3 | Share local programme managers | 0.4 0.1 0.8 | 50 |
| Strategy 4 | Changing publication method | Accuracy-focused<br>Time-focused | 50 |
| Strategy 5 | Handing-over knowledge | True / False | 50 |
| Strategy 6 | Handing-over contacts | True / False | 50 |

**Table 7.1:** Overview of experiments

argues that the assumptions underpinning this model are better rooted in literature and are closer to reality then the assumptions made by the preceding researchers. This paragraph considers the experiments that were executed to assess whether the model behaviour is effected by the more realistic assumptions.

### 7.1.1 Design of experiments

To evaluate the effects of the continuously evolving information landscape assumption, the model is ran with four different parametrisations. All four parametrisations of the model are replicated 100 times. In the first instance both the moment at which shocks take place and the location at which the shocks strike are fixed. Each replication, the shocks strike at the same day at the same place. In the second instance, the moments at which shocks strike are constantly changed but the locations are the same. In the third instance moments are fixed but locations are pulled from a random distribution with a different seed. In the fourth instance both moment and location are random each replication. In addition, the effects of the number of shocks is examined. In a different experiment with 100 replications, the number of shocks is increased from 2 until 40 to measure the effects on the three KPIs.

To evaluate the effects of the information sharing assumption, the model is also ran with four different parametrisations for 100 times. This time, a boundary test is conducted. Social network sharing and information management sharing are alternately switched off and on.

### 7.1.2 Effects core assumptions

Figure 7.1 shows the effect of adding randomness to the moment and locations at which shocks strike on the information diffused per programme manager per

day. A information diffusion level of 1.5 corresponds to a situation where every programme manager shares 1.5 information items per day. Information items can either be needs assessments or activities that correspond to one location at one moment in time. The figure shows that as the location and moment of shocks are different, the amount of information diffused is different both during the disaster and at the end. The effect of shocks striking at different moments is stronger than the effect of shocks striking at different locations.

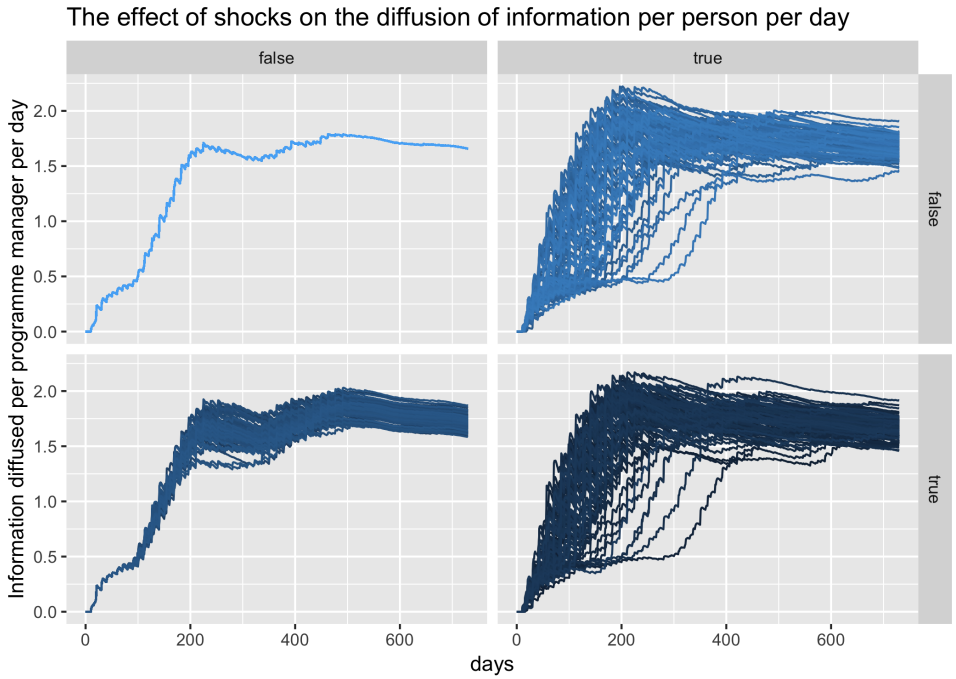


**Figure 7.1:** The effect of shocks on the diffusion of information. The figure illustrates the effect of making the moment and location at which shocks strike random (bottom right). This in contrast to series of moment and locations that are fixed (top left). The figure shows that the effect of the moment at which shocks strike (top right) is stronger then the location at which shocks take place (bottom left). The first effect adds more uncertainty to the level of information diffused then the latter.

Figure 7.2 shows the effect of various numbers of shocks on the three KPIs. The figure illustrates that as the number of shocks increases, information diffused per programme manager per day increases. It also shows that apart from disasters with a limited number of shocks, the relief gap stays constant as the number of shocks increases. While the relief gap stays constant, more working days are needed to maintain this constant level of support.

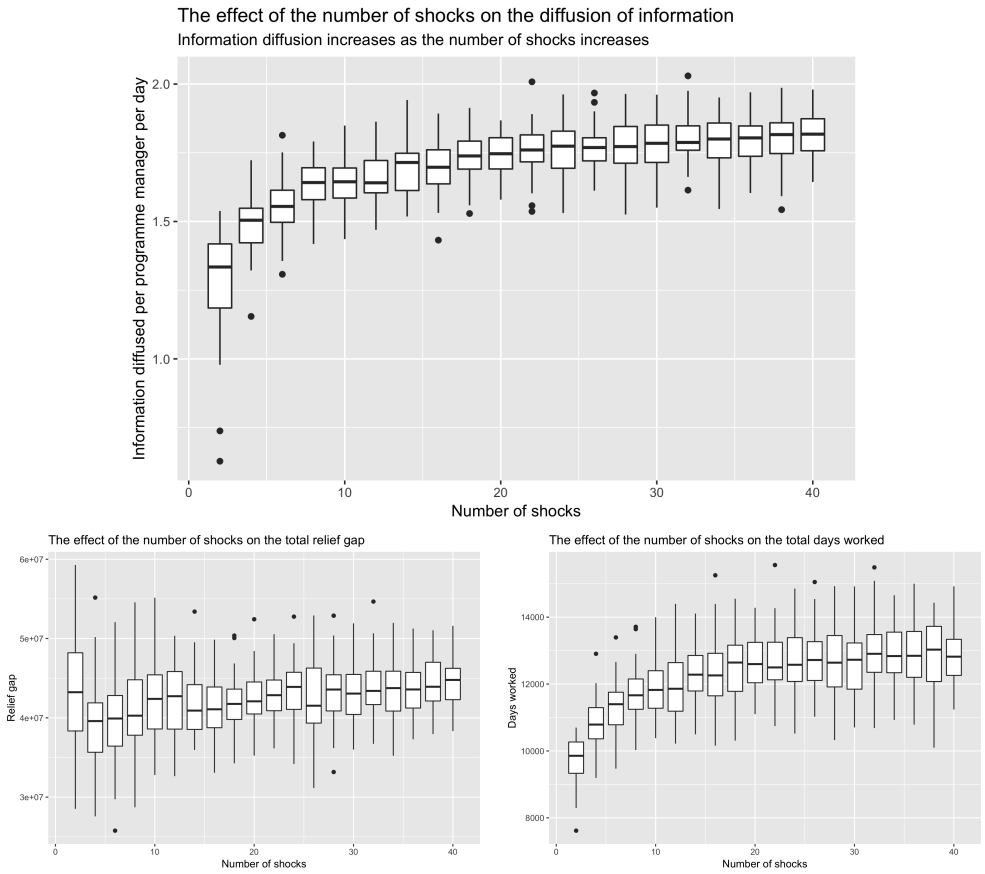


**Figure 7.2:** Non-monotonous behaviour of information needs assumption: effects different numbers of shocks.

Figure 7.3 shows the effect of no sharing, social sharing, IM sharing and combined social and information management sharing. This figure shows that information diffusion is highest if social sharing and information management sharing are combined. In addition, social sharing leads to more information diffusion than information management sharing. Social sharing decreases the days needed to provide a constant level of relief, as the two bottom plots show. This effects is, however, not significant.

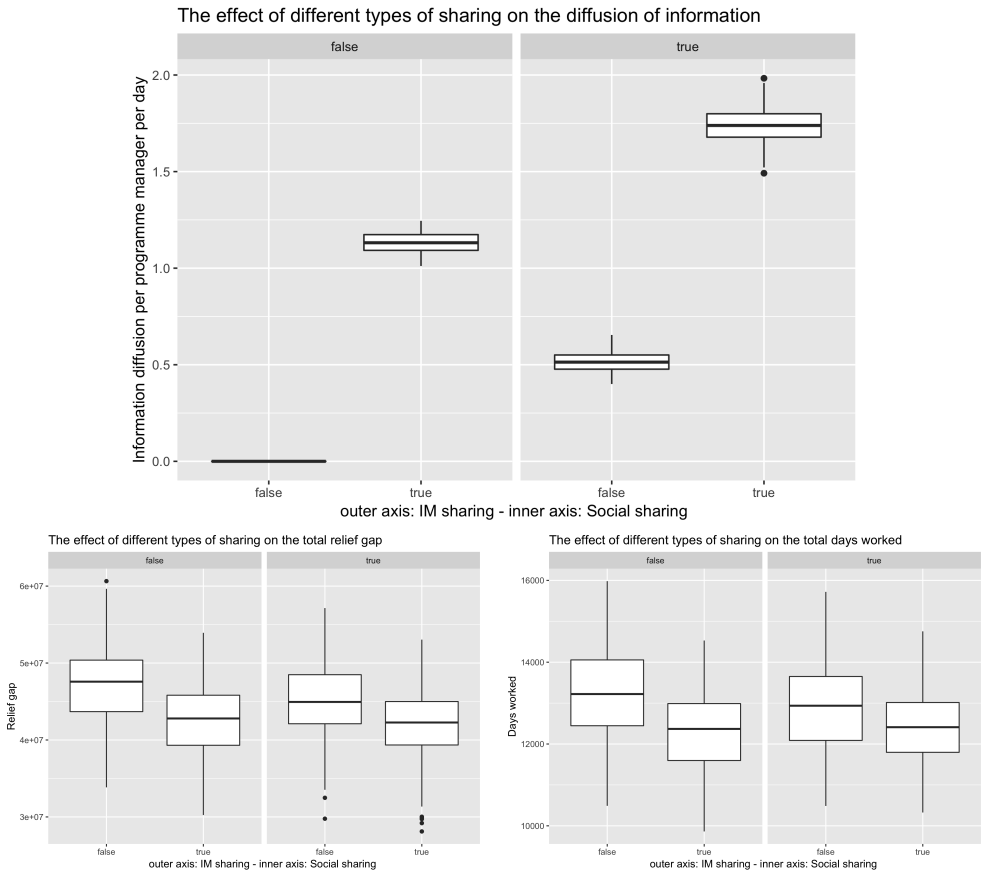


**Figure 7.3:** Information sharing assumption assumption: effect no sharing, social sharing, IM sharing and combined sharing.

## 7.2 INDIVIDUAL STRATEGIES

This study aims to evaluate six different strategies that aim to increase information diffusion. This section discusses the results and experiments that are used to obtain these results of individual strategies. In this paragraph, the design of individual strategy experiments is considered first. Subsequently, the results of these experiments are presented.

### 7.2.1 Design of experiments

Table 7.1 includes the parametrisation that is used to analyse the effects of the six individual strategies. For two individual strategies extra sensitivity tests are performed to assess whether the effects of these strategies are robust under different conditions. This is the case for both willingness to share information strategies. The reason for these sensitivity tests is elaborated on at the corresponding paragraphs.

### 7.2.2 Effects increasing willingness to share information between organisations

Figure 7.4 illustrates the effect of willingness to share information between organisations for values between 0% and 80%. The top plot shows the effect on the amount of information diffused per programme manager per day. Information diffusion is higher for higher levels of willingness to share information. The effect of increasing the willingness slightly smooth-ens out as the willingness approaches 80%. That more information is diffused does not mean that the relief gap decreases. Nor does

the number of days worked by programme managers change as a result of higher willingness to share information.

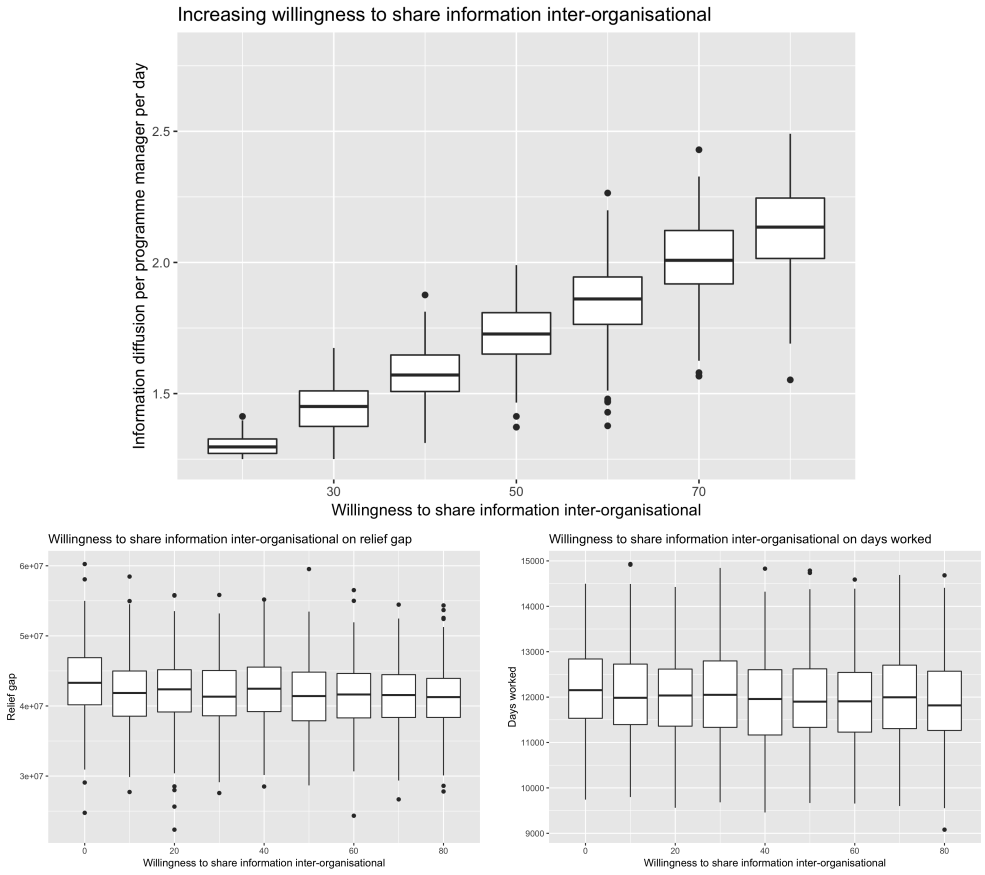


**Figure 7.4:** Effects increasing willingness to share information between organisations

### 7.2.3 Effects increasing willingness to share information within organisations

Figure 7.5 illustrates the effect of increasing willingness to share information within organisations for values between 0% and 80%. The top plot shows the effect on the amount of information diffused per programme manager per day. Information diffusion is higher for higher levels of willingness to share information within organisations, just as is the case for higher levels of willingness to share information across organisational boundaries. Also the behaviour of the total relief gap and days worked KPIs is not affected by the strategy.

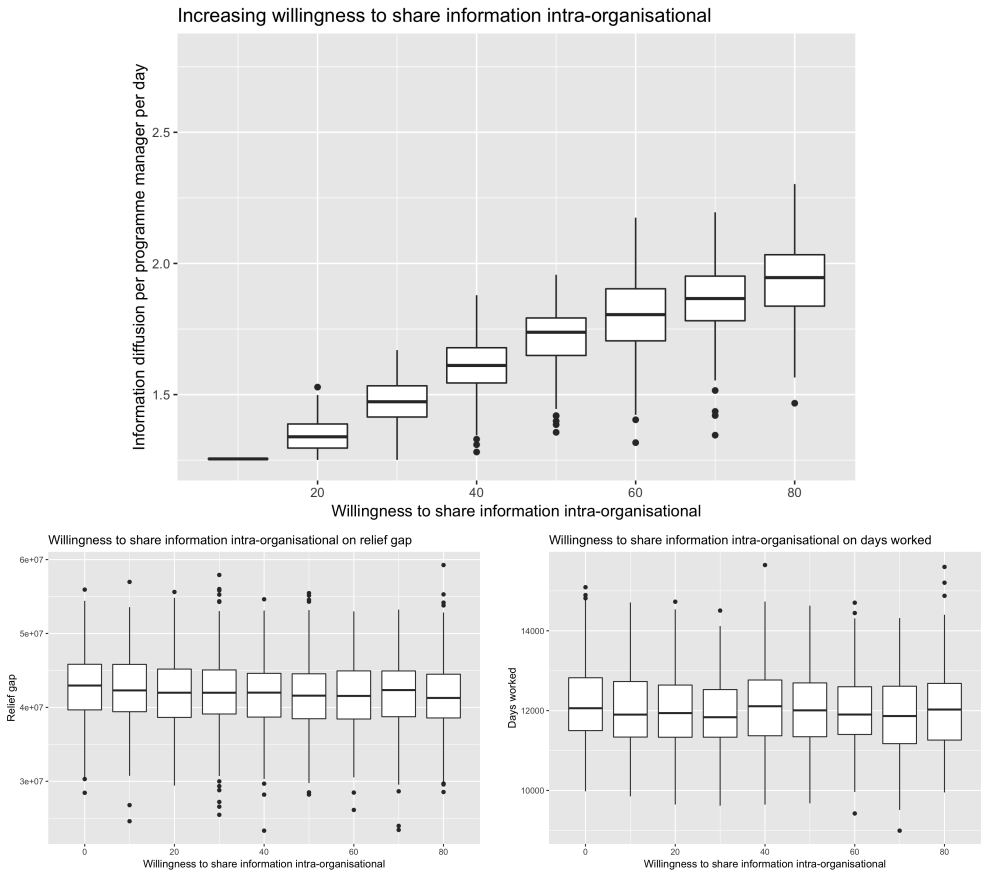


**Figure 7.5:** Effects increasing willingness to share information within organisations.

The comparison between the effects of increasing willingness to sharing information inter and intra-organisationally shown in figure 7.6, however, does show a difference between the two forms in information sharing. High levels of inter-organisational willingness to share information leads to more information diffusion then high levels of intra-organisational willingness to share information.

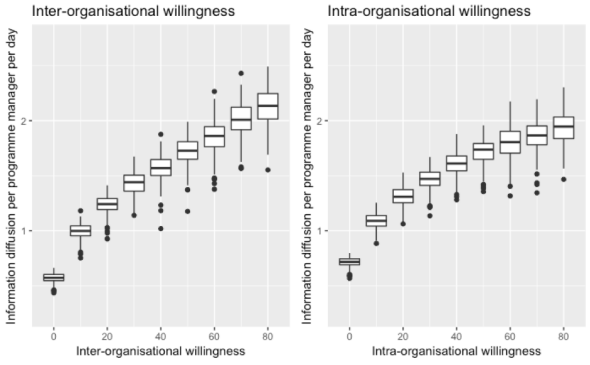


**Figure 7.6:** Comparison of effect of the two types of willingness to share information on information diffusion

Potentially, the effect of willingness to share information strategies is dependent on the number of different active organisations that is present in a disaster. If this hypothesis shows true and the effect of willingness to share information strategies is sensitive for changes in number of strategies active in a disaster, conclusions about these strategies could be distorted. It would be especially of interest for the conclusions of this study if one strategy is more effective in diffusing information with low number of organisations and the other with high number of organisations.

To test the hypothesis, the effect of both willingness to share information strategies are evaluated for disaster with 4 and 8 active organisations.

Figure 7.7 shows the results of these experiments. The figure shows the effect of increasing willingness to share information between and within organisations for disasters with four active organisations and eight active organisations. In the figure, it is noticeable that an increase from four to eight active organisations makes the effect of the inter-organisational information sharing strategy even stronger than the intra-organistional one. This implicates that the effect of both willingness to share information strategies is dependent on the number of organisations. Yet, increasing the number of organisations only enforces the effect of the inter-organisational strategy. The strategy that was already most effective in diffusing information.

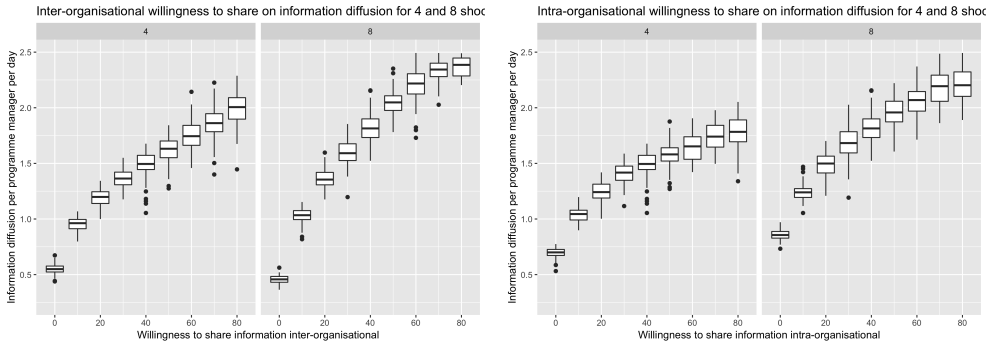


**Figure 7.7:** Effect willingness to share inter-organisational (left) and intra-organisational (right) on information diffusion for disasters with 4 (left side of either plots) and 8 (right side of either plots) active organisations.

### 7.2.4 Effects increasing share local programme managers

Figure 7.8 shows the results of the experiments that examined the effect of increasing the share of local programme managers. It shows that if the workforce consists of 50% local staff and 50% international staff each programme manager shares about 1.6 information items per day. This number is close to 1.8 information items per day if 80% of the workforce consists out of local programme managers. A more local workforce also means that the total relief gap is smaller: directors of international assistance reach their targets faster. It must be said, though, that this effect could also be due to the higher number of work days that are made by a more locally hired workforce.

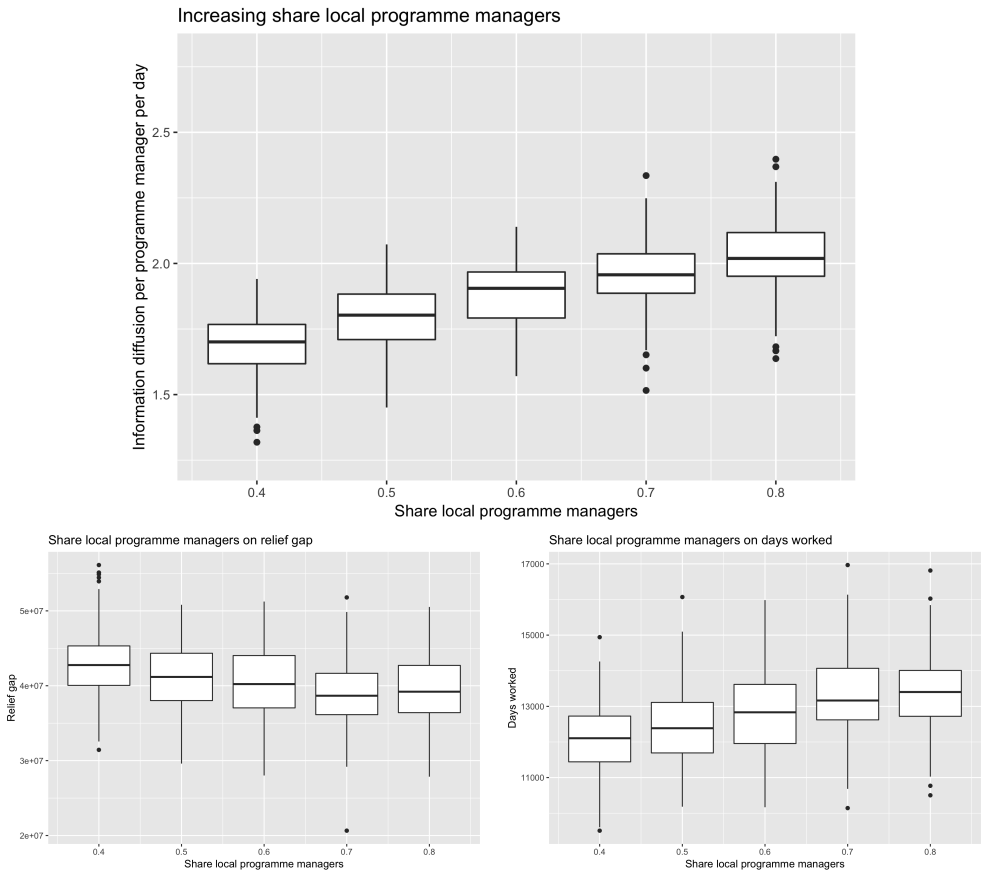


**Figure 7.8:** Effects increasing the share of local programme managers in a disaster.

### 7.2.5 Effects changing publication method

As discussed, in chapter 6, having a publication method that is *accuracy-focused* means that the accuracy of the assessment is high, but this assessment takes longer to perform. *Time-focused*, at the other hand, represents a publication method in which assessments are carried out fast, but with low accuracy. Figure 7.9 shows the results that where performed to evaluate the effect of these publication methods. This figure shows that the faster, time focused, strategy leads to more information diffusion. This strategy also leads to a lower relief gap. The higher level of information diffusion and lower relief gap is realised with fewer people, as is illustrated in the plot in the lower right side of the figure.

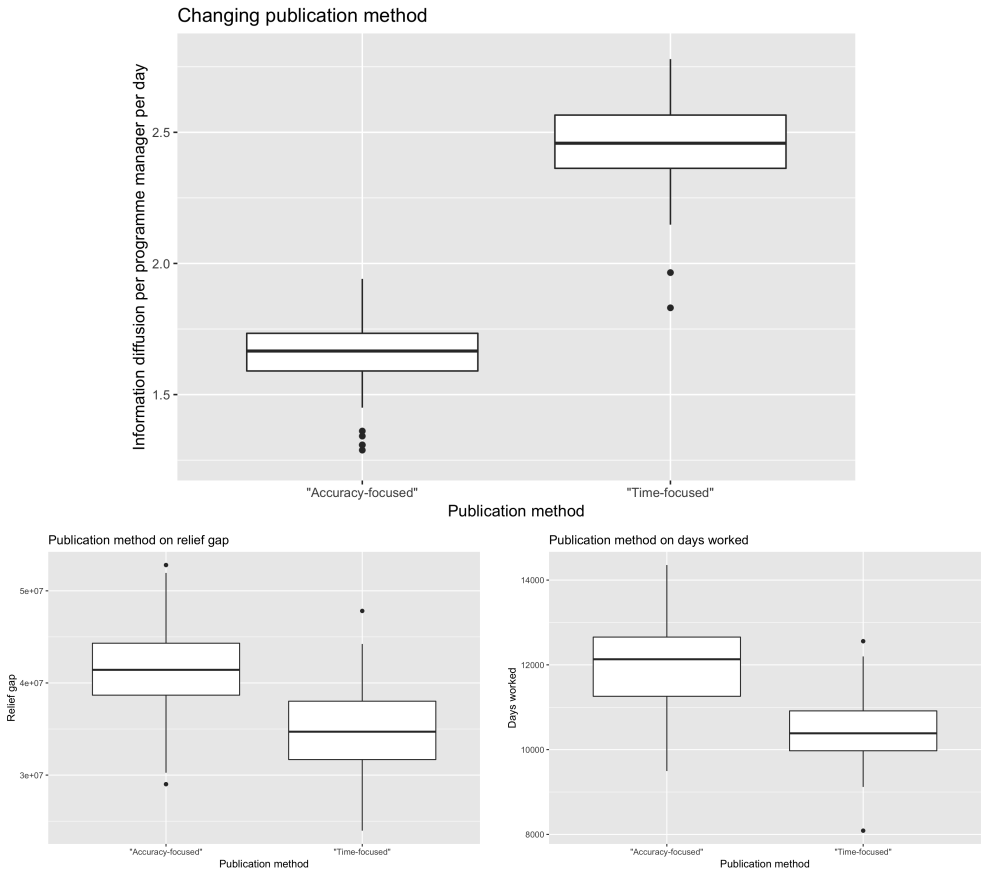


**Figure 7.9:** Effects changing between an accuracy focused and time focused publication method.

### 7.2.6 Effects handing-over knowledge

This study looks at two different kinds of handing-over strategies. Handing-over knowledge which relates to telling your successor what you know about the needs and activities in a disaster and handing-over contacts. In this strategy, the departing programme manager introduces his successor to fellow programme managers that he has met during his deployment.

Figure 7.10 shows the results that where performed to evaluate the effect of handing over knowledge to your successor. This figure shows that, in this model, handing over knowledge has no signification effect on information diffusion. Moreover, also the effect of this strategy on the total relief gap and total days worked is absent.

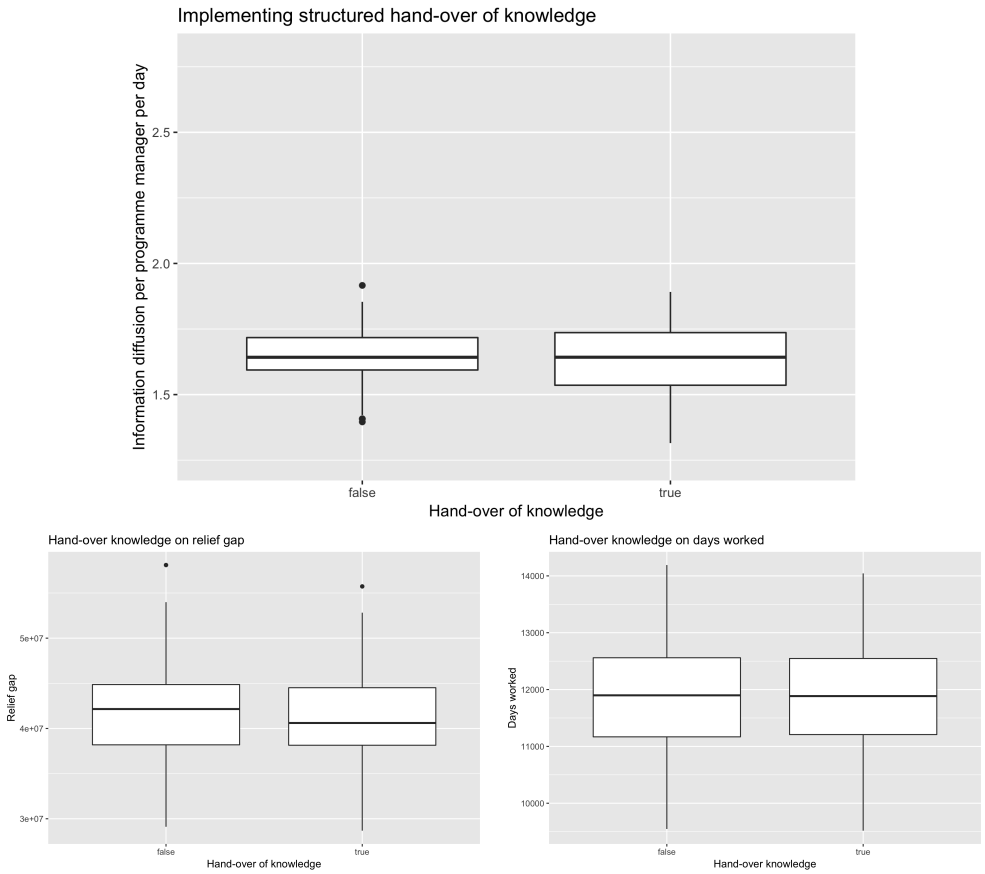


**Figure 7.10:** Effects handing-over knowledge

### 7.2.7 Effects handing-over contacts

The handing-over contacts strategy represents a strategy in which a programme manager introduces his successor to fellow programme managers that s/he has met during the deployment. Figure 7.11 shows the results of this strategy. In contrast to focusing on handing over knowledge, this strategy does have an effect on the KPIs. The figure shows that information diffusion increases from about 1.69 information item per programme manager per day to 1.8 information item per programme manager per day. There is no clear, significant effect on the relief gap or days work though.

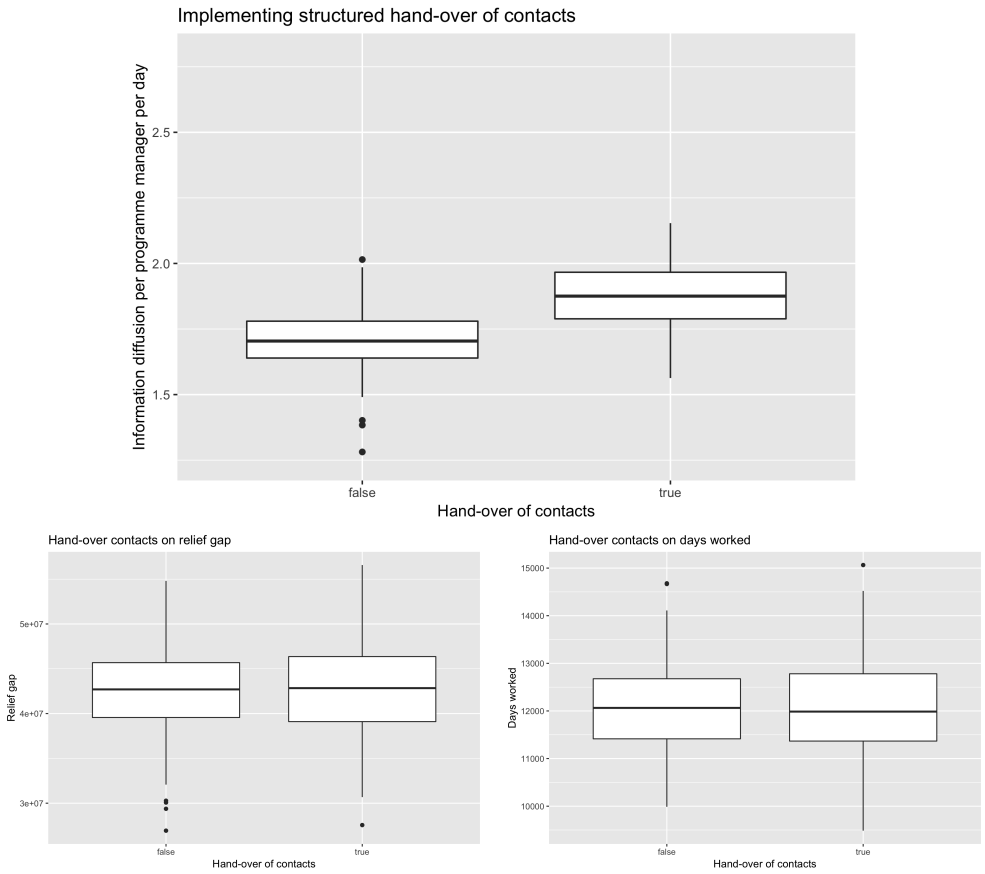


**Figure 7.11:** Effects handing-over contacts

## 7.3 CONCLUSION

This chapter discussed the results of over 10.000 experiments that are performed to evaluate the effects of the two core assumptions and the six individual strategies. The experiments show a wide range of outcomes that can be interpreted in a number of ways. The results are published online and are available for interpretation by fellow scholars. Those readers interested in knowing how the researcher interprets the results presented in this chapter are advised to consult the following chapter. This chapter also considers combinations of individual strategies in order to evaluate the combined effects of these strategies.

# 8 ANALYSIS

In this chapter the results of the experiments are analysed and interpreted. First, attention is devoted to the behaviour of the ABM that is observed in general and the effect of the core assumptions that were made for this study. The following paragraph focuses on the analysis and interpretation of the individual strategy experiments described in the previous chapter. This paragraph also describes which strategy is most effective in diffusing information, lowering the relief gap and decreasing the number humanitarians needed in the response. The 3rd paragraph is devoted to answering the questions of what the effect is of combining different individual strategies. First, the design of the experiments that are conducted to answer this question are explained. Subsequently, the results of these experiments are analysed and interpreted.

Taken as a triptych, the model, results and analysis chapters aim to reveal the answer to the third sub-question. This question reads:

**What is the effect of the information sharing strategies on information diffusion in the Bangladesh-Myanmar displacement crisis?**

## 8.1 ANALYSIS CORE ASSUMPTIONS

Altay and Pal (2014) and Bateman and Gralla (2018) were the first researchers to use agent-based modelling and simulations to model information diffusion and evaluate information sharing strategies in humanitarian disasters. These researchers assumed information landscapes to behave monotonously and state that representing information gathering as a random search is not far from reality. This study uses more realistic assumptions. It assumes information landscapes to evolve continuously and represents information gathering as a process in which information is gathered by assessments and subsequently shared in social networks and via information management channels. Chapter 7 discussed the results of the experiments that were conducted to evaluated how these assumptions affect the general behaviour of the model.

These results, specifically those about the continuously evolving information landscape assumptions shown in figure 7.1 and figure 7.2 show a number of things. First, they shows that the moment, location and number of shocks matters. The level of information diffused and days worked are different if the moment, location or number of shocks is different. This is relevant give that Altay and Pal and Bateman and Gralla assumed that a disaster can be reprehended by one shock, that strikes at t = 0 and which information corresponds to one location. Secondly, it shows us that shocks that strike at different moments, locations and in different numbers add uncertainty to the outcomes. While some decision-makers might be discouraged by a strategy that has an uncertain outcome, accounting for this uncertainty in the outcome allows the policy advisor to come up with strategies that are robust in more circumstances. Thirdly, the results about the effect of this core assumptions show that the moment at which a shock strikes adds more uncertainty to the model behaviour than the location that is strikes at. Lastly, figure 7.1 suggests

that if the number of shocks increases, information diffusion per programme manager per day and the total days worked increase, while the relief gap remains stable. In other words, a disaster with a higher number of shocks requires the diffusion of more information and the work of more programme managers to deliver the same stable relief gap. This behaviour stabilises as shocks happen very frequently. In this case the system reaches an equilibrium.

The results show that the moment, locations and number of shocks observed in a disaster influence information diffusion, the observed relief gap and the number of days programme managers have to work. This effect is not accounted for in the work of other scholars. Based on this results it is concluded that this model is more suitable to evaluate information sharing strategies than models of Altay and Pal and Bateman and Gralla.

Once we take a closer look at the results of the experiments designed to evaluate the sharing assumption, we also can draw a number of conclusions. While interpreting the results of the sharing assumption, it is good to keep in mind that in the ABM, the random search method of sharing information is represented by *information management sharing* and that the non-random way of sharing is represented by *the social network based way of sharing*. The first point that stands out, while interpreting figure 7.3, is that social network based sharing leads to up to 1.5 times more information diffusion. Secondly, having social network based, non-random sharing instead of random, information management based sharing influences the working days needed for the same stable relief, an effect that can be observed in the two plots at the bottom of figure 7.3. This is especially relevant given that multiple strategies, examined in this research, influence the mix of social network based, non-random sharing or random, information management based sharing. Hence, we can concluded that the evaluation of the strategies is affected by the more realistic social network assumption.

The results show that replacing information sharing represented by a random search with information sharing represented by a combination of social network based sharing and random search sharing influences the behaviour of the model and the outcomes of the evaluations. Moreover, it is argued that a combination of non-random social network based sharing and random information management sharing gives more structure to the way how information sharing is represented. Based on this argumentation it is concluded that the model comes closer to reality and is more suitable to evaluate information sharing strategies than the models of other scholars. It is also concluded that the effect of changing publication method on the relief gap and days worked KPIs is not significant. We can not confirm that the added structure leads to different outcomes in the observed relief gap or total days worked between not sharing and the reference scenario. The complexity of the assumptions that govern how information leads to the planning of relief activities is too limited to observe significant results for this effect on the latter two KPIs.

## 8.2 ANALYSIS INDIVIDUAL STRATEGIES

Figure 8.1 shows the effects of the six information sharing strategies on one of the KPIs, the diffusion of information per programme manager per day. Appendix I provides an overview of the effects of the six individual information sharing strategies on all three key performance indicators.

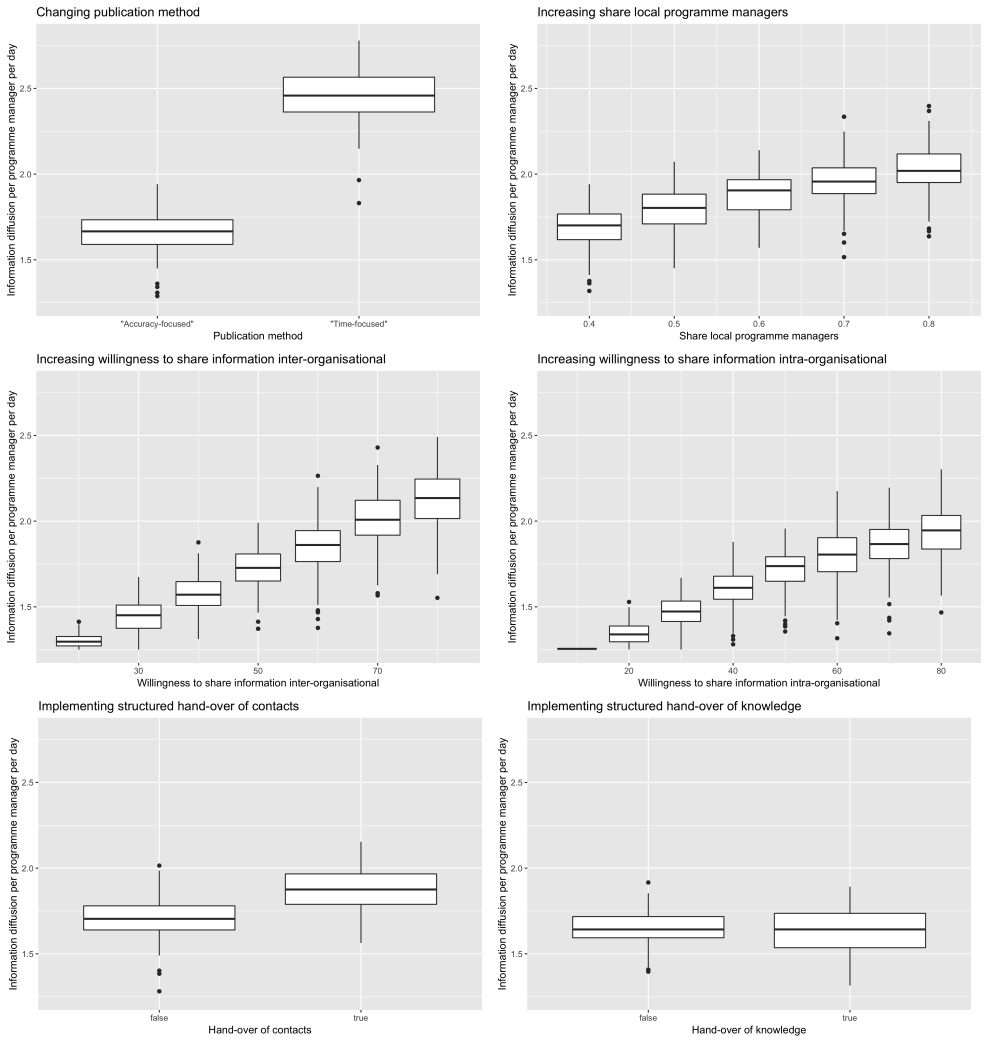


**Figure 8.1:** This figure shows the behaviour of the effect of the six evaluated information sharing strategies on the diffusion of information. The strategies are displayed in order of effectiveness based on the Bangladesh-Myanmar displacement crises. The plot shown in the top left of the figure shows the behaviour of the strategy that is most effective: change publication method from accuracy-focused to time-focused. The plot in the bottom right shows the effect of implementing structured hand-overs of knowledge, this strategy is not effective in increasing information diffusion.

The plot shown in the top left of the figure 8.1 shows the behaviour of the strategy that is most effective in increasing the diffusion of information: changing publication method from accuracy-focused to time-focused. Going over the effects of the strategies on the relief gap, as shown in appendix I, one sees that changing publication method is the only strategy that has a significant decreases the relief gap. Moreover, changing publication method is also the only strategy that significantly decreases the number of days programme managers need to provide the level of information diffusion and realise the relief gap shown in the previous figures. This effect can also be observed in figure 7.9. Changing publication method from accuracy-focused to time-focused enables less programme managers to diffuse more information. This happens while the relief gap remains constant.

Increasing the share of local programme managers is the second most effective strategy to increase the diffusion of information. Increasing the share of local programme managers from 50% to 80% increase the number of information items that a programme managers shares per day with about 0.25. This strategy has no signi-

ficant effect on the other KPIs.

Increasing inter-organisational willingness to share information is more effective once compared to increasing intra-organisational willingness to share. This statement is supported by both figure 8.1 and figure 7.6. The difference between the effectiveness of these strategies only increases as the number of organisations increases. If more organisations are active in a disaster it becomes even more favourable to increase inter-organisational willingness to share in comparison with intra-organisational willingness to share information. Neither strategies change the total relief gap or total days worked significantly. Set out to the other strategies the willingness to share information diffusion strategies are the third and fourth most effective strategies.

Handing over contacts at the end of a deployment is more effective than handing over knowledge. Yet, this strategy is less effective compared to the strategies discussed previously. Neither the handing-over contacts strategy nor the handing-over knowledge strategy change the total relief gap or total days worked significantly. Moreover, handing-over knowledge does not increase the amount of information diffused at all. As a result it is concluded that handing-over knowledge is the least effective strategy. According to this model that is parametrised for the Bangladesh-Myanmar displacement crisis, it is not effective.

## 8.3 COMPREHENSIVE STRATEGIES

The preceding paragraphs discussed the wide range of effects that the individual strategies have on the behaviour of the system. These results suggest that different individual strategies can be effective to increase information diffusion. At this point, however, it is not possible to make any statement about the combined effect of the strategies.

Potentially, the individual strategies could enforce or dampen each others effects. It is also possible that the individual strategies do not have any re-enforcing or dampening effect and that the strategies could be seen as independent options. The following paragraph discusses which combinations of strategies, the so called comprehensive strategies, are evaluated in this study.

### 8.3.1 Design of experiments

Based on results of the experiments discussed in the preceding paragraphs a selection is made of the strategies that will be evaluated in combination with each other. The strategies of which combinations are tested are changing publication method, increasing the share of local programme managers and the focus of the willingness to share information strategy. The latter refers to the dilemma between choosing between a situation where the willingness to share information between organisations is high, but the willingness to share information with-in organisations is low vis-a-vis a situation where the opposite is true, the willingness to share information within organisations is high but the the willingness to share information between organisations is low.

As a result, one should choose between:

- Near real-time or highly accurate information products
- Locally staffed or multinational teams
- Inward focused or outward focused organisations

Combining these choices results in eight different strategy combinations or comprehensive strategies. Each of these combinations is replicated 50 times. The results are analysed using the same methods as used for the individual strategies.

### 8.3.2 Analysis effects comprehensive strategies

Figure 8.2 shows the effect of the eight different comprehensive strategies on the diffusion of information. This figure shows that a locally staffed team, with an outward focused organisation that produces near real-time information products is most effective in diffusing information. The comprehensive strategy that is least effective in diffusing information is exactly the opposite strategy. This strategy is represented by a multinational team, with an inward focused organisation that produces highly accurate information products.

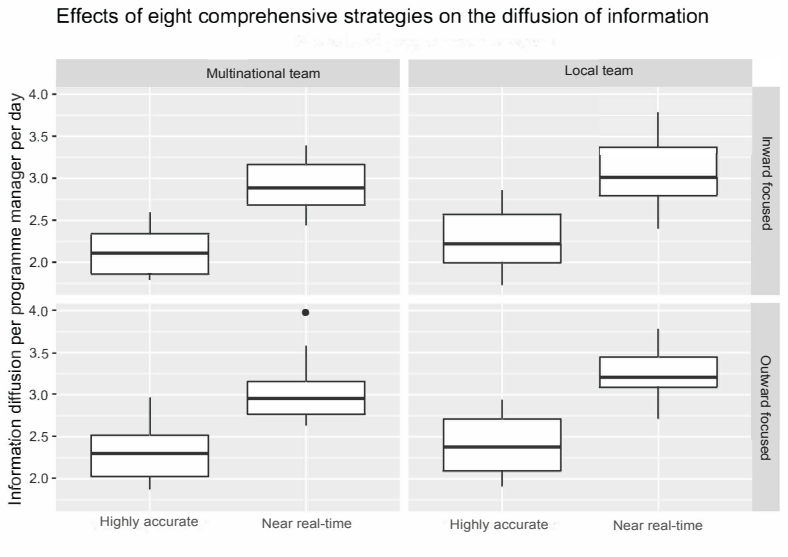


**Figure 8.2:** The behaviour of the effect of the eight comprehensive strategies on the diffusion of information. The horizontal axis in this figure shows the share of local programme managers. The vertical axis shows whether the organisation is inward focused or outward focused. The inner axes show the effect of accuracy-focused publication (left) and time-focused publication (right). This figure shows that a locally staffed team, with an outward focused organisations that produces near real-time information products is most effective in diffusing information.

Figure 8.3 shows the effect of the eight different comprehensive strategies on the relief gap. All the boxes in this plot overlap. Therefore, no difference can be claimed based on this analysis. The comprehensive strategies do not have a significant effect on the relief gap.

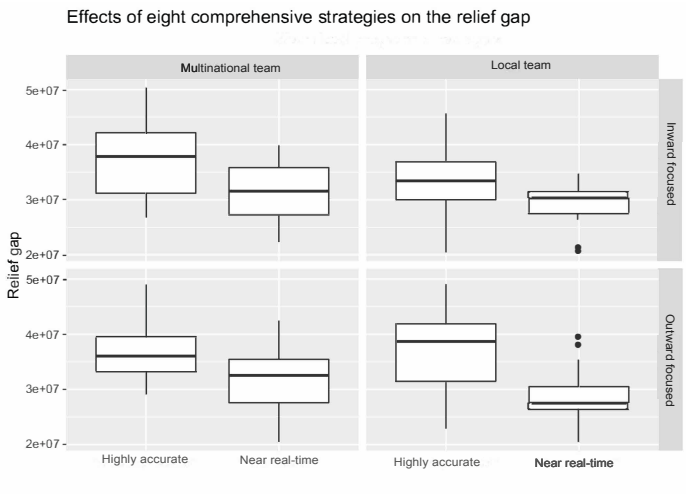


**Figure 8.3:** The effect of the eight different comprehensive strategies on the relief gap. The comprehensive strategies do not have a significant effect on this KPI.

Figure 8.4 shows the effect of the eight different comprehensive strategies on the days worked KPI. As in the previous figure, the boxes in this figure all overlap. As a result, no significant effect can be claimed. None of the comprehensive strategies change the relief gap and days worked KPIs significantly.

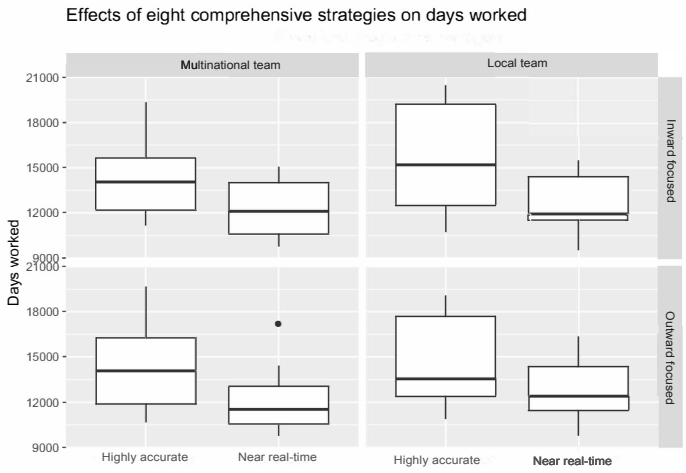


**Figure 8.4:** The effect of the eight different comprehensive strategies on the number of days worked. The comprehensive strategies do not have a significant effect on this KPI.

## 8.4 CONCLUSION

Together with chapters 6 and 7, this chapter aims to answer the question of what the effect of information sharing strategies are on information diffusion in complex emergencies. This chapter concludes that the developed ABM comes closer to the reality of hygiene kit distribution in Bangladesh and is more suitable to evaluate information sharing strategies than other models, including those of Altay and Pal and Bateman and Gralla.

The model results reaffirm that the moment, locations and number of shocks observed in a disaster influence information diffusion and the number of days programme managers have to work. Moreover, the results reconfirm that representing

information sharing by a combination of social network based sharing and random search sharing influences the behaviour of the model and the outcomes of the evaluations. This study can not confirm that the added structure leads to different outcomes in the observed relief gap or total days worked between not sharing and the reference scenario. The complexity of the assumptions that govern how information leads to the planning of relief activities is too limited to observe significant results for this effect on the latter two KPIs.

In addition, analysis and comparison of the effects of six individual strategies, lets us conclude that there are multiple options to increase the diffusion of information. Five of the six individual information sharing strategies increase information diffusion significantly. *changing publication method* from accuracy-focused to time-focused is the most effective individual information sharing strategy. This strategy is also the only strategy that shows a significant effect on the relief gap and days worked KPIs. Changing publication method from accuracy-focused to time-focused enables less programme managers to diffuse more information. This happens while the relief gap remains constant.

This chapter also concludes that *increasing the share of local programme managers* in a disaster is the second most effective strategy to increase the diffusion of information. Increasing *inter-organisational willingness to share information* is more effective once compared to *increasing intra-organisational willingness to share*. The difference between the effectiveness of these strategies only increases as the number of organisations increases. Handing over contacts at the end of a deployment is more effective than handing over knowledge. Yet, this strategy is less effective compared to the strategies discussed previously. The study also shows that *handing-over knowledge* is not effective strategy to increase information diffusion about hygiene kit distribution in the Bangladesh-Myanmar displacement crisis.

Finally, analysis of the effects of eight different strategy combinations or comprehensive strategies does not suggest that there is an information diffusion enforcing or dampening effect between the strategies. Implementation of the strategies will not lead to effects that are more than the sum of the individual strategies, nor will the effect be less that this sum. As a result, a locally staffed team, with an outward focused organisation that produces near real-time information products is most effective in diffusing information. It is unclear what the effect of this strategy is on the observed total relief gap and the number of days worked in a disaster, as none of the comprehensive strategies change the relief gap and days worked KPIs significantly.

**Overview 8.4.1: Main results analysis**

- A locally staffed team, with an outward focused organisation that produces near real-time information products is most effective in diffusing information.
- It is unclear what the effect of this strategy is on the observed total relief gap and the number of days worked in a disaster, as none of the comprehensive strategies change the relief gap and days worked KPIs significantly.
- There are multiple options to increase the diffusion of information. Five of the six individual information sharing strategies increase information diffusion significantly.
- Changing publication method from accuracy-focused to time-focused enables less programme managers to diffuse more information, while the relief gap remains constant. This is the most effective individual information sharing strategy.
- Handing-over knowledge does not increase the amount of information diffused.
- Increasing inter-organisational willingness to share information is more effective in diffusing information than increasing intra-organisational willingness to share information. Increasing inter-organisational willingness to share information becomes even more favourable as more organisation are active in the disaster.

# 9 VALIDATION

The previous chapters discussed the system description, conceptualisation, experimentation and interpretation of the model results. These chapters pertain to the conceptualisation, specification and experimentation steps of the modelling cycle used for this study. These three steps have been based on the Bangladesh-Myanmar case study. This chapter revolves around the question of how the findings based on the case study can be generalised to other complex emergencies.

The sub-question belonging to this chapter is formulated as:

**How could the outcomes of this study be generalised to other complex emergencies?**

To answer this question, paragraph 9.1 first discusses the design of the validation and the methods that are used to assess the generalisability of the outcomes. Paragraph 9.2 presents the outcomes of the validation. Subsequently, paragraph 9.3 is concerned with the implications of the validation. It interprets the outcomes of the validation in light of the agent based model and discusses what the outcomes mean in the broader context of the study. The chapter is wrapped up with a conclusion in paragraph 9.4. This final paragraph reiterates the answers to the sub-question.

## 9.1 VALIDATION SET-UP

Three types of validation methods are used to assess the generalisability of the outcomes presented in the previous chapters of this study. The fist method is validation by expert consultation in semi-structured interviews. The second method is validation by focus group discussion. Both methods are variants of face validation. The third type is structural validation. Table 9.1 presents details about the individuals that have been consulted for the validation. More details on the set-up and approach used for the focus group discussion can be found in appendix K.

## 9.2 VALIDATION

The face validation focuses on four aspects of the study. The first aspect is the system description. Two humanitarian professionals are asked on whether they recognise the barriers and driver and how the description of the case study selected for this study differs from other complex emergencies. The second aspect is the conceptual diagram and its suitability to capture the important concepts of information sharing in a complex disaster. Third aspect are the critical assumptions that underlie the ABM. The final aspect are the model results, specifically the effectiveness of the six individual information sharing strategies.

### 9.2.1 Validation of system description

Once confronted with the system description of information sharing in the Bangladesh-Myanmar displacement crisis, the interviewee sees similarities and differences between

| | Function | Organisation | Deployed | Session |
|---|---|---|---|---|
| 1 | Operational logistics coordinator | Médecins Sans Frontières International | BG | Interview |
| 2 | Information management officer | Unicef International | BG | Interview |
| 4 | Information management officer | 510<br>Red Cross NL | Other | Workshop |
| 5 | Information management officer | Disaster response unite<br>Red Cross NL | Other | Workshop |
| 6 | Community engagement officer | 510<br>Red Cross NL | Other | Workshop |
| 7 | Human centred design officer | 510<br>Red Cross NL | Other | Workshop |
| 8 | Policy advisor / project lead | 510<br>Red Cross NL | Other | Workshop |
| 9 | Software developer | 510<br>Red Cross NL | None | Workshop |
| 10 | GIS specialist (volunteer) | 510<br>Red Cross NL | None | Workshop |
| 11 | Online volunteering officer (volunteer) | 510<br>Red Cross NL | None | Workshop |

**Table 9.1:** Interviewees consulted for validation

how they experienced the crisis. Appendix J provides a more detailed description of their reflections.

Interviewee 1 mentioned that his organisation was already present in the refugee camps in Bangladesh before the 2017 influx and that this facilitates better information sharing. This is one of the drivers mentioned in the system description. This interviewee also mentioned the good networking opportunities especially with the government in Dhaka, Bangladesh's capital as additional driver. This driver is not mentioned in the system description nor is the government included as an agent in the model. Interviewee 1, does not see the absence of OCHA as a neutral and experience partner as a very important barrier. According to him, there is always another organisation that takes the lead if OCHA is not present. He does, however, emphasise that the Bangladesh-Myanmar displacement crisis is very political and that this influences information sharing.

Both interviewees mention that information sharing with regards to hygiene kit distribution differs from information sharing that pertains to other type of relief activities. Whether information is shared depends on the nature and content of the data. This is the case for information sharing in general and for increased information sharing that is the result of an implemented strategy. As an example, sharing of information related to hygiene kit distribution might increase as a result of an increase in local staff. However, this does not mean that sharing patient data will also increase as a result of that same strategy.

### 9.2.2 Validation of conceptualisation

Once presented with the conceptual diagrams made for this study, the interviewees recognised aspects of the processes from their own organisations. An example is the idea of disasters evolving as sets of shocks. Interviewees also mentioned differences between the conceptualisation developed for this study and the image they created

based on their experiences. Non of the interviewees that were presented with the question showed that they were able to systemically assess the generalisablity of the conceptual model. They did not state that the conceptual diagrams were wrong or right. Instead, they mentioned that they were not able to make any substantive comment about diagrams in the limited time that was available.

### 9.2.3 Validation of critical assumptions

The discussion on the assumptions in the focus group discussion mainly revolved around the assumption about the accuracy of assessments. Once confronted with the assumption that the overall accuracy of the assessments is represented by a normal distribution, the participants mentioned that this is also the distribution they would think of. There were, however, also reasons discussed that would justify a different distribution. A participant explained cases in which needs are structurally overestimated.

Another point of discussion in the focus group discussion was the use of information as strategic asset. As highlighted by the participants, some parties may purposely share biased information. Moreover, actors may share in-factual or false information. The model assumes that such sort strategic behaviour is absent.

Once confronted with the assumption that there is no difference in the ability between local and international staff in terms of executing assessments, the participants shared that they think it is a fair assumption. Both for the accuracy of the assessment and for time needed to do an assessment there is no difference between international and local delegates.

### 9.2.4 Validation of model results

Recurring element in the focus group discussion was the observation that response operations in humanitarian disasters are in general very context specific. The researcher and its audience should consider that, as one of the participants puts it: *"We are talking about data in an industry that was previously only pertaining to the skill set of humans involved in the procedures"*.

One of the participants discussed his experience with the share of local and international delegates in a response operation at Saint Martin. This professional shared that he thinks that increasing the share of local staff would not have been very beneficial in this situation especially because of cultural and political reasons. More participants highlighted the importance of cultural and political aspects. These dimensions are not included in the model.

Related to the changing publication method strategy, one of the participants shared that *"the question of the required sample size is one of the points that is most often discussed in the field"*. Her colleagues frequently questioned whether a bigger sample size was needed or that the current one was big enough. The same professional shared that she thinks increasing willingness to share information inter-organisationaly is especially a difficult strategy for the Red Cross because of political issues.

While being confronted with the effectiveness of the individual strategies, interviewee 1 expressed his experience with regards to the dissimilarity in which local staff and international staff is susceptible to pressure of the local community. This humanitarian professional also shared that he thinks that in his organisation increasing intra-organisational information sharing offers less room for improvement

once compared to increasing inter-organisational information sharing.

Once presented with the effectiveness of the six individual strategies, interviewee 2 mentioned that she expects that strategies that are less specific to the nature of the information are more likely to be effective in a general sense then others. According to her reasoning, increasing the share of local programme managers and the two hand-over strategies could be effective for a wider range of relief activities. In contrast, whether changing publication method and increasing willingness to share information are effective, is more dependent on the difference between hygiene kit distribution and the relief activity where is generalised to.

**Figure 9.1:** Impression of the validation workshop organised at the Red Cross.

### 9.2.5 Structural validation

To provide a deeper analysis of the effects of the information sharing strategies, chapter 7 discussed a boundary test. This test is an example of a method that evaluates the relation between the model and information diffusion in the real world. The boundary test in 7 simulated disasters where no information is shared at all. Humanitarians in disasters with zero information sharing are, as expected, still capable of bringing relief to people in need. It is also concluded that we can not confirm that the structure added by changing the sharing assumption leads to different outcomes in the observed relief gap or total days worked. Therefore, the model's understanding of how information leads to the planning of relief activities is too limited. M. To evaluate the effects of the assumptions, two additional experiments are performed as part of the structural validation. The structural validation is discussed in greater detail in appendix M.

The first experiment provides a sensitivity analysis of the assessment length variable. The objective of this effort is to test whether an equal number of shorter assessments effects the outcome of the model. Based on this experiment it is concluded that, because the assessment length influences the number of assessments

that are conducted, the outcome of the model is sensitive for changes in assessment length. Due to the construction of the model it is not possible to test the dedicated effect of starting the assessments earlier without getting more assessments.

The other additional experiment revolves around the assumption that accuracy of the assessment can be represented by a normal distribution with a mean that corresponds to the correct value. This experiment tests the effect of replacing the normal distribution with a skewed normal distribution, a bimodal distribution and a skewed bimodal distribution. The outcome of this experiment strengthens the belief that the normal distribution assumption is justified. The model yields largely similar results when the accuracy is represented by a normal distribution, compared to when the accuracy is represented by an alternative distribution.

## 9.3 INTERPRETATION AND IMPLICATIONS OF VALIDATION

From the preceding paragraphs, it might have become clear that a substantial part of the comments made by the interviewees and the focus group participants does not have a direct relation to subjects under study in this thesis. Both the interviewees, focus groups participants and the researcher agree that cultural, historical, financial and social dimensions of the strategies are essential aspects in a full evaluation of the strategies. These dimensions are, however, not part of the evaluation conducted in this study as they are, as discussed in earlier chapters, purposeful left outside the scope of this research on information diffusion. Based on the response of the interviewees, the observations registered in the focus group discussion and the outcome of the structural validation, five statements are formed about the generalisability of the outcomes of this study. These statements resemble the notion that the validation methods used in this chapter do not yield exact answers. In contrast, they gives impressions of the points that should be taken in to consideration once generalisations are made based on this studies findings.

The first statement is that before a generalisation can be made about effects of the information sharing strategies, one should reflect on the differences between information on hygiene kit distribution and the nature of information to which the generalisation is made. This relates to the point made by the interviewees and follows the same line of reasoning that is used to motivate the use of the decision-centric paradigm. The effects of the information sharing strategies are not likely to apply in exactly the same manner for information about relief activities that are more sensitive then hygiene kit distribution.

The second statement pertains to the comments made by interviewee 2. She expressed that strategies that are less specific to the nature of the information are more likely to be effective strategies in a general sense then the others. Increasing the share of local programme managers and the two hand-over strategies are strategies that could be effective for a wider range of relief activities. In contrast, whether changing publication method and increasing willingness to share information, are effective is more dependent on the difference between the relief activity and hygiene kit distribution.

The third statement is that when pursuing a generalisation, one should compare the parametrisation of the model used for the Bangladesh-Myanmar case study, as can be found in appendix G, to a parametrisation of the situation where is generalised to. As long as the parametrisation is changed accordingly, the agent based model can be valid to a wide range of complex disasters. In case the parametrisations differ, additional modelling research is advised to assess whether the general-

isation is valid. Needless to say, one should always consider other options that are available to make statements about the effects of an information sharing strategy and never solely based decisions on one model.

The fourth statement is that the outcomes of additional experiments for structural validation strengthen the belief that the normal distribution assumption is justified. When pursuing a generalisation, one should consult the list of assumptions as included in appendix F and evaluate whether these assumptions are also justified in the context of the generalisation.

The final statement is that the validation executed as part of this study, showed unable to validate substantial parts of this research. Some questions, such as the questions related to the conceptual diagrams showed to be too difficult to answer properly in a limited time frame. Other questions, such as whether an equal number of shorter assessments effects the outcome of the study, could not be answered with the current version of the model. Additional validation research is needed to assess the generalisability of the results. The process by which information leads to planning of relief activities and, as a result, effects the observed relief gap and days needed for the response, is an important direction for this research.

## 9.4 CONCLUSION

This chapter forms the fourth and final part of the modelling cycle used for this study. Where the three previous steps have been based on the Bangladesh-Myanmar case study does this chapter revolve around the question of how the findings based on the case study can be generalised to other complex emergencies. To answer this question two types of face validation methods are conducted with the help of 11 respondents. Moreover, additional experiments are performed for structural validation.

Based on the validation, five statements are made that form the answer to the fourth sub-question. Firstly, if one were to generalise the effects of the information sharing strategies one should reflect on the differences between information on hygiene kit distribution and the nature of the information to which the generalisation is made. Secondly, one should be aware that strategies that are less specific to the nature of the information are more likely to be effective strategies in a general sense then others. Thirdly, one should consider that the agent based model can be valid for a wide range of complex emergencies, but that comparison of the parametrisation of the model to a parametrisation of the situation where is generalised to, is required before making the generalisation. Fourthly, the outcomes of additional experiments for structural validation strengthen the belief that the normal distribution assumption is justified. When pursuing a generalisation, one should consult the list of assumptions made for the construction of this ABM and evaluate whether these assumptions are also justified in the context of the generalisation. Finally, one should be aware that the executed validation showed unable to validate substantial parts of this study and that more research is needed assess generalisability of the results. The next chapter discusses the results of the study.

# 10 DISCUSSION

The results of the modelling study presented in the previous chapter are discussed and reflected upon in this chapter. In this research, information sharing strategies are evaluated using an agent based model. The model has been developed after analysing the Bangladesh-Myanmar displacement crisis as a case study. This research and the model, however, are not perfect. The study and the developed model have limitations, amongst others because the model is based upon numerous assumptions. Furthermore, it is to be discussed to what extent the model and the conclusions about the effectiveness of the strategies can be considered valid, considering the fact that this research only contains partial validation.

This study is discussed in two steps. First, paragraph 10.1 discusses the limitations of the study. This involves reflecting on the model's critical assumptions, discussing what the model can and cannot do and also discussing the inherent limitations of the research design. The second step is a reflection on the chosen research approach. Therefore, paragraph 10.2 first discusses the suitability of agent based modelling. This paragraph also compares this study's modelling approach to the approaches of Altay and Pal and Bateman and Gralla and defends the statement that this study provides the most generic model-based approach to evaluate information sharing strategies in complex, humanitarian disasters. The concluding paragraph reiterates the main points made in the chapter.

## 10.1 LIMITATION OF THE STUDY

This discussion is structured in a divergent manner. It starts by discussing the aspect that could be seen as the centre of the study, the critical assumptions that underlie the model.

### 10.1.1 Critical assumptions

This sub-paragraph discusses a number of assumptions that are critical to the behaviour of the model and the societal outcomes of this study. Appendix F provides a longer list of assumptions. In addition, appendix G gives an overview of the parametrisation of the variables used in the model. As the assumptions define under which circumstance the outcomes of this study hold, discussing them forms a fundamental step of this discussion. This discussion, however, is not exhaustive. There are many more assumptions which, depending on your perspective, could be even more critical.

One critical assumption is the homogeneity of information. Although, this study is the first study to provide information items with a recency attribute, information items are still relative homogeneous once compared to information products in reality. In the model, once a programme manager receives information about a location where he already has information about, the most recent information item is chosen. In reality this might be different. One may accept information based on the reputation of the source, based on how trustworthy one may deem an information

product, or based on whether other organisations use the information.

In a same way are the humanitarian organisations, the individual actors and their social networks rather homogeneous and free of any strategic motive. As was also brought up during the validation workshop, in reality, biases may exist due to conflicting interests of relief organisations. All organisations may want to showcase their success even if they are difficult to attribute to one or maybe even to the humanitarian relief operations as a whole. In addition, some organisations in a relief organisation have interests that conflict with those of others. Especially in complex emergencies information is power. For strategic reasons, biased or false information might be shared and humanitarian organisations' impartiality may be violated. Strategic motives might also influence the decisions of individual humanitarians. An individual might, for example, overstate his accomplishments including the needs and activities it oversaw to advance his career. In addition, different social networks may exist for local and international programme managers. The developed model does not do justice to this reality. It is left to others to take up the research torch and, for example, add game theory elements to their research in order to further advance the understanding of these forces.

One assumption that also should be considered revolves around the infrastructure by which information is shared. As discussed in chapter 2, this study characterises the data ecosystem on five dimensions with corresponding characteristics: actors, data supply, data infrastructure, data demand and data ecosystem governance. While you could argue that the model contains elements of the actors, data supply, data demand and data ecosystem governance dimensions, its infrastructure is assumed to be monotonous. However, as discussed more elaborately by van den Homberg and Susha (2018), the status of infrastructure affects the way in which information diffuses in a disaster. This dimension is left for future research.

A final critical assumption is that the relief activities are solely based on needs information. In the model, humanitarians travel to the place with the highest relief gap where no other humanitarians already work. In reality, humanitarians might go to a place because they know that place well, because the needs of the people in that place receive a lot of media attention, because someone else told them to go there or because this is the place where they arrived or currently are. Why put effort in finding the place with the highest needs if the people next to you are starving, one could ask. The next paragraph discusses a model limitation that relates to this critical assumption.

### 10.1.2 Limitations of the model

The processes by which information leads to planning of relief activities provide an important limitation of the current model. In the developed model, the programme manager makes decisions based on all the information he has in his memory. The programme manager chooses the location with the highest need as the location where to start an activity. In reality, the decision-making process might be less directly based on needs. It could very well be, that programme managers learn and adapt to the changing needs. This dynamic is not included in the model and functions as an example of how the model could be extended to make it more realistic.

Chapter 4 discussed how the ISCG and WASH sector divided the geographical area where refugees reside in to four areas and over 25 camps. The ABM developed for this study is build using the GIS extension for ABM. As a result the camps or blocks in the crises are represented by one patch or pixel in the model. This approach is chosen to increase the ontological comparability and communicative value of the model. Yet, the extend to which this is pursued is limited. While in

the model, programme managers work in one camp at a time and activities are deployed per camp, their camps are not managed by one organisation. Everyone may perform assessments and start relief operations in every camp. In addition, the camps are represented by rectangles, sharing each others borders in a large grid. In reality, however, camps have focal agencies accountable for the management and overseeing the needs and activities in the camps. Moreover, camps are not all located next to each other, nor are they of equal size. Some camps are rather isolated as is shown in figure 4.3. The GIS extension offers possibilities to overcome this limitation and could form a good next step to extend the model in order to further increase the ontological comparability and communicative value of the model.

The developed model contains a substantial number of procedures, agents and links. The procedures that handle information exchange and movement of agents contain processes that are computationally intensive. As a result, the current model reaches the limitations of running Netlogo on one machine in a reasonable time. The experiments executed for this study required multiple days to run even while the number of organisations and thus agents was relatively low once compared with reality. This limitation could be addressed by making the code more efficient, potentially by decreasing the complexity of the information exchange procedures and replacing recursive functions in the movement procedures. Running the model in a distributed manner on a cluster would increase the number of runs that can be executed even further. Not only would this facilitate the further implementation of the GIS extension, the higher number of experiments enables a more extensive data analysis. This more extensive data analysis could, for example, focus on the outliers in the output data. Understanding what type of disaster with what combination of external factors and strategies leads to an ineffective response is another opportunity for future research.

### 10.1.3 Limitations of research design

This research has been conducted at The Netherlands Red Cross. In addition, a range of humanitarian professionals have been interviewed and consulted to develop the model. Yet, once informally explaining the research design there was one recurring question: "Why don't you go to the disaster site yourself?". Although, the researcher has experienced the complexities of working during a crisis situation at head quarters level, this does not compare to the extensive pressure and inherently different nature of being deployed to a disaster site yourself. As a result, it is advised to execute model extension in parallel with extensive field research in any future work related to this model. Amongst others, the parametrisation of the model can largely benefit from such an approach.

The partial validation that is executed for this study is a second limitation of the used research design. For the face validation part of the validation, a group of 11 humanitarians is consulted. It must be noted that one of the interviewees both supplied input in the round of interviews for the system description and the validation. Involving experts in two phases of a research project is not fully in accordance with academic philosophy of consultation of independent experts. Additional research is advised to assess the effect of this limitation and to explore the effects of information sharing strategies with other research methods. An example of a research project that could complement the validation of this study is an analysis of HR data. Interviewing chief human resource officers and analysing HR data of multiple humanitarian organisations could enable a comparison of HR strategies. The outcome could sketch the outline of an image that expresses the effects of having various numbers of locally sourced staff.

## 10.2 REFLECTION ON THE USED APPROACH

This modelling study belongs to the first group of studies to use agent based modelling to evaluate information sharing strategies in humanitarian disasters. This paragraph aims to contribute to the academic debate about how modelling and simulation can be used to increase our understanding of information sharing and information diffusion in the humanitarian context. To do this, sub-paragraph 10.2.1 first reflects on the suitability of agent based modelling for information diffusion research. Subsequently, sub-paragraph 10.2.2 compares the approach used for this study to that used by other scholars. Amongst others, it defends the statement that this study is able to evaluate strategies that have a level of complexity that could not be apprehended by the existing models.

### 10.2.1 Suitability agent based modelling

Chapter 3 discussed the research design that is used to fill the knowledge gap that is identified based on the literature review presented in chapter 2. Moreover, chapter 3 discussed other options to evaluate information sharing strategies. Specifically, analysis of big unstructured (social media) data, analysis of beacon data and field research focused on interviewing humanitarian responders. As explained in chapter 3, the choice to use modelling and simulation is motivated from a methodological perspective by the fact that few research has been done in this area. Better understanding the suitability of modelling research in this domain provides us with a better understanding of the available research tools to evaluate information sharing strategies.

Humanitarian disasters are characterised by their inherent complex and sometimes chaotic nature. As individuals active in these disasters are under constant pressure, decisions need to be made in short time frames and with limited and often partly non-digital information. It is challenging to get an accurate overview of how information is shared in these disasters when only social media data or beacon data is analysed. In addition, humanitarians find it hard to attribute their decisions to one information product that they have seen, especially if this attribution is done days after the decision. By conducting modelling and simulation research, one can derive patterns from the decisions-making processes, strategy choices and the behaviour of individuals in a disaster. Making assumptions about the processes and behaviour allows us to understand the implications of their choices.

Agent based modelling proved to be especially useful to analyse information sharing strategies because of its bottom up approach. The results presented in chapter 7 show the effect of relatively small changes in the parametrisation of the model. Figure 7.1 and figure 7.2, for example, show that information diffusion and the total relief gap can vary substantially based on the moment at which a shock strikes.

While the approach showed clear advantages it also showed limitations. These limitations are not new and revolve around the arguments that models, and agent based models in particular, rely on a great number of assumptions. and These assumptions, and the models, can be difficult to understand and validate, partly because they do not necessary have a direct representation in reality. The KPIs used for this study provide a concrete example of the mentioned limitation. Validating the study is difficult because it is almost impossible to objectively measure the total information diffused of total a relief gap in a disaster.

Going over the advantages and limitations of the approaches, it is tempting to argue that it is best to use combinations of both approaches and choose hybrid research designs. In such designs, analyses of social media and beacon data are

used by researchers that have extensive knowledge about the complexities in the field to develop models that fully capture our current understanding of the system. Scholars that draw this conclusion are, however, advised to consider the status quo of modelling and simulation research in the humanitarian sector. While in other sectors, such as the energy sector, one often hears leaders say that they do not need extra models because they already have so many of them that it is too difficult to understand which serves which purpose, the opposite seems true for the humanitarian sector.

Modelling research for information sharing evaluation in humanitarian response is still in its infancy. Less then 5 years ago, Altay and Pal published the first paper that used a model-based approach to evaluate the effects of various information sharing strategies. Until today Altay and Pal framework for information diffusion in humanitarian disasters and its relating agent based model can be seen as the state-of-the-art in model-based evaluation of information sharing strategies. Bateman and Gralla evaluated different information sharing strategies in a different context. Besides these modifications, they used the framework provided by Altay and Pal. As a result, this study offers the first alternative framework to the one introduced by Altay and Pal. This paragraph, therefore, ends with the statement that the current knowledge base cannot only benefit from studies that combine modelling with analysis of real world data and field research. Given the limited number of studies done in this area, the academic knowledge base would also benefit from studies that solely aim to understand how information sharing in humanitarian disasters can be better conceptualised, modelled and simulated. Appendix N discusses two directions for future research that use the approach proposed in this study. Research in these directions can help to increase our understanding of information diffusion in sudden-onset disasters and about the effects of climate shocks.

### 10.2.2 Comparison earlier ABM studies

A difference between the work of Bateman and Gralla and this study is that the studies of the fellow researchers evaluate information sharing strategies in humanitarian disasters in sudden-onset and not in slow-onset, man-made emergencies. As discussed in chapter 2, sudden on-set and complex emergencies differ in nature but can both be seen as instances of a humanitarian disaster. It should be kept in mind that in relation to the work of the other scholars, the construction and parametrisation of the model developed for this study is more tailored towards complex emergencies.

Compared to the studies performed by Altay and Pal and Bateman and Gralla this study is the first study to model a number of concepts that are, according to the academic literature on humanitarian relief, more realistic. These are, first, the social networks that are used to share information and second, the continually evolving information landscape that is a consequence of series of need altering shocks at the one hand and rotating humanitarians at the other hand. Analysis discussed in chapter 8 concluded that the model results reaffirm that the moment, locations and number of shocks observed in a disaster influence information diffusion and the number of days programme managers have to work. Moreover, the results reconfirm that representing information sharing by a combination of social network based sharing and random search sharing influences the outcomes of the evaluations.

As the developed model gives a deeper and more accurate representation of reality compared to the other models, this study poses that, in a general sense, the model developed for this study is more suitable to evaluate information sharing

strategies then the models of Altay and Pal and Bateman and Gralla.

The expressed statement is supported by the fact that the models of Altay and Pal and Bateman and Gralla, conceptually, can be seen as instances of the model developed for this study. Indeed, the developed model can be parameterised to evaluate strategies in a disaster with just one shock, no rotation and only information sharing that is represented by a random search. This model corresponds the models developed by Altay and Pal and Bateman and Gralla.

That the developed model is more suitable to evaluate information sharing strategies in a general sense does note exclude the possibility that the models of Altay and Pal and Bateman and Gralla are more suitable in specific situations. This is a result of the fact that the models all evaluate different information sharing strategies. As example, the model of Altay and Pal amongst others evaluates the effects of increase trust among agents and changing the role for the cluster leads. As this study does not evaluate the latter two strategies, Altay and Pal's model is for obvious reasons more suitable then this study's model.

For a significant number of analysed assumptions and strategies, this study cannot confirm that the changes in information diffusion lead to significantly different outcomes in the observed relief gap or total days worked. This, in contrast to the models developed by Altay and Pal and Bateman and Gralla, which 'total time' indicator is reported to provide results that are significantly different. This study argues that a more detailed comparison between the models is needed to provide a judgement on why the other scholars are able to generate significant results on a KPI that measures the effectiveness of humanitarian response and this study is not. It could be that the assumptions of Altay and Pal and Bateman and Gralla that govern how information leads to the planning of relief activities are realistic. It could also be that this model's assumptions on how information is used for decision making comes closer to reality. To facilitate a more thorough comparison, this study's agent based model is made publicly available on this Github page: https://github.com/JasperCM/information-diffusion.

Increasing willingness to share information is the only strategy evaluated by all three models. Though, what kind of willingness to share information is evaluated differs between the two studies. The results obtained by Altay and Pal suggest that *"willingness to exchange information has more of an impact on information diffusion than the existence of an information hub"*. In fact, it is the most effective strategy to increase information diffusion in their model. Bateman and Gralla conclude the following: *[Surprisingly,] "willingness to share information does not, in this model, make a significant impact on information acquisition in the focal organization. However, this model focuses primarily on a single organization, rather than the humanitarian system as a whole in a response. Both in practice and in research [...], information sharing is emphasized for the impact it can have across organizations, when every actor in the system opts to increase their willingness to share. The results from this model should not be taken as justification for refusing to share information in a response. Instead, the results simply show that increasing willingness to share does not increase willingness to share does not increase a single organization's own information-seeking capabilities in the environment we modeled"*.

This study examined both inter-organisational and intra-organisational information sharing strategies. It is therefore possible to reflect on the outcomes of both previously published studies. The results of this study suggest that increasing inter-organisational willingness to share information is more effective once compared to increasing intra-organisational willingness to share. This statement is supported by both figure 8.1 and figure 7.6. The difference between the effectiveness of these strategies only increases as the number of organisations increases. If more organ-

isations are active in a disaster it becomes even more favourable to increase inter-organisational willingness to share in comparison with intra-organisational willingness to share information. While increasing inter-organisational willingness to share information is more effective in diffusing information then intra-organisational information sharing, it is not the most effective strategy in this evaluation. Both changing publication method from accuracy-focused to time-focused and increasing the share of local programme managers is more effective.

In addition to comparing the two willingness to share strategies, this study also evaluated a number of other strategies. Given that these strategies relate to either the social network of humanitarians or the non-monotonous nature of the information landscape, these strategies cannot be evaluated with the models of Altay and Pal and Bateman and Gralla. Among these strategies are the two most effective strategies: changing publication method and increasing the share of local programme managers.

## 10.3 CONCLUSION

This chapter provides a discussion of the results of this study. The first part discusses the homogeneity of information, organisations, social networks and infrastructure and the absence of strategic behaviour as examples of the model's critical assumptions. It also highlights that the processes by which information leads to planning of relief activities is an important limitation of the current model. Subsequently, it provides argumentation for the idea that Netlogo's GIS extension forms an appropriate method to overcome some of the limitations of the model. Currently, this method is only implemented partially. In addition, the the current model reaches the limitations of running Netlogo on one machine in a reasonable time. Furthermore, the decision explains that field research was not part of the research design and provides an alternative to the partial validation that is executed for this study.

Reflection on the used approach in the second part of this chapter, leads to the observation that modelling research for information sharing evaluation in humanitarian response is still in its infancy. It is a field that can both benefit from specific modelling research as from hybrid research projects, that combines modelling research with more comprehensive data analysis and field research. From the perspective of analysing information sharing strategies, the agent based modelling school showed especially useful because of its bottom up approach.

Based on a comparison discussed in this chapter, the conclusion is drawn that the model belonging to this study provides a deeper and more accurate representation of reality then the models of Altay and Pal and Bateman and Gralla. As a result, this study is able to evaluate strategies that have a level of complexity that could not be apprehended by the existing models. It extends the knowledge base on model-based evaluation of information sharing strategies by providing the most generic model-based approach to evaluate information sharing strategies in complex, humanitarian disasters. Other researchers are encourage to extend this approach and explore how this approach can be used in other contexts.

# 11 CONCLUSION, RECOMMENDATIONS AND SUGGESTED FUTURE RESEARCH

This research started by emphasising the constant pressure under which the humanitarian system is operating. It also stated that this study aims to contribute to effective humanitarian responses by evaluating the effects of various information sharing strategies on the diffusion of information in complex emergencies. The previous chapters discussed the system description, conceptualisation, experimentation, interpretation and discussion of the results obtained in this study. This chapter aims to connect the objective of this research with the final outcomes by bringing all pieces of this study together.

To do so, this chapter starts by providing a short recap of the problem, the knowledge gap and the research design by which it is addressed. Subsequently, paragraph 11.2 discusses the answers to the sub-questions. Based on the answers to the sub-questions, an answer to the main research question is provided in paragraph 11.3. Subsequently, paragraph 11.5 and paragraph 11.4 mention the academic and societal contribution of this study. The later paragraph also discusses a number of recommendations for the 510 initiative and the humanitarian community in general. The last paragraph of this study suggests a number of directions for future research.

## 11.1 SYNOPSIS RESEARCH PROJECT

In a disaster, all actors are in need of information to determine their strategy, planning and operations. Obtaining information for decision-making is challenging (Gralla et al., 2015; Comes et al., 2015; van den Homberg, Monné & Spruit, 2018a). In most humanitarian organisations, information management officers work to collect relevant data and convert these into information products. One of their most important challenges is to create products that are useful in dynamic and uncertain contexts within a very short time (Comes et al., 2015). Humanitarian decision-makers that use these products are working in stressful, high-pressure conditions where information is often lacking, distorted or uncertain. These conditions are known to introduce or enforce biases (Comes, 2016).

Humanitarian organisations share information to prevent redundant data collection and avoid gaps and overlap in the relief activities that they commence. Increasing the number of times a piece of information is shared, or in other words, increasing the diffusion of information, can potentially counter these effects.

This research is performed at 510, the data initiative of the Red Cross. Enabling 510 and other humanitarian organisations that produce information to better understand how information diffuses in a disaster can help them to make humanitarian response more efficient. In addition, humanitarian organisations that use information for strategy, planning or operations can benefit from a better understanding of information diffusion. These humanitarians are often confronted with information gaps and information overloads at the same time. Moreover, they could rely on wrong, outdated or skewed information. Yet, as the amount of information that is produced exceeds the amount that is shared, it could very well be that one is closer to the information then he or she thinks. Understanding how choices in relief op-

erations effect the diffusion of information can help them to address these problems.

While Altay and Pal (2014) and Bateman and Gralla (2018) evaluated various strategies for information sharing using a model-based approach, their approach does not account for a number of dynamics that are reported to exist in reality. First, as discussed by Van de Walle, Comes, Meesters, van den Homberg et al. (2013), humanitarians in this day and age, face situations where decision problems and the information that is required to address them evolve highly dynamically. The information landscape is more volatile than ever before. The existing approaches for model-based evaluation of information sharing strategies do not reflect this non-monotonous behaviour of information needs. The effect of these contradicting views is both unclear for the context of sudden-onset disasters, the focus of the study conducted by Bateman2018EvaluatingResponse, as for the context of slow-onset disasters.

Secondly, to model the dynamics of an international response both Altay and Pal and Bateman and Gralla assume that searching for information can be represented by a random search. As amongst others discussed by Van de Walle and Comes (2015), especially in complex emergencies, the humanitarian community must work in a very fragmented information landscape, which is characterised by amongst others a strong role of individual networks. As the existing approaches for model-based evaluation of information sharing strategies represents information gathering as random search, it is currently unknown what the effects of information sharing strategies are while considering the strong role of social networks.

Finally, while some researchers evaluated the effect of information sharing strategies this area is largely untouched territory. A great number of strategies has not been included in an evaluation. In addition, increasing willingness to share information, a strategies that was included in the studies of Altay2014InformationOperations and Bateman2018EvaluatingResponse was evaluated differently. While this could be explained by the different purposes for which these models have been developed, it could also be argued that a full understanding of the effect of this strategy is absent. The strategies that are evaluated in this study are:

- Increasing willingness to share information across organisational boarders
- Increasing willingness to share information within organisations
- Increasing the share local programme managers
- Changing assessment and publication method from accuracy-focused to time-focused
- Implementing structured handing-over of knowledge
- Implementing structured handing-over of contacts

The research approach chosen to evaluate these strategies aims to describe the information diffusion system in complex emergencies based on a case study, the Bangladesh-Myanmar displacement crisis. Subsequently, it deduces a conceptual model on information diffusion in complex emergencies from the available theory on disaster management, information diffusion, data ecosystems and intelligence processing and from experience expressed by humanitarian professionals active in disasters. Thereafter, it implements this conceptual model in an agent based modelling environment. Experiments are preformed to analyse the effects the strategies. Finally, various validation methods are deployed to assess the generalisability of the results.

## 11.2 ANSWERING THE RESEARCH SUB-QUESTIONS

To be able to answer the main question, this paragraph first provides answers to this research's four sub-questions.

**Sub-question 1: What barriers and drivers affect information sharing in the Bangladesh-Myanmar displacement crisis?**

Based on interviews with 5 humanitarian professionals, seven drivers and barriers that effect information sharing are identified for the Bangladesh-Myanmar displacement crisis. Within this crisis the only activity that, according to recent 3W data, is performed by all 10 most active humanitarian organisation in the WASH Sector is the distribution of hygiene kits. The decision about when and where to distribute hygiene kits is chosen as the focal decision for the modelling study.

The three major drivers for information sharing in the Bangladesh-Myanmar displacement crisis are:

- The long presence of data collection projects in Bangladesh.
- The 2017 refugee influx, bringing more information management partners that generate more data activities.
- The ISCG platform, as it acts as the key advocate for data sharing, pushing all big data owners to share information on public forums.

The four major barriers for information sharing in the Bangladesh-Myanmar displacement crisis are:

- Absence of OCHA as neutral and experienced partner in information sharing.
- Unwillingness to share information, completely or in a specific data format.
- Sub-optimal transparency about data collection methods.
- Inter-agency competition.

**Sub-question 2: How can a conceptual model of information diffusion in a complex emergency be made?**

The overview of the drivers and barriers in combination with the literature review and semi-structured interviews executed for the first sub-question provides a system description of information sharing in complex emergencies. Based on this description a conceptual model is constructed that consists of four different agent types which have their own specific behaviour.

Local information management, local programme managers, directors of international assistance and remote support agents use different strategies to share information. The social network and (un)deploy dynamic belonging to local programme manager agents make this conceptualisation more realistic than the conceptualisations used by other scholars. This is also the case for the way in which needs of (potential) beneficiaries are conceptualised. These needs change as a results of shocks. Programme managers perform assessments to start activities to address needs. They also share their information with other agents. Remote support sends remote assessments based on satellite or drone imagery to the field. They are more efficient in performing assessments as their assessments cover more areas. Directors of international assistance deploy programme managers to the field. Information management exchanges aggregated information to the programme managers on the

ground.

The performance of the system in evaluated based on three KPIs. The main KPI is the number of information items shared per programme manager per day. A information item relates to information about a needs assessment or activity at one specific block in a refugee camp at one specific day. The other KPIs are the total relief gap and the total days worked per programme manager per day. Figure **??** provides a high level overview of the procedures executed by the four agent types. More elaborate IDEFo and UML inspired diagrams are included in appendixes E and D.

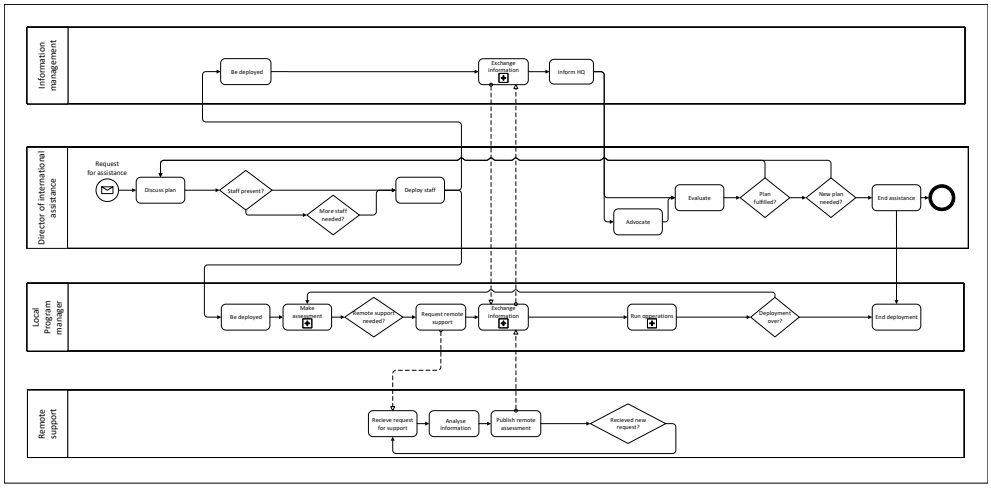


Figure 11.1: BPMN inspired diagram that captures the conceptualisation of information sharing in complex emergencies. This figure was first introduced in chapter 5.1 on page 36. It is repeated here for easy reference.

**Sub-question 3: What is the effect of the information sharing strategies on information diffusion in the Bangladesh-Myanmar displacement crisis?**

The conceptualisation provides a bases for the development of an agent based model. The developed ABM is parameterised based on the Bangladesh-Myanmar displacement crisis. The model's variables, however, enable the user to calibrate the model on other complex emergencies. Over 10.000 experiments are performed to evaluate the effects of the two core assumptions, the six individual strategies and 8 combinations of individual strategies, the so called comprehensive strategies.

The model results reaffirm that the moment, locations and number of shocks observed in a disaster influence information diffusion and the number of days programme managers have to work. Moreover, the results reconfirm that representing information sharing by a combination of social network based sharing and random search sharing influences the behaviour of the model and the outcomes of the evaluations. This study can not confirm that the more realistic assumptions lead to different outcomes in the observed relief gap or total days worked between not sharing and the reference scenario. The complexity of the assumptions that govern how information leads to the planning of relief activities is too limited to observe significant results for this effect on the latter two KPIs.

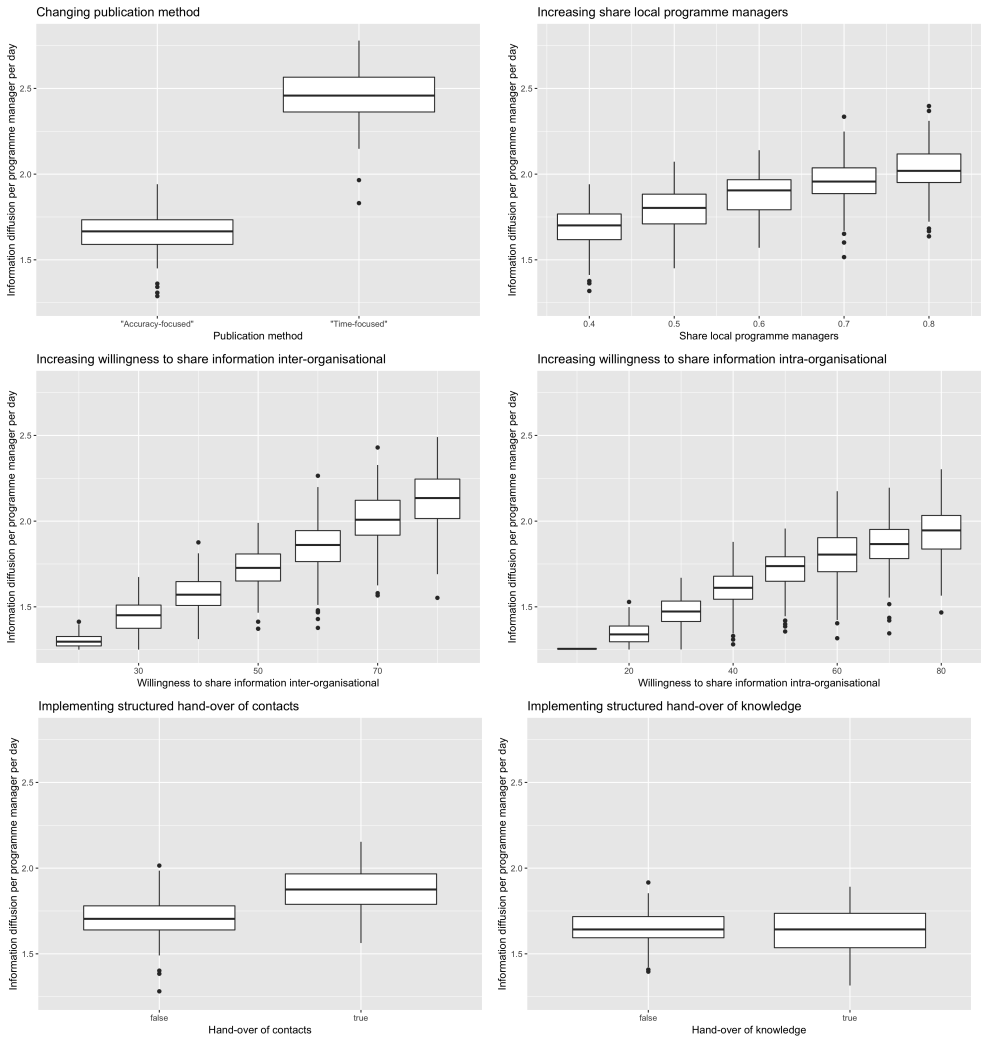


**Figure 11.2:** The behaviour of the effect of the six information sharing strategies on the diffusion of information. The plot shown in the top left of the figure shows the behaviour of the strategy that is most effective: change publication method from accuracy-focused to time-focused. This figure was first introduced in chapter 8.1 on page 60. It is repeated here for easy reference.

Analysis of the results of the experiments conducted with this agent based model shows that there are multiple options to increase the diffusion of information. Five of the six individual information sharing strategies, shown in figure 11.2, increase information diffusion significantly.

Based on analysis of the results, it is also concluded that replacing assessment methods that are highly accurate but slow by less accurate assessments that are created in near-real time is the most effective individual strategy. It enables fewer responders to diffuse more information, while the gap between the needs and the relief activities remains constant. The effect of this strategy on the diffusion of information is shown in the top left plot in 11.2.

Figure 0.1 furthermore shows that *Increasing the share of local responders* in a disaster is the second most effective strategy to increase the diffusion of information. In addition, analysis shows that increasing *inter-organisational willingness to share information* is more effective once compared to *increasing intra-organisational willingness to share*. Lastly, the study into the effects of the individuals information sharing strategies shows that *handing-over knowledge* is not an effective strategy to increase

information diffusion. In this regard, handing over contacts is more effective.

In addition to the analysis of the effects of the individual strategies, this study also examines the effects of implementing combinations of strategies. The effects of eight comprehensive strategies on the diffusion of information are displayed in figure 0.2. Analysis shows that there is no enforcing or dampening effect between the individual strategies. The results of this study suggest that implementation of combinations of strategies will not lead to effects that are stronger than the sum of the individual strategies nor will the effect be weaker than this sum. As a result, it is concluded that a locally sourced team, with an outward focused organisation that produces near real-time information products is the most effective comprehensive strategy to diffuse information. It remains unclear what the effect of this strategy is on the observed total relief gap and the number of days worked in a disaster, as none of the comprehensive strategies change these indicators significantly.

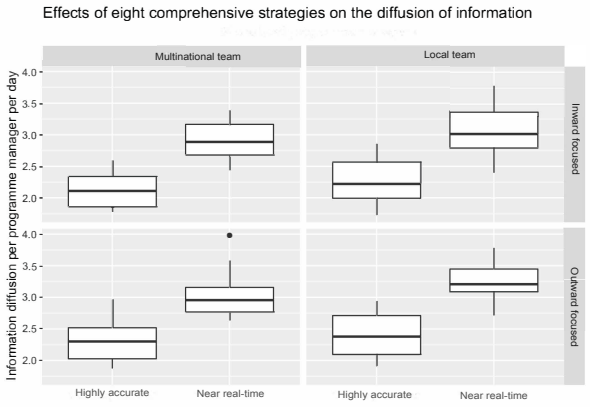


**Figure 11.3:** The behaviour of the effect of the eight comprehensive strategies on the information diffused per person per day. This figure shows that a locally sourced team, with an outward focused organisation that produces near real-time information products is most effective in diffusing information. This figure was first introduced in chapter 8.2 on page 62. It is repeated here for easy reference.

**Sub-question 4: How could the outcomes of this study be generalised to other complex emergencies?**

To answer this question two types of face validation methods are conducted with the help of 11 respondents. Moreover, additional experiments are performed for structural validation. Based on the validation, five statements are made that form the answer to the fourth sub-question.

Firstly, if one were to generalise the effects of the information sharing strategies one should reflect on the differences between information on hygiene kit distribution and the nature of the information to which the generalisation is made. Secondly, one should be aware that strategies that are less specific to the nature of the information are more likely to be effective strategies in a general sense then others. Thirdly, one should consider that the agent based model can be valid for a wide range of complex emergencies, but that comparison of the parametrisation of the model to a parametrisation of the situation where is generalised to, is required before making the generalisation. Fourthly, the outcomes of additional experiments for structural validation strengthen the belief that the normal distribution assumption is justified. When pursuing a generalisation, one should consult the list of assumptions made for the construction of this ABM and evaluate whether these assumptions are also justified in the context of the generalisation. Finally, one should be aware that the

executed validation showed unable to validate substantial parts of this study and that more research is needed assess generalisability of the results. The next chapter discusses the results of the study.

## 11.3 ANSWERING THE MAIN RESEARCH QUESTION

This research uses a model-based approach to evaluate information sharing strategies in complex emergencies based on a case study. This approach is used to answer the main research that reads as follows:

**"What are the effects of information sharing strategies on the diffusion of information in complex emergencies?**

Analysis of the Bangladesh-Myanmar displacement crisis and consulting both literature and numerous humanitarian professionals led to the construction of a model on information diffusion in complex emergencies.

Based on analysis of the results, it is also concluded that replacing assessment methods that are highly accurate but slow by less accurate assessments that are created in near-real time is the most effective individual strategy. It enables fewer responders to diffuse more information, while the gap between the needs and the relief activities remains constant. The effect of this strategy on the diffusion of information is shown in the top left plot in 11.2.

Figure 0.1 furthermore shows that *Increasing the share of local responders* in a disaster is the second most effective strategy to increase the diffusion of information. In addition, analysis shows that increasing *inter-organisational willingness to share information* is more effective once compared to *increasing intra-organisational willingness to share*. Lastly, the study into the effects of the individuals information sharing strategies shows that *handing-over knowledge* is not an effective strategy to increase information diffusion. In this regard, handing over contacts is more effective.

Ordering these strategies based on reported effectiveness results in the following list:

- Changing assessment and publication method from accuracy-focused to time-focused
- Increasing the share local programme managers
- Increasing willingness to share information between organisations
- Increasing willingness to share information within organisations
- Implementing structured handing-over of contacts
- Implementing structured handing-over of knowledge

In addition to the analysis of the effects of the individual strategies, this study also examines the effects of implementing combinations of strategies. The effects of eight comprehensive strategies on the diffusion of information are displayed in figure 0.2. Analysis shows that there is no enforcing or dampening effect between the individual strategies. The results of this study suggest that implementation of combinations of strategies will not lead to effects that are stronger than the sum of the individual strategies nor will the effect be weaker than this sum. As a result, it is concluded that a locally sourced team, with an outward focused organisation that produces near real-time information products is the most effective comprehensive strategy to diffuse information. It remains unclear what the effect of this strategy

is on the observed total relief gap and the number of days worked in a disaster, as none of the comprehensive strategies change these indicators significantly.

It must be emphasised that the model used to obtain these results is parameterised for the Bangladesh-Myanmar displacement crisis. As the effectiveness of the strategies is context dependent, the results can not directly be generalised to other disasters. If one were to conclude on the effects of the information sharing strategies in another context one should reflect on the differences between information on hygiene kit distribution and the nature of the information to which the generalisation is made. In addition, one is also advised to consider using the model and changing the parametrisation to reflect the disaster at hand. Lastly, one should be aware that the objective of this study is to evaluate the effects of information sharing strategies on the diffusion of information. Before deciding to implement one of the strategies, reflection on the strategies from amongst others a political, financial and cultural perspective is advised.

## 11.4 SOCIETAL CONTRIBUTION

The effects of six strategies on the diffusion of information are evaluated in this study. A number of socially relevant outcomes that are provided by this evaluation, as well as a number of recommendations for practitioners in disaster response are synthesised in this paragraph. These recommendations are provided for the benefit of all humanitarian practitioners as well as for the 510 initiative of The Netherlands Red Cross.

As part of this research the findings are discussed in a validation workshop. During this session one of the participants emphasised that the required sample size of an assessment is often one of the most discussed topics during the deployments. This research does not provide a blueprint of which method for assessments should be chosen. Yet, it suggest that chasing high accuracy levels at the cost of time is not beneficial for information diffusion, closing the relief gap or decreasing the number of people in a disaster. In addition, it provides argumentation for the use of assessments that do not structurally under or over-estimate expected needs. It is, for example, at least doubtful whether assessments that use the number of reported deaths to estimate expected needs are as effective in diffusing information as assessment that account for continuous variations in needs. Humanitarians are recommended to thoroughly reflect on the rational behind their current choices for assessment and publication methods.

In 2016, dozens of the world's largest donors and humanitarian groups signed the *'Grand Bargain'* and pledged to put more power and funding in the hands of local aid groups (Inter-Agency Standing Committee, 2016). This study provides support for those that aim to accelerate the implementation of the statements pledged in this agreement. In January 2019, Geneva-based journalism platform IRIN, mentioned *'outsourcing risk'* as one of the trends that it will be watching for the new year. According to the platform, "international aid groups are relying more and more on local responders, but those responders don't always have the resources to stay safe" (IRIN, 2019). The findings provided by this study indicate that information diffusion is aided by a higher share of local staff. They therefore provide support for those that are trying to improve safety of responders belonging to the local community. In this light, humanitarians including those at the Red Cross are encouraged to distinguish reasons from excuses in the discussion about the number of locals versus internationals in a response.

Multiple studies examined the motives behind willingness to share information. One of these is the research conducted by Haak. She observed that *"the willingness to share data varies greatly per data provider"*. The findings of this study support Haak's statement that incentives to not share data should be removed. Although some arguments such as preserving independence could be valid reasons to not share information, the outcomes of this study add weight to the other side of the balance by arguing that from a information diffusion perspective increasing willingness to share information is beneficial. Moreover, they provide potential alternatives to increase information diffusion once increasing willingness to share is not desirable. It provides evidence that supports efforts to decrease bureaucracy and align the formats that are used to share information. Continued efforts in this direction is recommended.

This study concludes that handing over contacts or knowledge to a successor are the least effective strategies to increase information diffusion. It must be emphasised that this does not mean that hand-overs are ineffective. First of all, there are countless of hand-overs that are not considered in this study. For example handing over needs information to bigger groups of people. Moreover, the conclusion only applies to the effectiveness of the diffusion of information. One could have completely different motives for handing over knowledge. It could, for example, be that handing-over knowledge is an effective strategy to familiarise the successor with the procedures in the new team. The results of this study suggest that it is not an effective strategy to increase information diffusion. It is therefore recommended to reflect on rationale behind a hand-over. If the reason behind a hand over is to share information, so the successor will share it with the rest of the community, it could be better to use the energy on other strategies.

## 11.5 SCIENTIFIC CONTRIBUTION

According to Whipkey and Verity (2015) and Nissen (2015), the humanitarian information management community seems to be predominantly focused on collecting, analysing, and visualising data quicker and better - the supply side - and less with understanding how the outcomes of their efforts are used for decision-making - the demand side of information management.

This study aims to move away from this focus on the supply side of information management by contributing to the knowledge about model-based evaluation of information sharing strategies. It proposes an approach that reflects that information needs in a disaster are constantly changing. In this approach information is shared in social networks of humanitarians. Based on a comparison discussed in chapter 10, the conclusion is drawn that the model belonging to this study provides a deeper and more realistic representation of reality then the models of Altay and Pal and Bateman and Gralla. As a result, this study is able to evaluate strategies that have a level of complexity that could not be apprehended by the existing models. It provides an addition to the academic knowledge on model-based evaluation of information sharing strategies by providing the most generic model-based approach to evaluate information sharing strategies in complex, humanitarian disasters.

The reflection on the used approach discussed in chapter 10 also led to the observation that modelling research for information sharing evaluation in humanitarian response is still in its infancy. It is a field that can both benefit from specific modelling research and from hybrid research projects, that combine modelling research with more comprehensive data analysis and field research. From the perspective of analysing information sharing strategies, the agent based modelling school showed especially useful because of its bottom up approach. Other researchers are encour-

age to extend the approach proposed and used in this study and explore how it can be used in other contexts.

## 11.6 RECOMMENDATIONS FOR FUTURE RESEARCH

During the limited time that this study carried the research torch on model-based evaluation of information sharing strategies in humanitarian disasters, a number of directions for further research are identified.

First, there is an opportunity for future research in the direction of expending the developed model. The processes by which information leads to planning of relief activities and, as a result, effects the observed relief gap and days needed for the response, is an important direction for future research and extension of the model. In addition, The GIS extension of Netlogo offers multiple possibilities to increase the ontological comparability and communicative value of the model. As more elaborately discussed in chapter 10, it enables a more accurate representation of locations in the model. Furthermore, the model can be expanded to account for the heterogeneity of (false) information, organisations, social networks and infrastructure as well as strategic behaviour of agents.

Secondly, additional research is suggested that validates the outcomes of this study. An example of a research project that could complement the validation of this study is an analysis of HR data. Interviewing chief human resource officers and analysing HR data of multiple humanitarian organisations could enable a comparison of HR strategies. The outcome could sketch the outline of an image that expresses the effects of having various numbers of locally sourced staff. An results that could complement the findings of this study.

Finally, fellow researchers are encouraged to explore how an approach that recognises the effects of the non-monotonous behaviour of information needs and the role of social networks in information sharing can be used outside the context of complex emergencies. This could be in the wider research field of humanitarian disasters or it could be in another field that experiences (climate)shocks or information diffusion in social networks.

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# A SETUP SEMI-STRUCTURED INTERVIEWS

To draft a case description of information sharing in a complex emergency, a number of humanitarian professionals that worked in the Bangladesh-Myanmar displacement crisis is approached to participate in an interview. The objective of the interviews is to explore the information sharing system. The method that is chosen to reach this objective is conducting semi-structured interviews. The semi-structured interviewing is an explorative, open method, that allows new ideas to be brought up during the interview as a result of what the interviewee says. Table **??** provides an overview of all the professionals that are invited to take part in the interviewing exercise. To find participants for the interviews, first the social network of the research team is utilised. Subsequently, other interview candidates are sought by snowballing, asking the interview candidates for people in their network that can provide a complementary perspective. The invitation email that is used to approach the interviewee candidates is included in the box A1.

The interviewees are asked for their consent to digitally record the interviews. Based on the recordings a structured summary of the interviews is created. In this summary the answers are grouped together to facilitate easier comprehension and comparison of the answers. To make sure the summary reflects the actual content of the meeting, the summary is shared and agreed upon by the participants. Table A.1 provides an overview of the details of the interviews.

| # | Org | Position | Location | Deployment | Interview mode | Interview Language |
|---|---|---|---|---|---|---|
| 1 | Unicef | Information Management Officer WASH | Cox's Bazar | 3 months | In person & Skype (3 times) | Dutch |
| 2 | IOM | Acting Head of Programme Support Unit | Cox's Bazar The Hague | 3 weeks | In person | English |
| 3 | IOM | Monitoring and Evaluation Officer | Cox's Bazar | 9 months | Written, via interviewee 2 | English |
| 4 | IOM | Programme Support Officer | Cox's Bazar | 9 months | Written, via interviewee 2 | English |
| 5 | IOM | Information Management Officer | Cox's Bazar | 9 months | Written, via interviewee 2 | English |

**Table A.1:** Details interviews

**Interview guide**

In contrast to structured interviews which have rigorous sets of questions that do not allow one to divert, the interviewing method that is used for this research is open and explorative. To prepare the interview, a interview guide is prepared. This guide contains an informal grouping of topics and questions that the interviewer can ask in different ways for different participants. During the interviewees the

questions might be tailored to fit the context of the interview or the experience of the interviewee. In addition, information that is presented by the respondents may influence the questions. This method facilitates exploration of the information sharing system in complex emergencies.

The interviewees are asked questions that can be grouped in the categories general, information sharing, social network and focal decision. The following questions are asked to the participants of the semi-structured interviews:

- General: Can you describe the position and responsibilities you have/have in the Bangladesh response?
- Information sharing: From your perspective, what are main drives and barriers for information-sharing in the Cox Bazar displacement crisis?
- Information sharing: By what means does your organisation share its analysis (formally and informally)?
- Information sharing: Does you organisation, or do your partners, make a distinction between assessments for advocacy and assessments operations? How?
- Information sharing: How do you reflect on how others the use the data-products that your organisation produced?
- Social network: Can you describe how you got introduced to all the people in Cox Bazar?
- Focal decision: What do you know about how agencies decide on health kit distributions?

The synthesised answers to these questions can be found in the interview summaries, that are included in appendix B.

**Box A.1: Invitation email for the interviews**

Dear [],

Hereby I would like to contact you regarding my MSc thesis research project on inter-organisational information sharing in complex crises (case study: Bangladesh-Myanmar displacement crisis).

I'm interested to learn more about your work for [organisation] in general and specifically related to your mission in Cox Bazar. I think I could really benefit from your perspective and experience regarding reporting cycles and information sharing practices (both formal and informal) in Bangladesh, especially because I'm not able to go into the field myself.

I would like to ask you whether you are available for a meeting at a moment of your convenience.

Please let me know if this would work for you.

I'm looking forward to hearing from you.

Best regards,
Jasper Meijering

ps. a short introduction to the research project:
Since World War II the number of people forcibly displaced from their homes has not been as high as it is today. In a complex and fragmented humanitarian ecosystem, data is needed to make decisions about highly dynamic and uncertain situations. Moreover, new data-analytical techniques are expected to have the capacity to improve efficiency of the humanitarian response. While policies are present to improve inter-organisational data and information sharing, data availability and data quality still form major challenges for humanitarian organisations. At this moment, it is largely unclear what the effect of information sharing strategies are on the diffusion of information in the continuously evolving information landscapes observed in the response phase of complex disasters. To fill this void, the development of an agent-based model based on the work of scholars in the field of information diffusion and on a framework that has been deduced from data-ecosystem and disaster management theory is suggested. The Bangladesh-Myanmar displacement crisis will act as a case study for the development of this model.

# B SUMMARIES SEMI-STRUCTURED INTERVIEWS

**Interviewee 1**

**Can you describe the position you have in the Bangladesh response?**

I work as WASH information manager officer for UNICEF. I have been approached for this position via one of the stand-by partners. I may work as multiple aspects including supporting the work of the WASH cluster in Bangladesh. Amongst others this involves requesting, collecting and aggregating 3W / 4W information from WASH partners. We do this every other week. My team also provides various data analysis for amongst others the joint response plans. I am deployed here for a period of three months, but I expect to extend my stay here with an additional 3 months. I'm stationed in an office about 1 hour driving from the camps.

**From your perspective, what are main drives and barriers for information-sharing in the Cox Bazar displacement crisis?**

In my role of information manager, I noticed that sometimes, it can be difficult to get all parties and individuals on board. Sometimes partners hand in their information too late or in a different format. Occasionally, it happens sometimes that one of our smaller partners becomes 'inactive' and we do not receive any updates any more. What I understand is that during the 2017 influx, assistance was focused on pushing as much volume as possible. Now, we can we can focus more efforts on quality of relief, as this pressure has lessened.

**By what means does your organisation share its analysis (formally and informally)?**

In general, we use the same means of communication that they use in the rest of the world. We sent out the 3W information by email and we publish them on humanitarianresponse.info. In the camps in limited telephone servers so there they use radios, but I do not have experience with that. It would be good to address the other questions in this category to individual that are in a better position to answer them.

**By what means does your organisation share its analysis (formally and informally)?**

Before I arrived in Cox Bazar, I was offered a two-day training that aimed to prepare for my work. Subsequently, the team introduced me to the work. I noticed that the introduction and opportunity for hand over is deepened on the availability of your predecessor.

**What do you know about how agencies decide on health kit distributions?**
I do not have experience with health kit distribution on the ground. Though I processed data on health kit distribution. In contrast with other relief activities From this perspective I know that hygiene kit distribution differs from other types of relief activity because it is relatively easy to measure. As one hygiene kit serves a fix number of people (one person or one family), it is easy to calculate how many

people have been reached by this type of relief. In contrast, if an organisation is building latrines, it is more difficult to assess how many beneficiaries have been reached by one latrine. Indeed, how many people are reached by latrines depends on the number of people that use it and this cannot be measured easily as it is dependent on a lot of factors, including time. As a result, hygiene kit distribution may seem an activity that compared to other activities reaches a lot of people while in reality this might be less.

**Interviewee 2**

**Can you describe the position you had in the Bangladesh response?**

I have been in Bangladesh for three weeks as head of the information management unit of one of the major humanitarian agencies there. This agency is amongst others working in data collection, camp development, camp management and shelter. In this capacity, I was responsible for evaluating the IM strategy, including redesigned our agency's bi-weekly external situation reports and a number of other information products. I partly base my answers for this interview on the correspondence I had with my IM colleagues (interviewee 3, 4 and 5), who has been in Bangladesh from august 2017 until June the next year. Direct quotes from my colleague are in *italic*.

**From your perspective, what are main drives and barriers for information-sharing in the Cox Bazar displacement crisis?**

Regarding the drivers;

Firstly, *before the 2017 influx, the environment was already data-rich. Also, there was a structured information sharing mechanism. Secondly, over time more and more IM actors came to CXB, bringing more IM projects and generate more data activities.* The need for data- gathering, the number of deployed data-gathering methods, and the amount of data gathered only increased. As an example, over time there were more and more questions added to our questionnaires. A third driver is the *ISCG platform, as it acts as the key advocator for data sharing, pushing all big data owners to share information on public forums*. The last phenomena that acts as driver for information sharing is the *relatively effective coordination to channel information needs and field data collection, so all information is relevant.*

Regarding the barriers;

Firstly, it is inevitable that *inter-agency competition acts as a barrier.* It would be interesting to know why OCHA isn't present in CXB. OCHA has years of experience in information sharing. Now, the organisations present in Bangladesh have to set up the whole infrastructure themselves. A second benefit of having OCHA present is that it acts as a neutral partner. Possibly, actors can think the IGSC is biased. *Unwillingness to share information in a specific data format is a second force that acts as a barrier.* While products are publicly available, they might not be sent in the requested format. For example, some agencies only share PDFs.

The third phenomena that acts as a barrier is *the absence of a bilaterally screening system that could be used if other organisations were to request to use certain data or information.* With this we mean that there is no bilateral screening on the correctness of numbers. In other words, it is not clear how other organisations come to their findings. As an example, there are three official refugee numbers. If one would ask a partner how they come to their numbers, they probably won't explain their exact method. There are various reasons for this, including inter-agency competition. As

a result, you have to live with the numbers you get. It is, therefore, really difficult to say what information is correct and what is wrong. Internally, everyone uses their own numbers but if it is shared with other agencies it is up to them which number they use. Lastly, *the unparallel and incompatible information management system and information collection activities used by the various actors act as a barrier.*

**What are the means by which IOM and partners formally and informally share their analyses?**

*Publicly the analyses are shared through disseminating reports and information products, publications on ReliefWeb, HR.info, HDX, Open Aerial Map and on the NPM platform and on our website.* For everyone that is outside CXB these are the major sources. People that are actually working in CXB are also tapping into relevant sector forums. *For example, cluster meetings, workshops and other coordination forums such as ICC, IMWG, team meetings etc.* The benefit of having these groups is that they can acts as places where confusion can be resolved, additional information can be shared, certain conclusions could be reached, or specific decision can be made. Information is also shared in Information Management Working Group meetings. This meeting is an example of meetings that are important for coordination.

We have two distribution lists for email, one for the sitrep in English and one for the Bangla version. These lists include colleagues, government members, donors, partners. And I assume also the ISGC, head of IM unit, cluster sector coordinator, emergency coordinators, IM officers, reginal offices and all agencies in Dhaka. People can subscribe to these list by sending an email to cxbpsu@iom.int. We don't share our sitreps on social media.

*More importantly, extensive amount of field work with camp managers, government officials and camp governors help to share information. This is done to internalize and incorporate analysis, products, drone image maps and other useful operational tools developed by various programmes.*

Information sharing could be based on a request. E.g. when there is a flood or when camp managers want to have a map of latest camp boundaries or of who is doing what and where. It, however, does not have to be based on a request. Some information is sent out on a regular based e.g. the external sitrep.

**Do you, or do your partners, make a distinction between assessments for advocacy and assessments operations? How?**

*This feels more like a question you should ask to an IOM programme manager. Unfortunately, I lack the insight to fully answer it.*

*Coming from IM perspective, there are numerous periodic assessment activities in this response that all partner and clusters are aware of. They produce data on a monthly basis, based on the indicators given by the operational partners. An example is the NPM site assessment that assess multi sectoral needs and is conducted on every 2 months. Such assessment activities give the big picture of need-based information and satisfy most the advocacy needs. There are always more agency-wise assessments ongoing to obtain more programme orientated information.*

I think you could say that needs assessments mostly cover the advocacy needs. E.g. we need more funding, attention and goods for the affected people.

**How do you reflect on how others the use your agency's data-products?**

*We are one of the biggest data producers in the response and have certainly established ourselves with the brand of the needs assessments, drone image update, community governance structure mapping. All are widely used and demanded products for agencies, government counterparts and coordination bodies. The data quality is at times not consistent. This has caused public confusion with the fluctuation in population numbers in sensitive times. This is due to the limitation in the methodology.*

For example, it takes very long before you completed the whole needs assessments. What should you do when refugee numbers increase in the meantime? Used old numbers, use forecasting or use other methods?

*Overall, our GIS products and operationalized KI (Key Informers) network are serving a bigger purpose to the entire response by providing an information collection mechanism, supplying the army of trained enumerators, getting highly operational updates on admin boundaries, community governance structure, than the KI assessments itself. The assessment information become more and more reductant, generalized and subjected to its own KI methodology limitation. With different population data, competition, and government led registration coming into shape, our data collection activities would probably also transfer itself and keep the focus on more field-orientated data activities*. It could be that in addition to our teams, teams of other organisations come to a camp as well. In this case our agency's way of working has to chance.

*Whether the data are used as only or as one of the data sources depends on the sectors. ISCG as a coordinating body, shelter and the site management sector use NPM for population figures and needs. Other sectors, such as WASH, Education, Communications with Communities, integrate their assessments with ours. Protection does not integrate our assessment because it is fully UNHCR. Food security I suppose relies on VAM/REVA.*

**How do you gather information for your agency's external situation reports?**

We don't send out official request. Other sectors know that we make this weekly report, so they send information to our team that they think is interesting. They want to highlight their achievements, so that is also driver for them to share data. Information comes in different formats and that can be a problem. You have to read a lot of documents of change formats. We are exploring ways to overcome this.

**Can you describe how you got introduced to all the people in CXB?**

The department knew that I was coming. The more senior resource introduced me with all other members of the internal IM team. Then the emergency coordinator sent out an email to the whole agency introducing me. Subsequently, I scheduled meetings with all internal sector teams. Later, I went to meet the ISCG members. Obviously, I didn't go to all their headquarters to meet them. Instead, I met these people at the meetings.

Regarding the people in the field; You don't have to be in contact with everyone. Let say there are 200 people in the camp management field team. You only need to know the managers. They are mostly in the office. You generally don't really need to know the people in the camp on a daily basis, since their work is more of a practical nature.

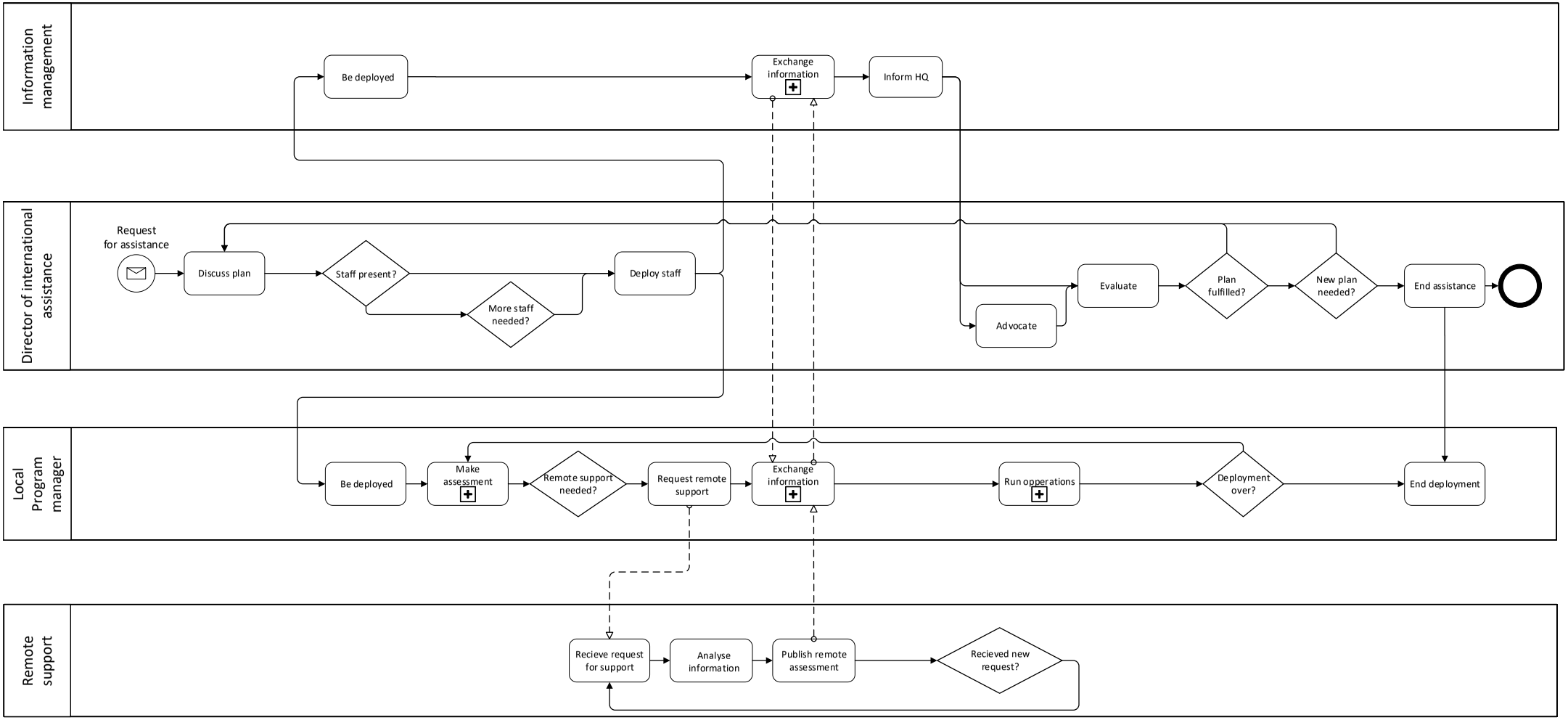
**What do you know about how agencies decide on health kit distributions?**

Our need assessment could either be the only source they use, or it could be one of their sources. In case of the latter, the other sources could be their own assessments. Our need assessment is then additional and can be used for cross checking.

It is good to know that decisions are mostly made on sector level but there are always also more agency-wide assessments being done to obtain more programme orientated information. Some of these assessments are shared, others not. This relates to my answer to your first question.

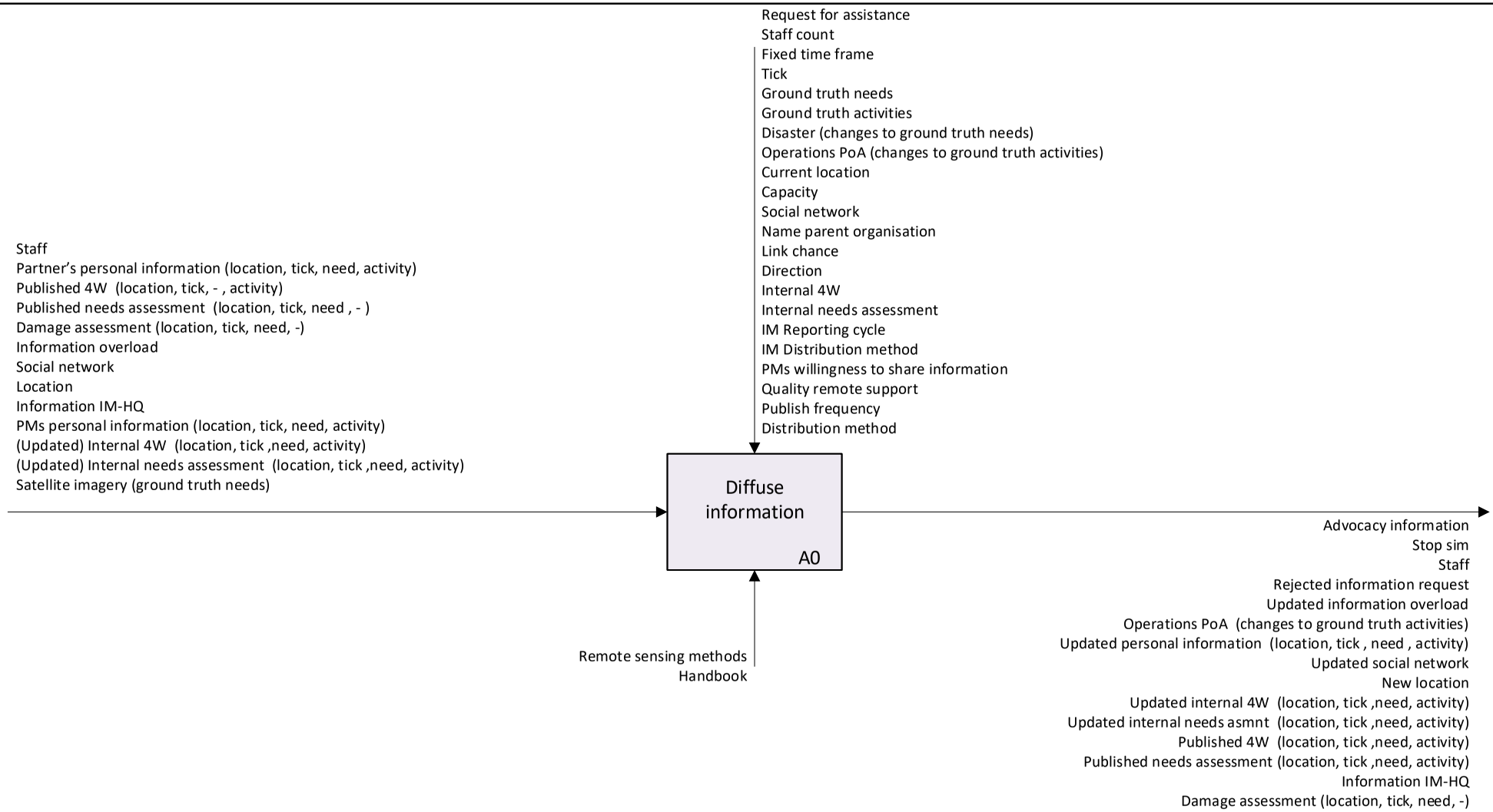
# C BPMN INSPIRED DIAGRAM

The figure on the next page shows the BPMN diagram that provides an overview of the conceptualisation of information diffusion in complex emergencies. The figure is an enlargement of figure 5.1. The diagram shows four rectangles, or 'swim lanes'. These swim lanes contain the processes and choices that correspond to four types of agents. These agent types are: Director of international assistance, information management, local programme manager and remote support. The rectangles show activities, the diamond shaped figures show choices and the circles represent the start and stop node of the system.

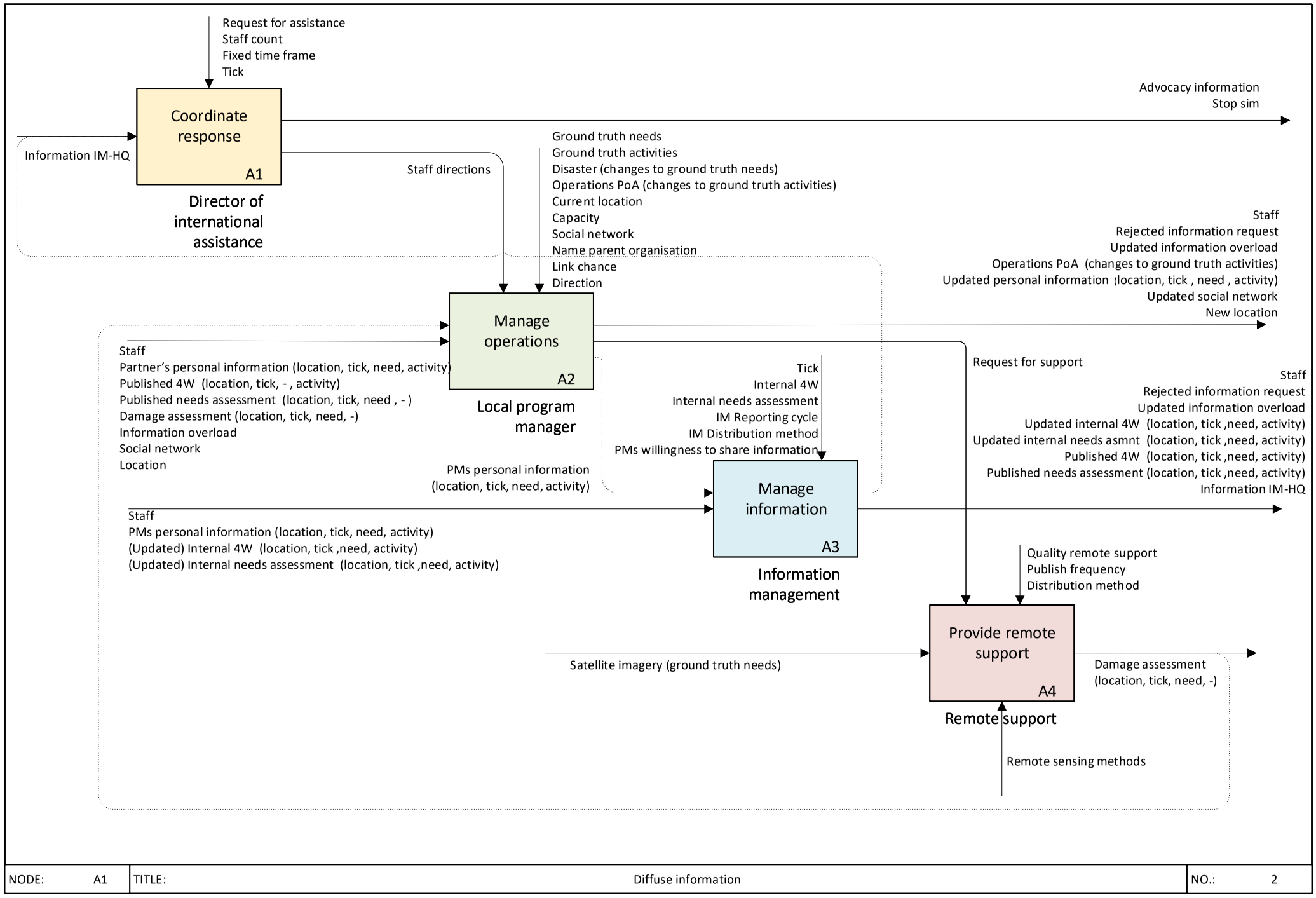

Information management
Be deployed
Exchange information
Inform HQ
Director of international assistance
Request for assistance
Discuss plan
Staff present?
More staff needed?
Deploy staff
Advocate
Evaluate
Plan fulfilled?
New plan needed?
End assistance
Local Program manager
Be deployed
Make assessment
Remote support needed?
Request remote support
Exchange information
Run opperations
Deployment over?
End deployment
Remote support
Recieve request for support
Analyse information
Publish remote assessment
Recieved new request?

# D IDEF0 INSPIRED DIAGRAMS

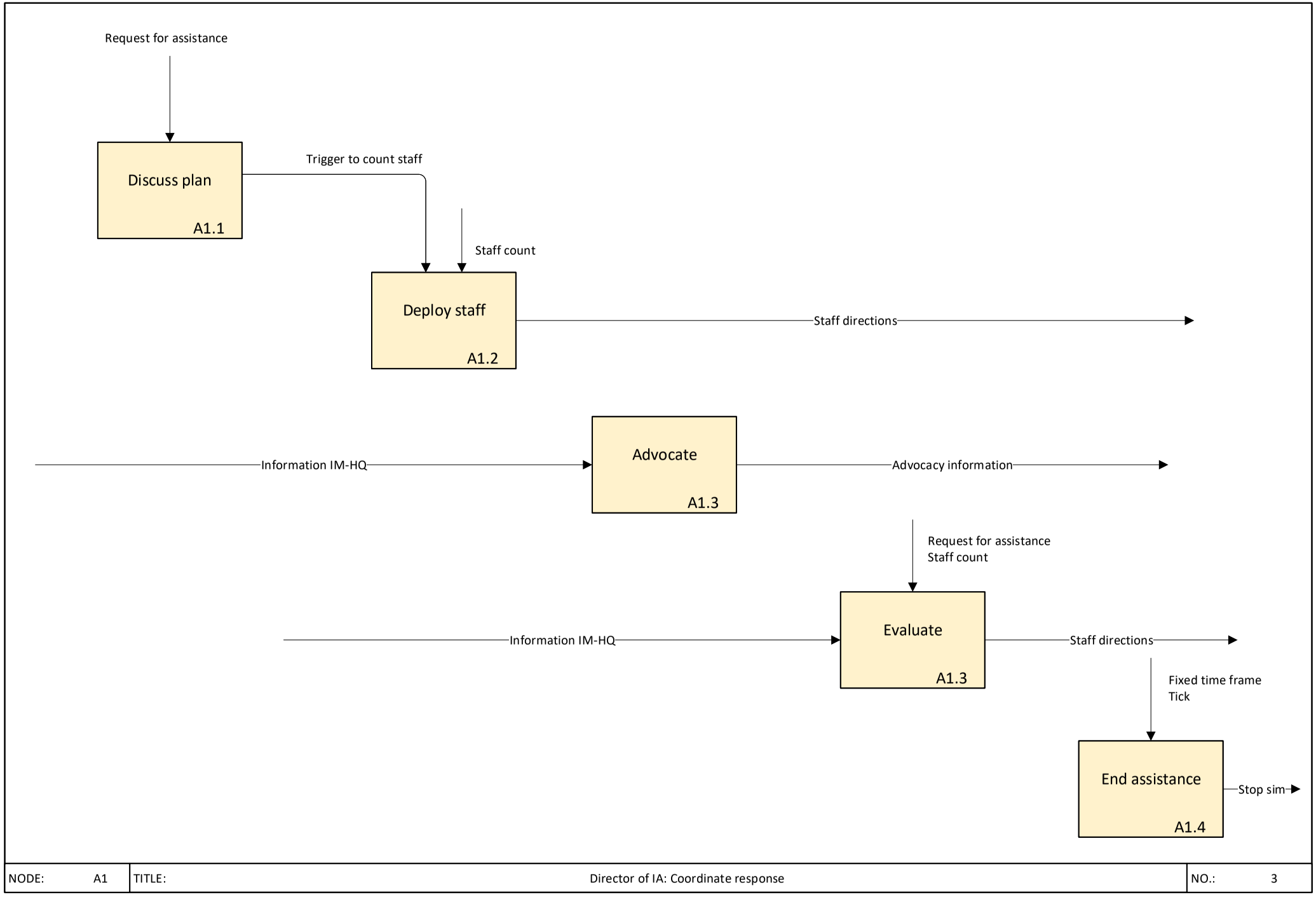
The figure on the next pages shows an IDEF0 inspired diagram that provides an overview of the agent based model. The IDEF0 functional modelling method is designed to model the decisions, actions, and activities of an organisation or system. The IDEF0 inspired diagram shows the information diffusion system on various levels, ranging from a very high level, A0, to more detailed levels such as A2.4.1.1. The diagram shows the actions, activities and processes related to four agent types: the director of international assistance, the local programme manager, information management and remote support. Each agent types has an own colour. Actions, activities and processes are represented by boxes. Each box is controlled by one or more control variables or flows and can have one or more support variables or flows. In addition, each box has input and output variables. One of the most prominent 'goods' being processed in the system is information. Information is amongst others gathered, analysed, exchanged, received and published. On a high level one calls these processes the diffusion of information. The IDEF0 inspired diagram formalises how this process can be conceptualised and modelled. The diagram included on the following pages is developed in the pre-implementation stage of the modelling cycle. To facilitate easier and more efficient programming the modeller sometimes slightly differed from the IDEF0 diagram. Nevertheless, the IDEF0 diagram is the most detailed, non Netlogo code, representation of the model. Readers interested in gaining a more extensive overview of the model are encouraged to consult the agent-based model and the documentation that are published on this Github page: https://github.com/JasperCM/information-diffusion.



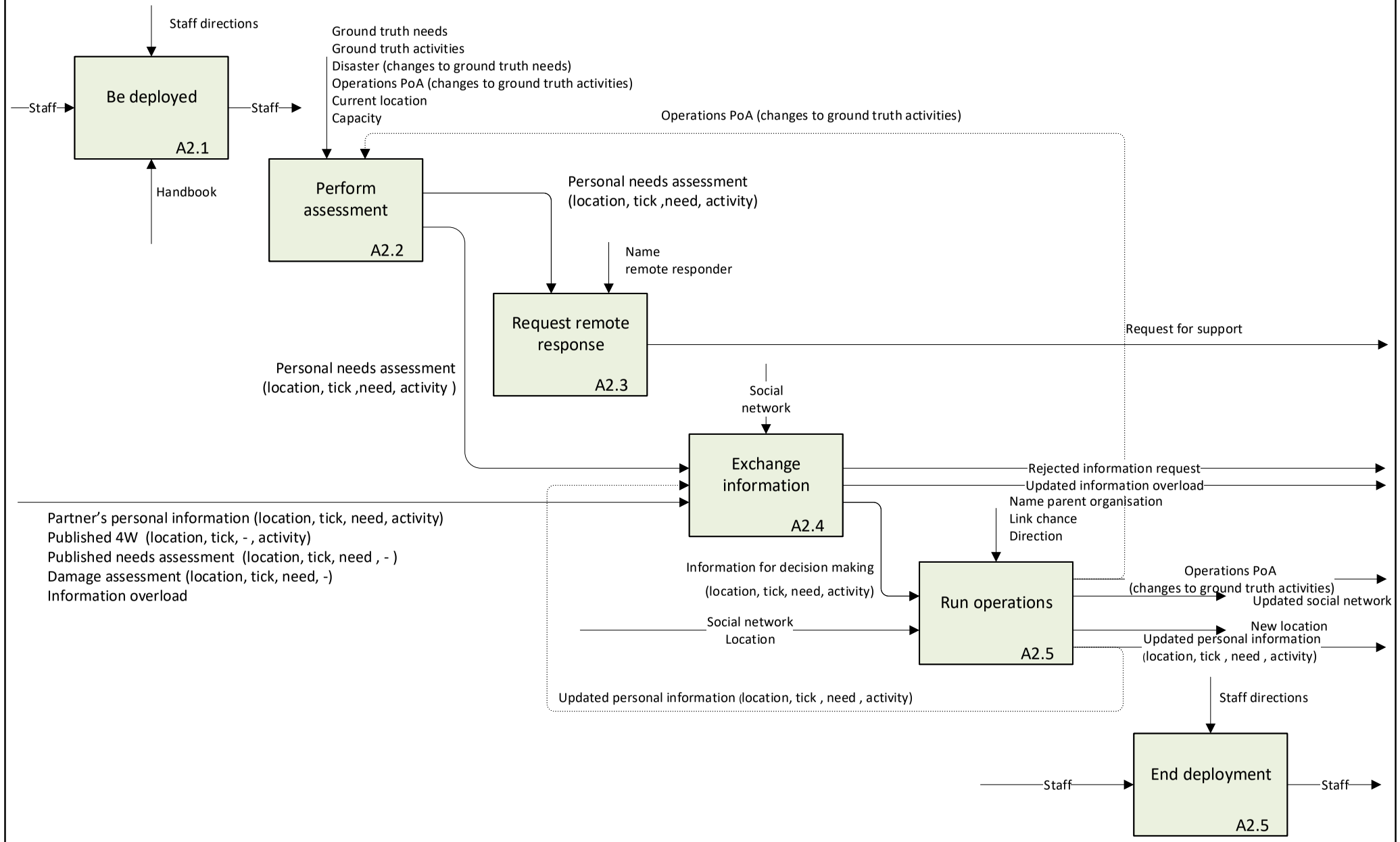

| NODE: A-0 | TITLE: Information diffusion | NO.: 1 |
|---|---|---|



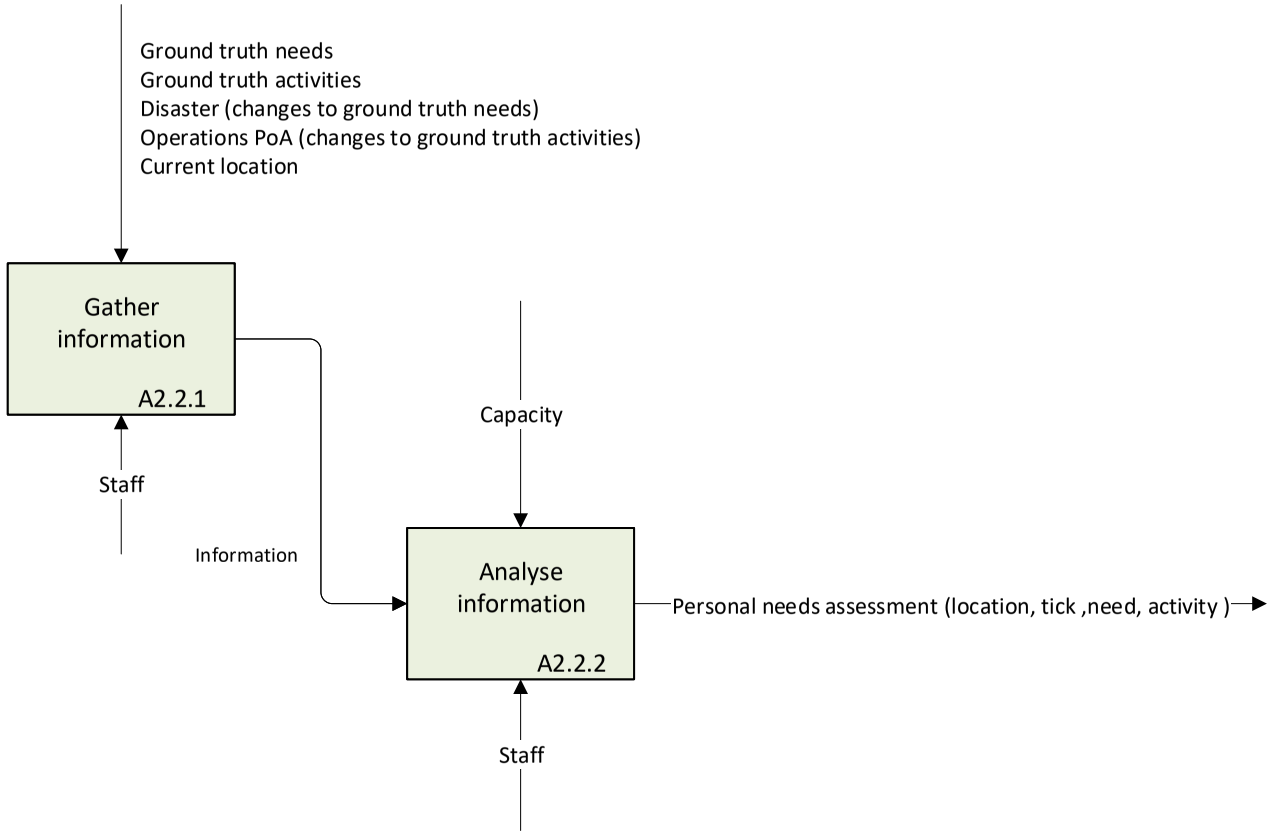

| NODE: A1 | TITLE: Diffuse information | NO.: 2 |
|---|---|---|



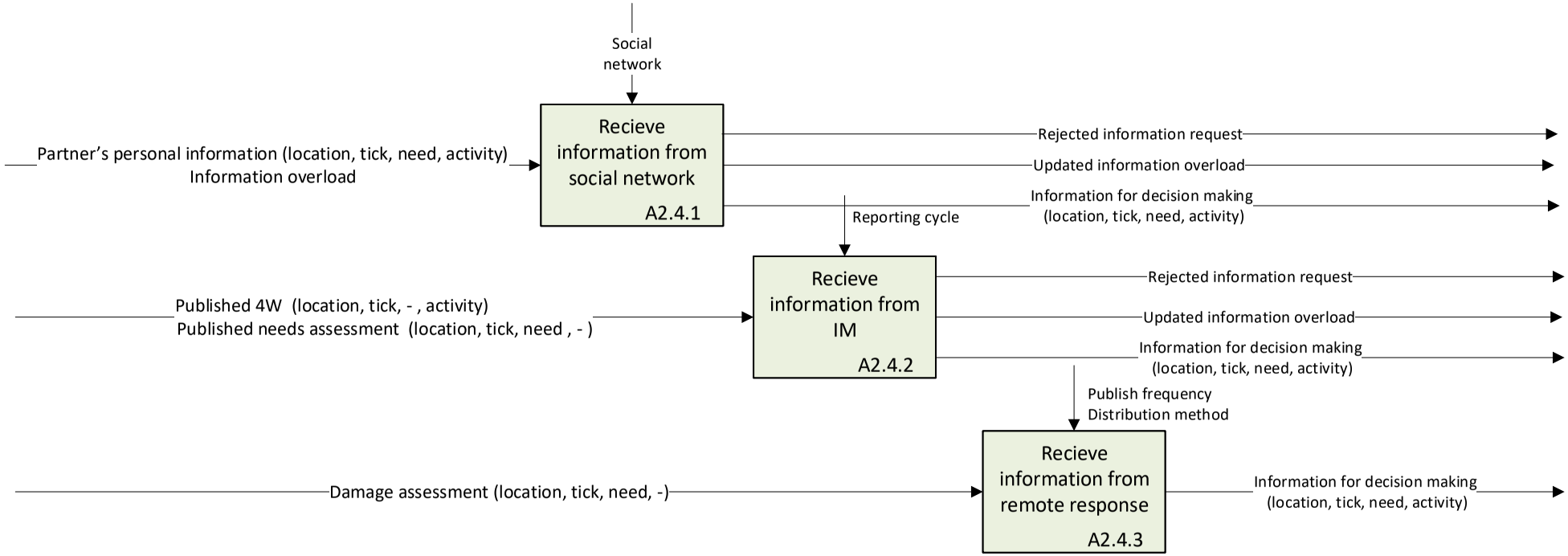

| NODE: A1 | TITLE: Director of IA: Coordinate response | NO.: 3 |
|---|---|---|



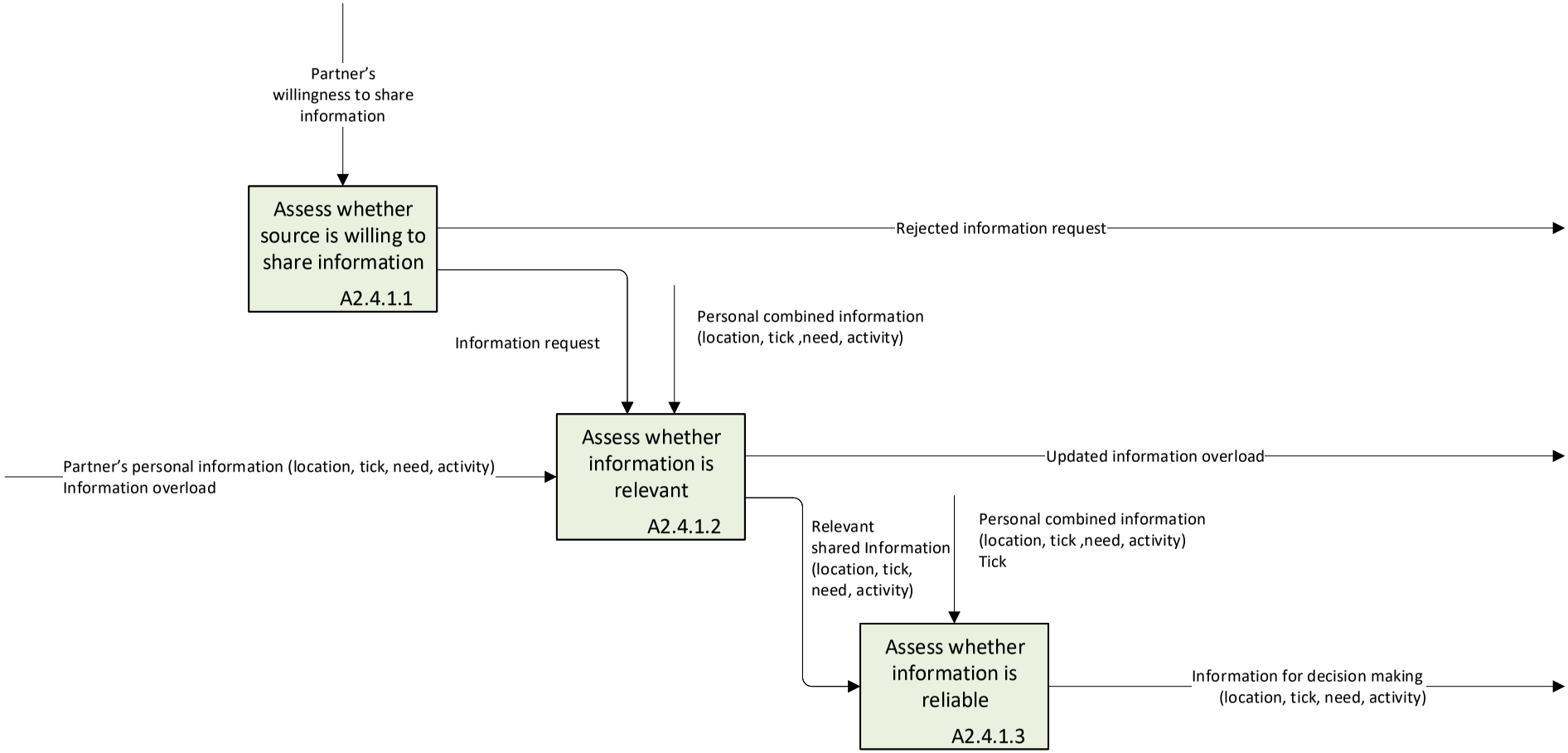

| NODE: A2 | TITLE: PM: manage operations | NO.: 4 |
|---|---|---|



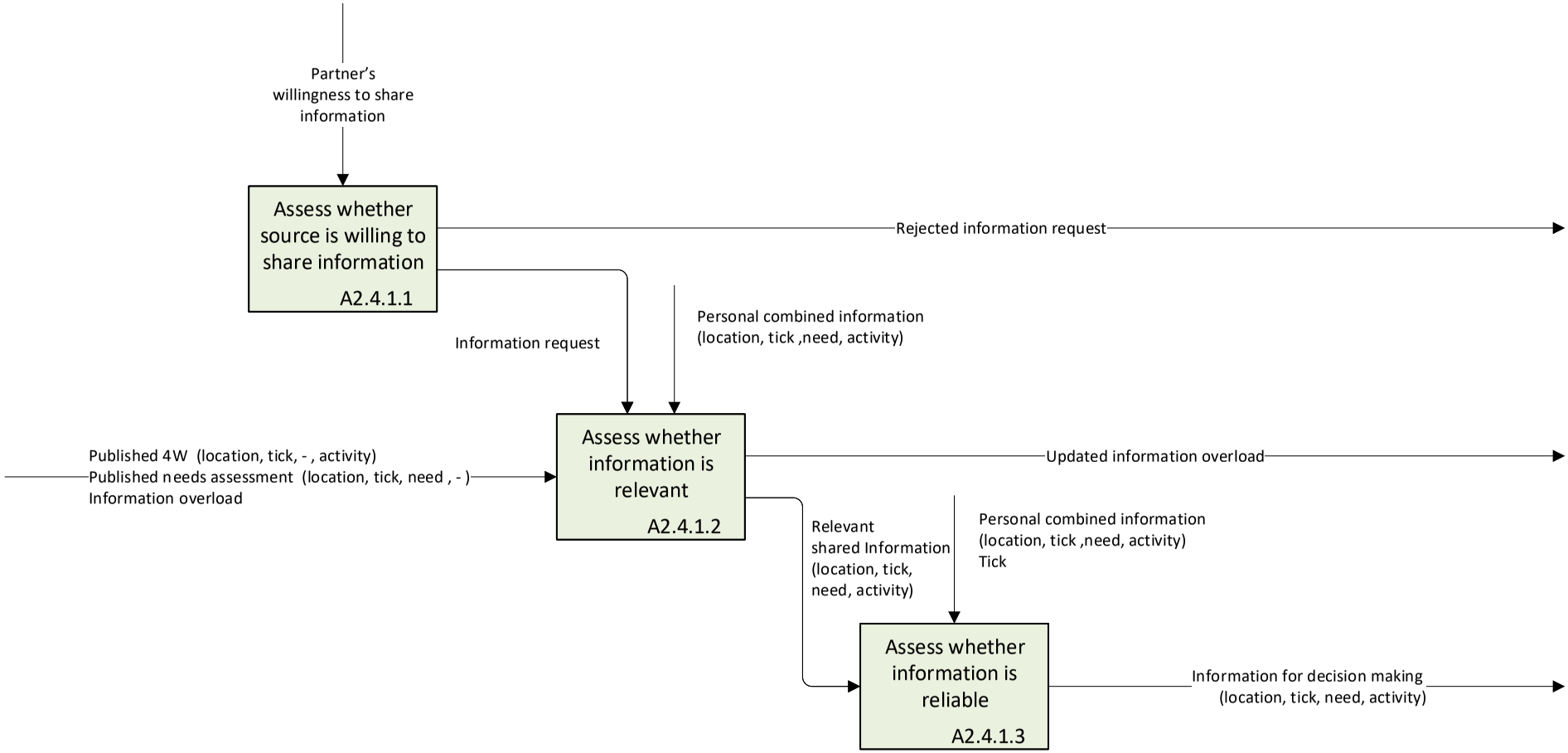

| NODE: A2.2 | TITLE: PM: make (initial) assessment | NO.: 5 |
|---|---|---|



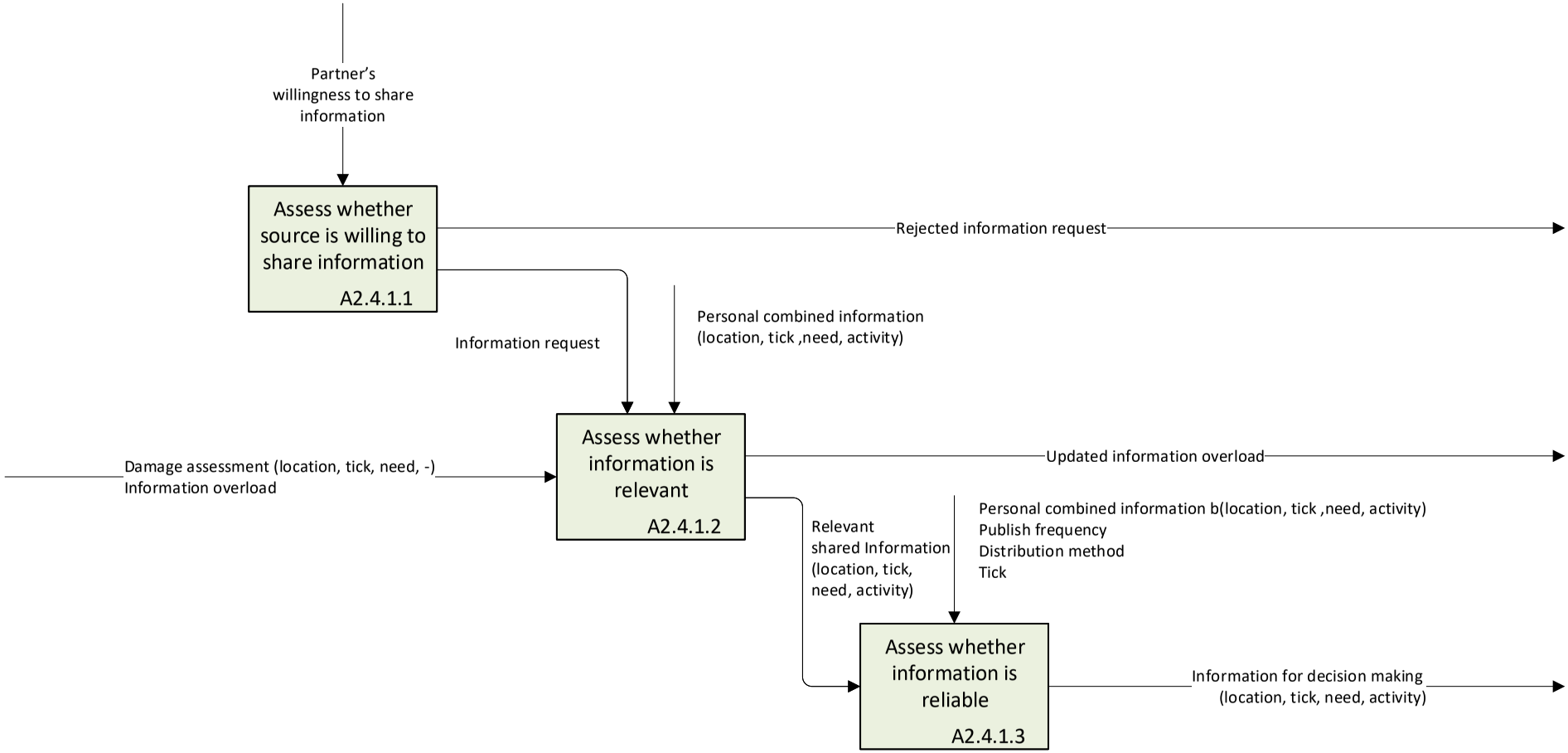

| NODE: A2.4 | TITLE: PM: exchange information | NO.: 6 |
|---|---|---|



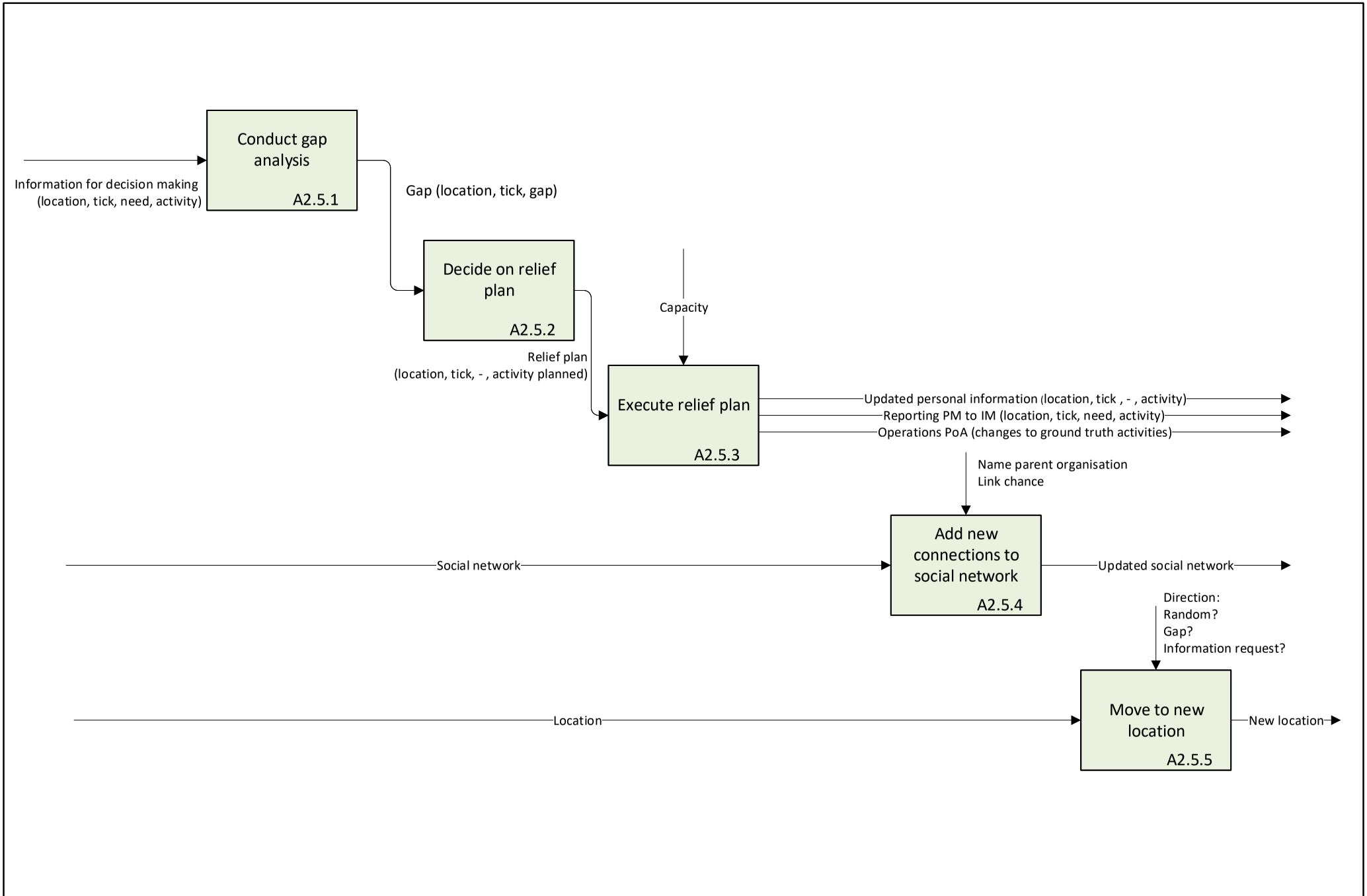

| NODE: A2.4.1 | TITLE: | PM: Recieve information from social network | NO.: 7 |
|---|---|---|---|



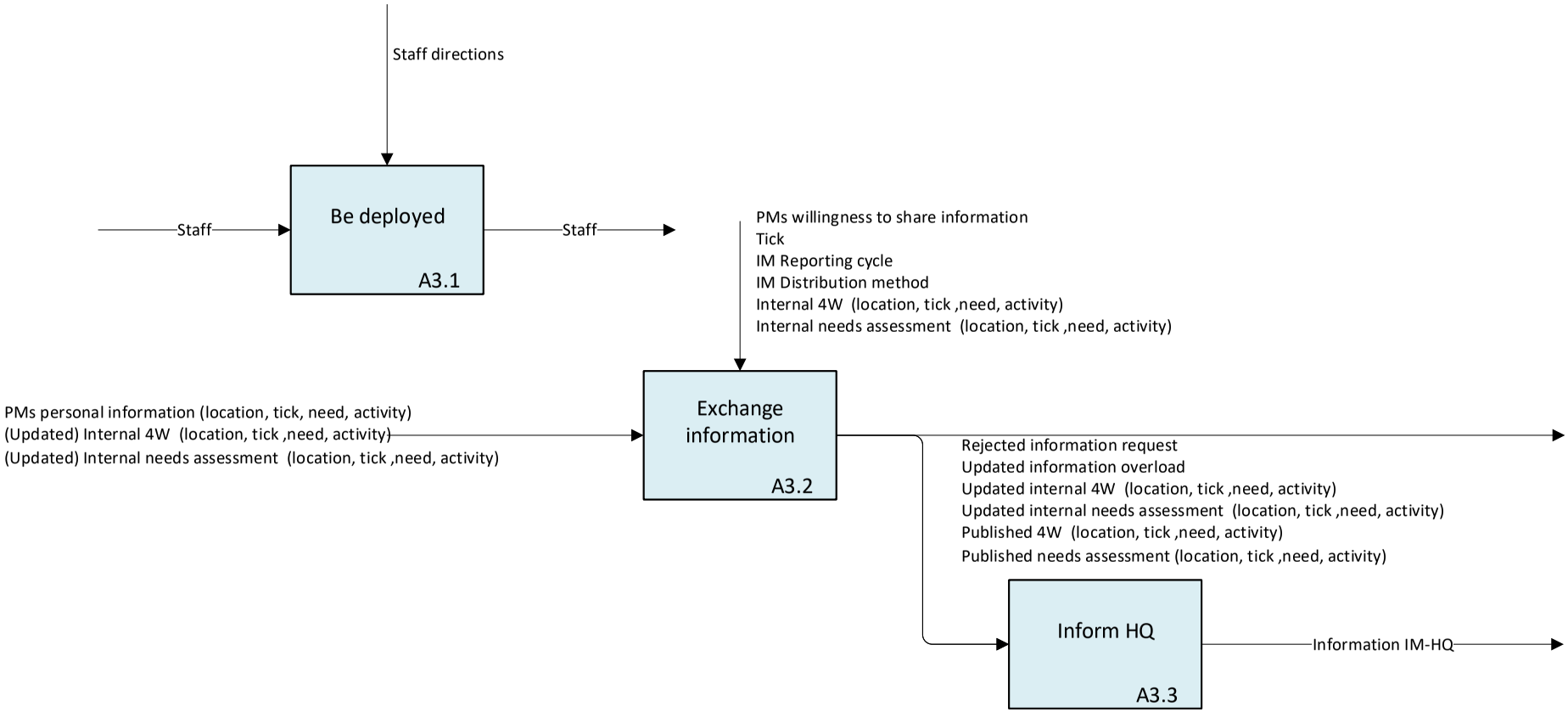

| NODE: A2.4.2 | TITLE: PM: Recieve information from IM | NO.: 8 |
|---|---|---|



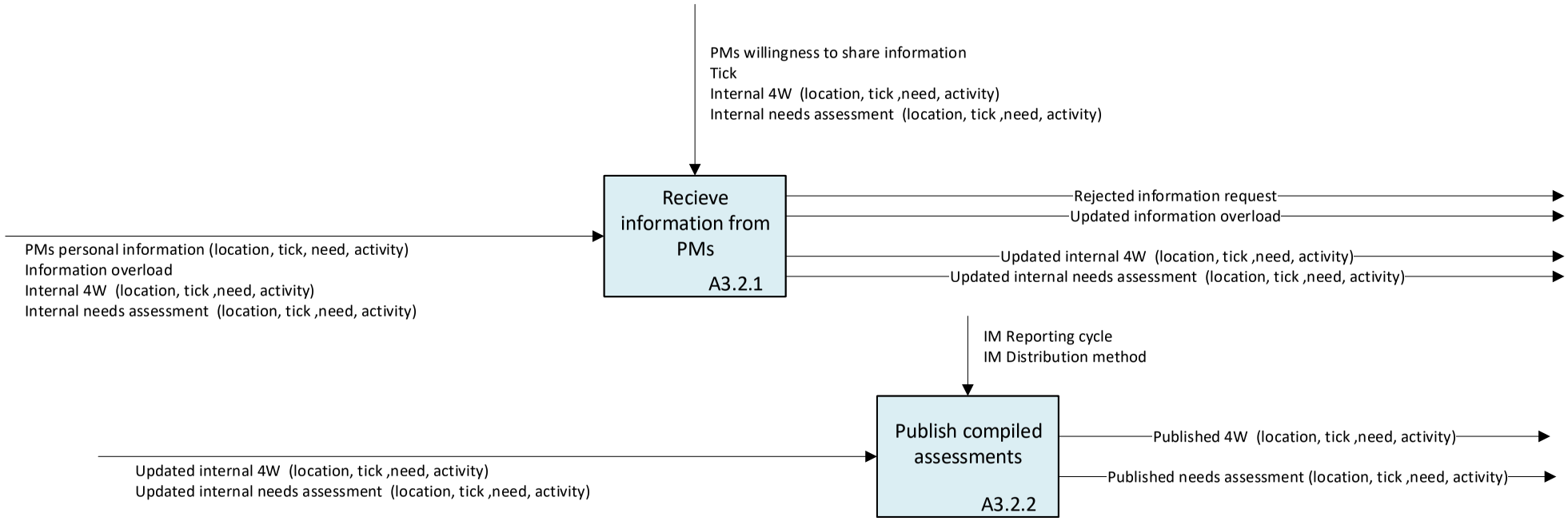

| NODE: A2.4.3 | TITLE: PM: Recieve information from remote support | NO.: 9 |
|---|---|---|



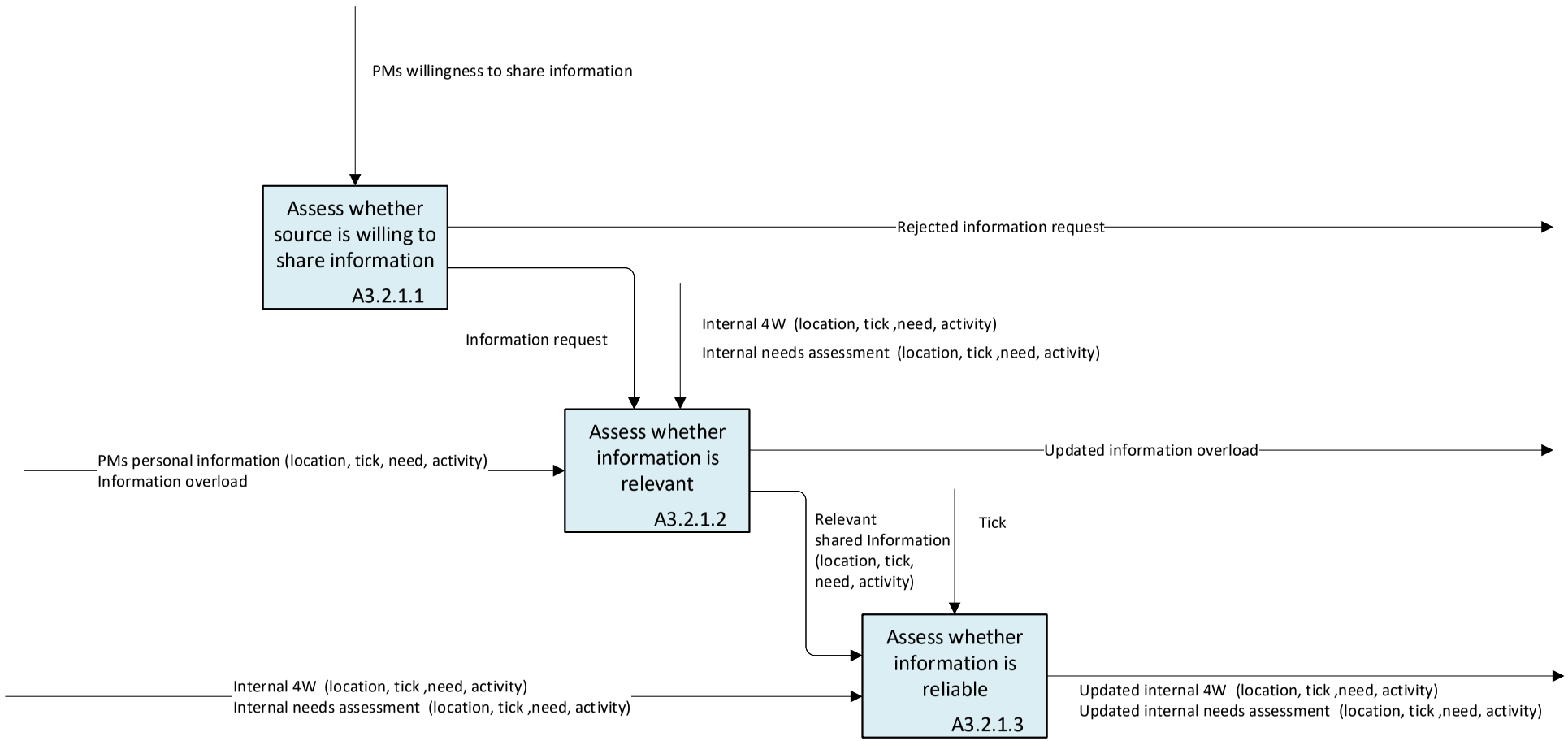

| NODE: A2.5 | TITLE: PM: Run operation | NO.: 10 |
|---|---|---|



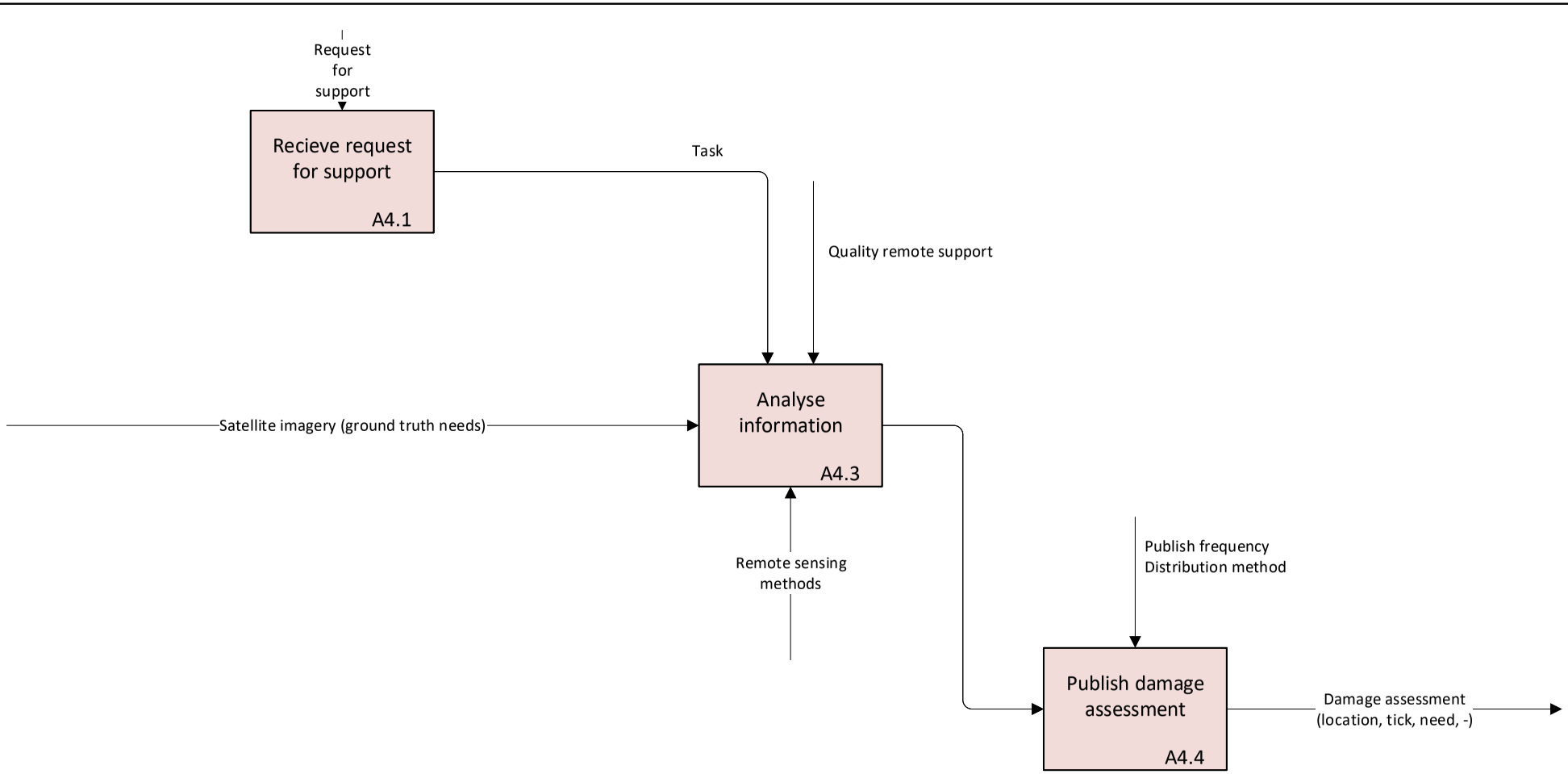

| NODE: A2 | TITLE: IM: Manage information | NO.: 11 |
|---|---|---|




| NODE: A3.2 | TITLE: IM: Exchange information | NO.: 12 |
|---|---|---|



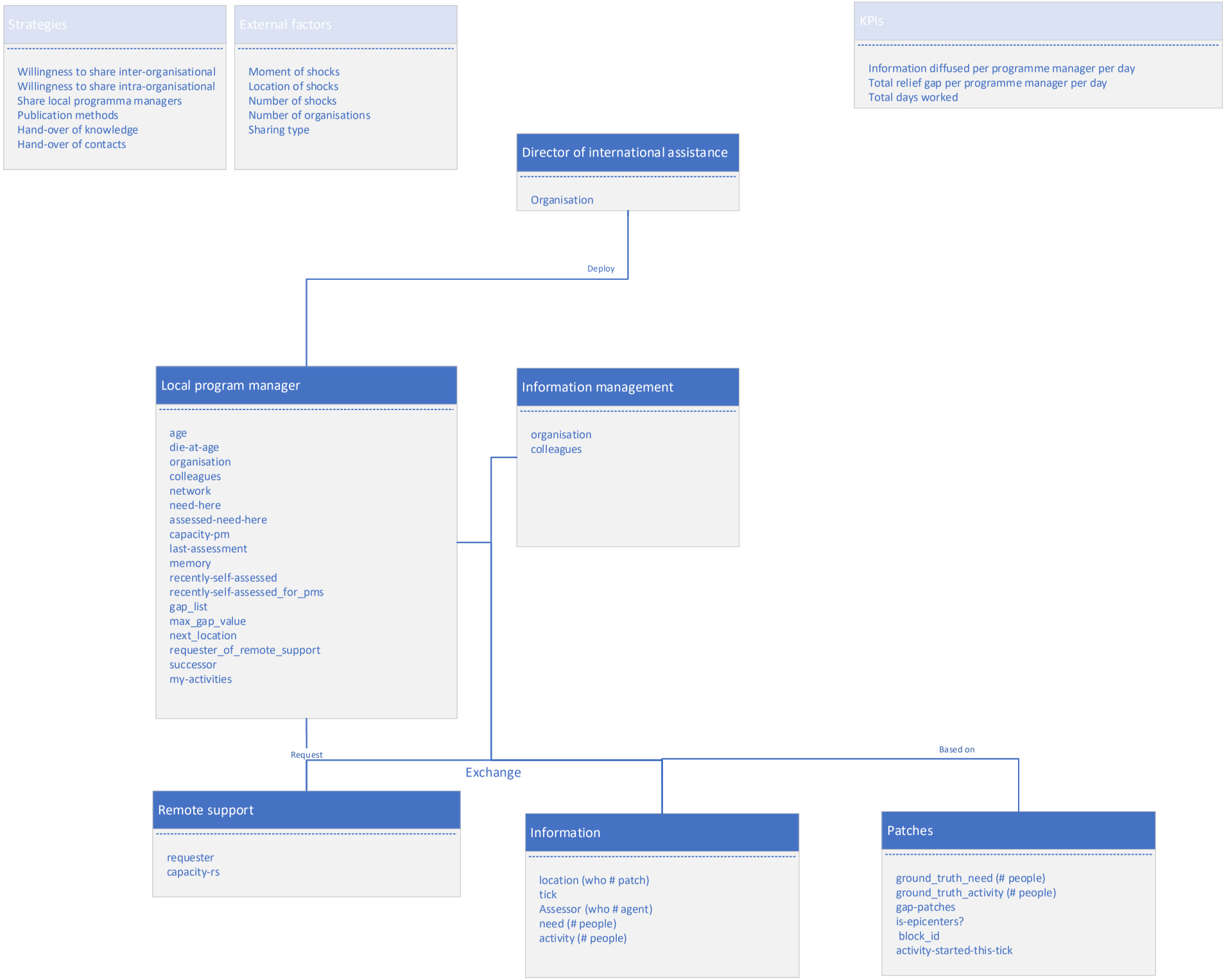

| NODE: A3.2.1 | TITLE: IM: Recieve information from PMs | NO.: 13 |
|---|---|---|




| NODE: A4 | TITLE: Remote support: provide support | NO.: 14 |
|---|---|---|

# E | UML INSPIRED DIAGRAMS

The figure on the next page shows an UML inspired diagram that provides an overview of variables used in the agent based model. The figure is an enlargement of figure 5.2. The two boxes in one of the corners of the diagram show the strategies and external factors that are changed in the experiments. The KPI box shows the variables by which the performance of the system is evaluated. The other boxes show agents or concepts, the variables that relate to these agents or concepts and the relations between the agents and concepts. Unlike other UML (class) diagrams this figure does not show aggregation relations. Moreover, it most be noted that, while the figure was used to develop the model, it does not provide an exhaustive overview of all the variables that are used in the model. Readers interested in gaining a more extensive overview of the variables are encouraged to consult the agent based model and the documentation that are published on this Github page: https://github.com/JasperCM/information-diffusion.


Strategies
Willingness to share inter-organisational
Willingness to share intra-organisational
Share local programma managers
Publication methods
Hand-over of knowledge
Hand-over of contacts
External factors
Moment of shocks
Location of shocks
Number of shocks
Number of organisations
Sharing type
KPIs
Information diffused per programme manager per day
Total relief gap per programme manager per day
Total days worked
Director of international assistance
Organisation
Deploy
Local program manager
age
die-at-age
organisation
colleagues
network
need-here
assessed-need-here
capacity-pm
last-assessment
memory
recently-self-assessed
recently-self-assessed_for_pms
gap_list
max_gap_value
next_location
requester_of_remote_support
successor
my-activities
Information management
organisation
colleagues
Request
Exchange
Based on
Remote support
requester
capacity-rs
Information
location (who # patch)
tick
Assessor (who # agent)
need (# people)
activity (# people)
Patches
ground_truth_need (# people)
ground_truth_activity (# people)
gap-patches
is-epicenters?
block_id
activity-started-this-tick

# F LIST OF ASSUMPTIONS

Table F.1 shown on the next page provides a list of assumptions that are made to construct the model. Although the list aims to show the most important assumptions, the list is not exhaustive. Readers interested in gaining a more extensive overview of all assumptions made for the model are encouraged to consult the agent-based model and the documentation that are published on this Github page: https://github.com/JasperCM/information-diffusion.

| Assumption # | Content of the Assumption |
|---|---|
| 1 | The behaviour of information needs is non-monotonous. Needs change as a result of shocks that strike at different locations at different moments in time. |
| 2 | Information is shared through social networks and through information management. |
| 3 | Information that is shared through information management in represented by a random search. |
| 4 | Programme managers are more likely to make a connection with fellow programme managers that already have many connections than with fellow programme managers that only have few connections. |
| 5 | The overall accuracy of assessments follows a normal distribution with the correct need as mean. |
| 6 | A remote assessment assesses the needs at all camps. |
| 7 | A remote assessment is only (directly) shared with the requester of the assessment. |
| 8 | Programme managers do not segment the disaster. They provide relief in all camps. |
| 9 | Programme managers start activities at the camp that, to the best of their knowledge, has the highest relief gap and where no other activities started that day. |
| 10 | Programme managers either start a needs assessment in a random camp of which they have no information or at a random camp that is close to their current location. |
| 11 | After leaving the disaster programme managers do not return. |
| 12 | A 3W only contains the most recent information that is available. |
| 13 | The size of a relief activity is a percentage of the ground truth needs at that location. |
| 14 | Needs and activities diffuse to neighbouring camps. |
| 15 | Programme managers do not deliberately share false or strategic information. Organisations are rather homogeneous. |
| 16 | Information is composed of a location, time, assessor, need (measured in # people) and activity (measured in # people). Once making decisions all information items are considered equal. Information is rather homogeneous. |
| 17 | Local and international staff have the same capabilities. |
| 18 | The amount of information or contacts that are handed over depends on the deployment length of the new programme managers. |

Table F.1: List of assumptions

# G MODEL PARAMETRISATION

Table G.1 shown on the next page provides an overview of the parametrisation of the agent-based model. Parameterising the model involves finding appropriate values for the model variables. For this study the model parametrisation has been based on the Bangladesh case study. The parameter values are set to values that are derived from literature or based on consultation with information managers in the field. the larges part of the model variables are set to constant variable. Table G.1 does not aim to provide an exhaustive overview of all the variables that are used in the model. Readers interested in gaining a more extensive overview of the variables and their values are encouraged to consult the agent based model and the documentation that are published on this Github page: https://github.com/JasperCM/information-diffusion.

| Variable | Description | Value |
|---|---|---|
| number-of-organisations | Number of organisations active in the disaster. | 4 |
| total-people-in-need | Number of people affected by the disaster. | 1000000 |
| mean_deployment_length_local | Mean of the number of ticks a local programme manager is deployed. | 180 |
| mean_deployment_length_inter | Mean of the number of ticks an international programme manager is deployed. | 90 |
| sd_deployment_length | Standard deviation of deployment length, used for normal distribution. | 6 |
| assessment_length | The number of ticks a programme manager need to conduct an assessment from start to end. | 10 |
| sd-accuracy-pms | Standard deviation of the accuracy of needs assessments conducted by programme managers. | 2 |
| sd-capacity-rs | Standard deviation of the accuracy of needs assessments conducted by remote assessment. | 4 |
| willingness_to_share_intra-org | Willingness to share information within the own organisation. | 45 |
| willingness_to_share_inter-org | Willingness to share information across organisational borders. | 45 |
| disaster-length | Number of ticks after which the simulation stops. | 730 |
| shocks | Number of shocks in a disaster. | 12 |
| epicenters | Number of epicenters at which one shocks strikes. | 2 |
| extend-network-every-n-ticks | Number of ticks between successful network events. Programme managers extend their network of this many thicks. | 14 |
| forget-after-n-ticks | Number of ticks after which programme managers forget the information that is stored in their memory. | 20 |
| min_number_of_PMs | Minimum number of programme manager that is active in the disaster independent of deployments by directors of international assistance. | 10 |
| length_IM_reporting_cycle | Number of ticks information management needs to fulfil one reporting cycle (requesting, aggregating, publishing) | 14 |
| size_activity | Percentage of the ground truth needs that are met as a result of an relief activity. | 100 |
| length_activity | The number of ticks a programme manager need to perform an activity. | 4 |
| number_of_remote_assessments | The number of remote assessments conducted in a disaster. | 4 |
| PMs-per-tick-per-DoIA | The numbers of programme managers that are deployed simultaneously by a director of international assistance. | 1 |
| goal | Percentage of the sum of the ground truth needs that the agents aim to meet. | 0.15 |
| need-diffuse-coefficient | Percentage of the needs and activities that diffuse to neighboring patches per tick. | 0.2 |

**Table G.1:** Variable description and parametrisation.

# H MODEL VERIFICATION

During and after model developed, various verification tests are executed. The verification process consists of four steps. The first step is extensive code walk-through. The second step is recording and tracking agent behaviour. The third step is interaction testing in a minimal model and the last step is extreme values verification.

**Extensive code walk-through**

During multiple stages of model development the entire code is checked. It is check whether the model functions as is expected from the conceptual model and as expected based on the description of the individual procedures. Two aspects that showed challenging to model are the link between information and relief and the way in which agents move through the grid based on their information. For these aspects multiple checks and code revisions are made. Throughout the programming process the comments are added to the model code. In addition, addition documentation is added to the model towards the end of the project. The process of adding documentation showed an effective way of checking whether the code acts as is expected. Figure H.1 shows an example of the Netlogo code. The figure, amongst others, illustrates how the documentation process complemented the extensive code walk-through

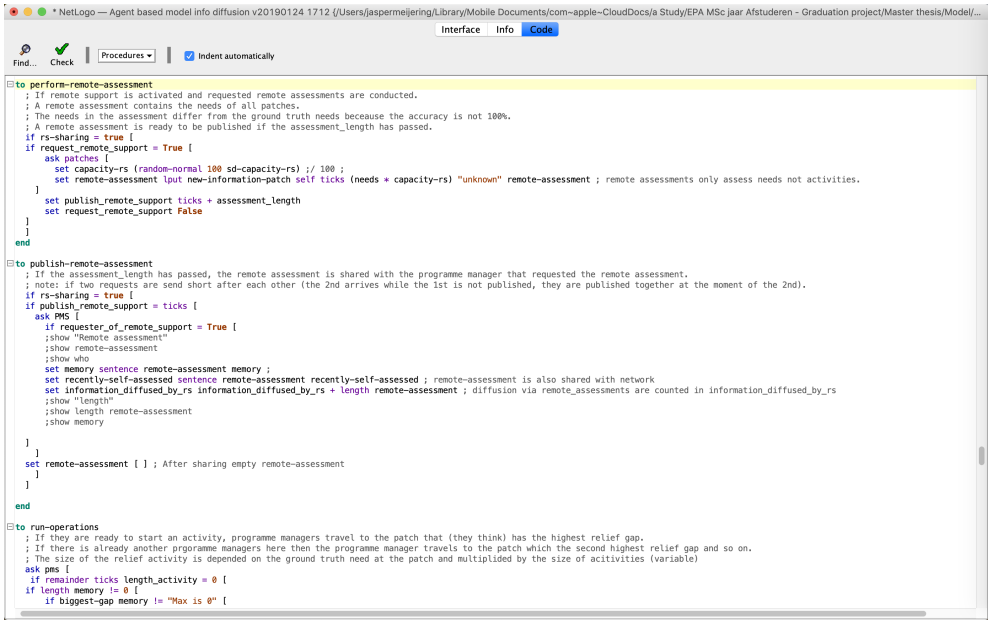



**Figure H.1:** Verification by extensive code walk-through and tracking agent behaviour

**Recording and tracking agent behaviour**

To verify the model operation relevant output variables are be selected and monitored. A number of plots in the model interface are created specifically for this purpose. Moreover, global values and values of individuals agents are tracked through global and turtle monitors. In addition, internal values of the model are reported in the command centre. Figure H.1 shows that in the *'publish-remote-assessment'* procedure various report functions are commented out. Once the semicolons are

removed, the agents report the internal values related to the variables. This enables the modeller to evaluate whether the model behaves as expected. During a relative long period in the model development process the *'exchange-information'* procedures did not behave as expected as information list were too long. This problem has been solved by extensively tracking and recording the behaviour of programme managers that were exchanging information. The recording and tracking agent behaviour verification steps are both executed for single agents and multiple agents at once.

**Interaction Testing in a Minimal Model**
Recording and tracking agent behaviour verification steps are both executed for single agents and multiple agents at once. In the 'interaction testing in a minimal model' verification step the model is run with the minimum numbero of agents necessary. It is examined whether the basic agent interactions happen correctly as laid out in the conceptualisation. Test are conducted to check whether the model produces the desired interaction and whether it executes "undesired" or unintended interactions. During a relative long period in the model development process the *'exchange-information'* procedures did not behave as expected, as information list were too long. This problem has been solved by extensively tracking and recording the behaviour of programme managers that were interacting by exchanging information in a minimal model.

**Extreme value tests**
Another method that was used for verification is the extreme-condition test. In particular, checking the behaviour of information sharing procedures under a variety of extreme conditions proved useful in checking for errors and optimising code. An example is setting the values of the *'willingness-to-share'* variables to 0 or 100%. For some variables, such as the *number of shocks* or the *number of epicentres* setting the variables to 0 was pointless so a value of 1 was chosen. The test resulted in behaviour that is in line with the expectations that stem from the interviews and literature review.

**Conclusion**
After performing and analysing all verification tests, the modeller is confident that there are no errors in the code. It is concluded that the model works as expected.

# I OVERVIEW EFFECTS INDIVIDUAL STRATEGIES

This appendix provides an overview of the effects of the six individual information sharing strategies on the three key performance indicators. Figure I.1 shows the effects on the diffusion of information per programme manager per day. The plot shown in the top left of the figure shows the behaviour of the strategy that is most effective: changing publication method from accuracy-focused to time-focused. The plot in the bottom right shows the effect of implementing structured hand-overs of knowledge, this strategy is not effective in increasing information diffusion.

Figure I.2 shows the effects of the six strategies on the relief gap. To facilitate easy comparison the order in which the strategies are presented is the same as the order in figure I.1. The plot shown in the top left of the figure shows the behaviour of the only strategy which effect is significant. Changing publication method increases the efficiency by which the goal of the relief operation is met. As a result, it significantly decreases the relief gap in a disaster. For the other strategies this effect is not significant.

Figure I.3 shows the effects of the six strategies on the number of days worked. To facilitate easy comparison, the strategies are, again, presented based on their effectiveness to increase information diffusion. The plot shown in the top left of the figure shows the behaviour of the only strategy which effect is significant. Changing publication method significantly decreases the number of days programme managers need to provide the level of information diffusion and realise the relief gap shown in the previous figures. The plot in the top right corner of the figure suggests that the number of days worked increases as the share of local programme manager increases. This effects is, however, not significant. This is also the case for the effects of the other strategies.

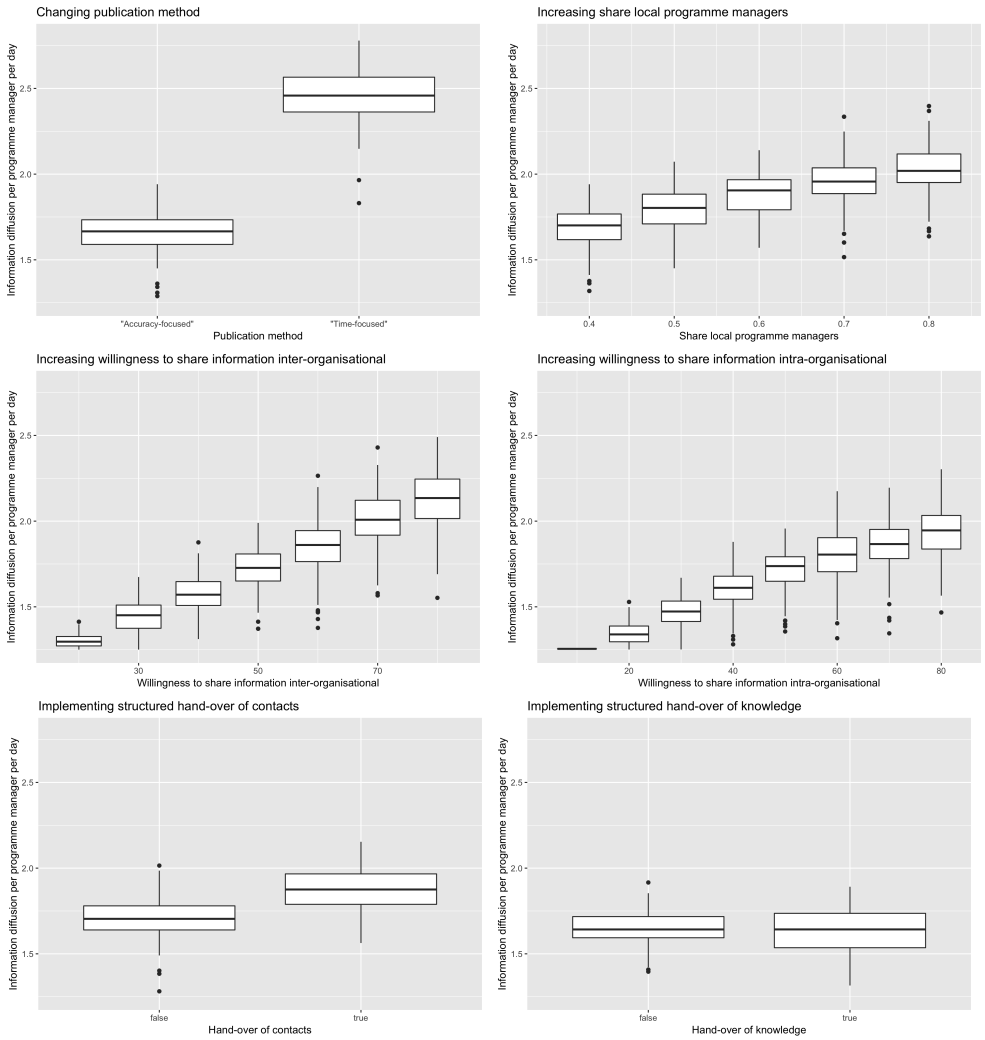



**Figure I.1:** This figure shows the behaviour of the effect of the six strategies on the diffusion of information. The plot shown in the top left of the figure shows the behaviour of the strategy that is most effective: change publication method from accuracy-focused to time-focused. The plot in the bottom right shows the effect of implementing structured hand-overs of knowledge, this strategy is not effective in increasing information diffusion.

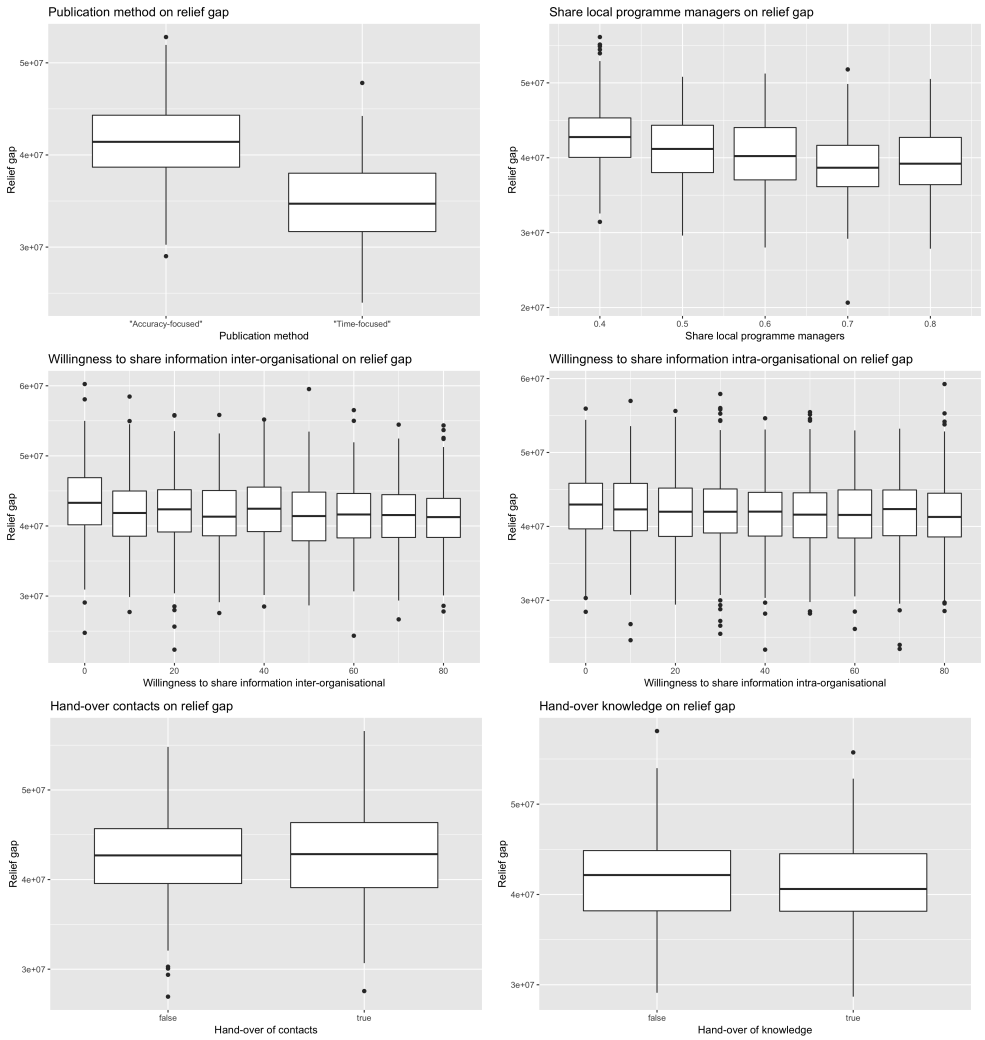



**Figure I.2:** This figure shows the behaviour of the effect of the six strategies on the relief gap. The plot shown in the top left of the figure shows the behaviour only strategy which effect is significant. Changing publication method increases the efficiency by which the goal of the relief operation is met. As a result, it significantly decreases the relief gap in a disaster. For the other strategies this effect is not significant.

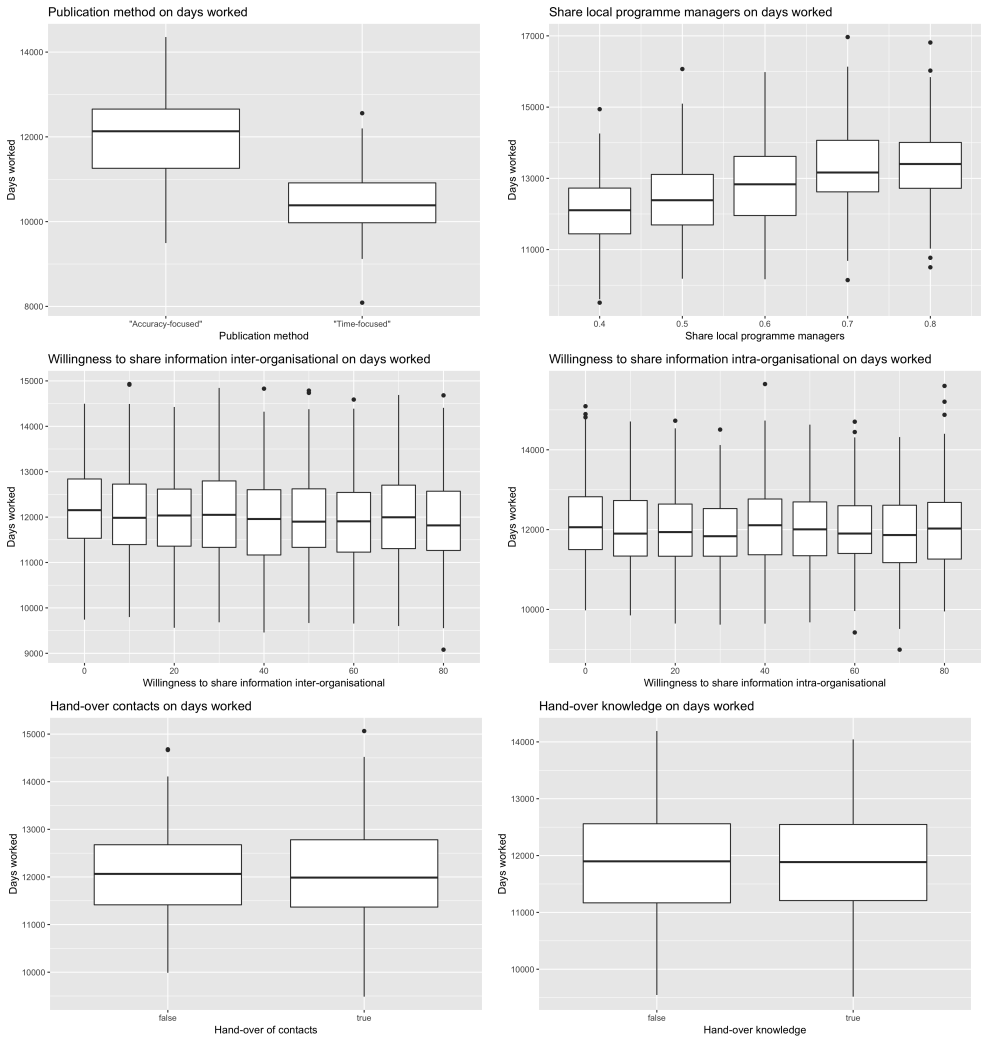



**Figure I.3:** This figure shows the behaviour of the effect of the six strategies on the number of days worked. The plot shown in the top left of the figure shows the behaviour of the only strategy which effect is significant. Changing publication method significantly decreases the number of days programme managers need to work in the response. For the other strategies this effect is not significant.

# J VALIDATION BY EXPERT CONSULTATION

The validation effort conducted for this study revolves around the question of how the findings based on the case study can be generalised to other complex emergencies. The first validation method that is used is validation by expect consultation. This appendix discusses the setup and outcome of applying this method.

**Set up expert validation interviews**
Two humanitarian professionals are approached through the professional network of the research team. The details of these individuals are shown in figure 9.1. The interviewee are asked to reflect on the system description, conceptualisation and outcomes of this study. Specifically they are asked whether they recognise the barriers and driver and how the description of the case study and focal decision selected for this study differs from other complex emergencies. In addition, the researcher explains the BPMN conceptual diagram and asks questions on its suitability to capture the important concepts of information sharing in a complex disaster. Lastly, the researcher presents the effects of the six individual information sharing strategies on the 3 KPIs. The interviewees are asked how effective they think the strategies would be in a disaster in which they have been deployed to.

The entire interviews are recorded digitally. Based on the recordings a structured story line is created. In this story line the discussion points, comments and remarks are grouped in three categories: system description, conceptualisation and outcomes of this study.

**Reflection system deception**
According to interviewee number 1, the Bangladesh-Myanmar displacement crisis is not a disaster that faced many issues. The interviewee is an experienced humanitarian who now takes the role of operational logistics coordinator. He evaluated multiple responses, including the the logistics response in Bangladesh. The interviewee mentioned that his organisation was also already present in the refugee camps in Bangladesh and that this facilitate better information sharing. This is one of the drivers mentioned in the system description. The interviewee also mentioned the good networking opportunities especially with the government in Dhaka, Bangladesh's capital as additional driver. This driver is not mentioned in the system description nor is the government included as an agent in the model.

Regarding the barriers, the interviewee stated that, in his opinion, some of the barriers are almost inevitable. An example is the sub-optimal information sharing through organisations fighting for the same funds. Interviewee 1, does not see the absence of OCHA as a neutral and experience partner as a very important barrier. According to him, there is always another organisation that takes the lead if OCHA is not present. He does, however, emphasise that the Bangladesh-Myanmar displacement crisis is very political and that this influences information sharing.

Interviewee number 2 mentioned that hygiene kit distribution differs from other types of relief activity because it is relatively easy to measure. As one hygiene kit serves a fix number of people (one person or one family), it is easy to calculate how many people have been reached by this type of relief. In contrast, if an organisation is building latrines, it is more difficult to assess how many beneficiary have been

reached by one latrine. Indeed, how many people are reached by a latrines depends on the number of people that use it and this cannot be measured easily as it is dependent on a lot of factors, including time. As a result, hygiene kit distribution may seem an activity that compared to other activities reaches a lot of people while in reality this might be less.

Interviewee 1 and 2 both mention that information sharing with regards to hygiene kit distribution differs from information sharing that pertains to other type of relief activities. Whether information is shared depends on the nature and content of the data. This is the case for information sharing in general and for increased information sharing that is the result of an implemented strategy. To illustrate this with an example, sharing of information related to hygiene kit distribution might increase as an effect of a strategy. This, however, does not mean that sharing patient data will also increase with the same amount as a result of that same strategy.

**Reflection conceptualisation**

Once presented with the conceptual diagrams made for this study, the interviewees recognised aspects of the processes from their own organisations. An example is the idea of disasters evolving as sets of shocks. Interviewees also mentioned differences between the conceptualisation developed for this study and the image they created based on their experiences. Non of the interviewees that were presented with the question showed that they were able to systemically assess the generalisablity of the conceptual model. They did not state that the conceptual diagrams were wrong or right. Instead, they mentioned that they were not able to make any substantive comment about diagrams in the limited time that was available.

**Reflection effectiveness strategies**

While being confronted with the effectiveness of the individual strategies, interviewee 1 expressed his belief that once compared to international staff, local staff can be more susceptible to pressure of the local community. According to this interviewee, it could even be that a local staff member has a own agenda that is not aligned with the interest of the broader community or the relief agencies. In addition, the interviewee mentioned that while increasing the share of local programme managers could increase a bias, this does not mean that international programme managers are 'clean'. This humanitarian professional also shared that, in his opinion, information sharing within his organisation is quite clear. He thinks that increasing intra-organisational information sharing offers less room for improvement once compared to increasing inter-organisational information sharing.

Once presented with the effectiveness of the six individual strategies, interviewee 2 mentioned that she expects that strategies that are less specific to the nature of the information are more likely to be effective strategies in a general sense then others. According to her reasoning, increasing the share of local programme managers and the two hand-over strategies are strategies that could be effective for a wider range of relief activities. In contrast, whether changing publication method and increasing willingness to share information are effective is more dependent on the difference between the relief activity where is generalised to and hygiene kit distribution.

# K | SET-UP FOCUS GROUP DISCUSSION

This study is conducted at 510, the data initiative of The Netherlands Red Cross. As part of the face validation of the study, the team members of 510 are asked to structurally reflect on the critical assumptions and main findings of the analysis. About 100 team members are approached by sending them a message on the internal communication platform. In an attempt to have a participating group that is both large in number and divers in responsibilities, experience and background, this message is kept to the point and informal. As a result, 16 individuals participated in the workshop. Of this group, 8 team members actively participated in the discussion. Table 9.1 provides an overview of the functions and experience of the active participants with regards to their deployments. Some of the team members have years of experience, working for different organisations in the humanitarian and development sector in many different countries. Others were only deployed once or twice. Two of the participants do not have in field experience. In addition, two of the participants join 510 on a voluntary basis.

The workshop consists of three parts. The first part introduces the problem, research questions, approach chosen for the study. This part also explained the conceptual and agent based model for the study. In addition to setting the stage for the subsequent parts, this part was also aimed at explaining what their colleague, the writer of this thesis, has been doing in the previous months. The second parts discussed the information sharing strategies and their effects according to the information diffusion model that is parameterised for the Bangladesh-Myanmar displacement crisis. The discussion was facilitated by asking questions about expected effects and about to what extend the participants recognised the findings. Main goal was to point the group, including the researcher, into the direction of the strategies which outcome is most surprising. Because the time for the workshop was limited to one hour, this effort helped distillation of directions for further discussion. The strategies with the most surprising effects were discussed in more detail, amongst others by discussion what effects could be of the strategy in another response. The last part of the discussion involved the critical assumptions of the model. A number of critical assumptions was introduced, as shown on the slides on the next pages. Important questions in this final part of the discussion were 'do you think this assumption is valid' and 'what could be an alternative assumptions'.

The entire discussion is recorded digitally. Based on the recordings a structured story line is created. In this story line the discussion points, comments and remarks are grouped in three categories general comments, strategy related comments and assumptions related comments. This effort facilitates easier comprehension of the comments and allows for a comparison of all the points raised. To make sure the story line reflects the actual content of the meeting and to prevent cherry picking, the story line was discussed and agreed upon by one of the participants.

The slides that were used to facilitate the presentation and the discussion are shown on the next pages. The story line drafted to structure the comments made by the participants is included in appendix L.


510 AN INITIATIVE OF THE NETHERLANDS RED CROSS

HumTechLab TU Delft

## CONTENT

- Introduction to research project and the developed model.
- Discussion on the effectiveness of information sharing strategies.
- Discussion on the assumptions made for the model.



## Problem: What happens after publishing?

**Some questions:**

What happens with our assessments?

Do people understand how to interpret our products?

Are our assessments used in a responsible manner?

How do partners deal with uncertainty in the predictions of the priority index model?

Are our partners satisfied?

Did our work have impact?

How can we get more feedback?



## Problem: What happens after publishing?

Objective:

**Evaluate** the effects of various **information sharing strategies** on the **diffusion of information** in complex disasters.

Approach:

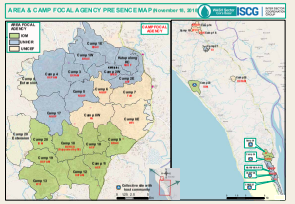
Develop agent based model based on a case study.

Today:

Assess generalisability of the model and its results



## Case study: Displacement in Bangladesh



Complex disaster

+/- 925.000 people displaced

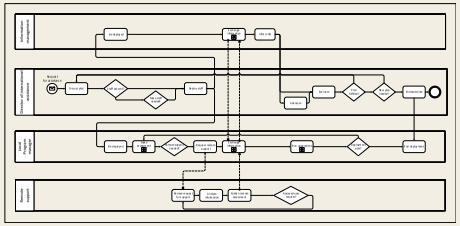
Large Influx fall 2017

**Specifically looked into**

WASH: Hygiene kit distribution

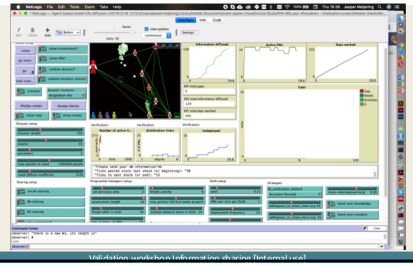
Need assessments and 4Ws

## Conceptual model





## Agent based model



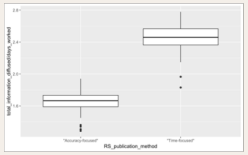



## Information sharing strategies

| Changing publication method | Increasing share of local staff | Increasing willingness to share x2 | Implementing structured hand-overs x2 |
|---|---|---|---|
| Highly accurate information products or near real-time | Or increasing length of international deployments | Either within organisations or between organisations | Either of knowledge or of contacts |

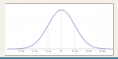


## Changing publication method



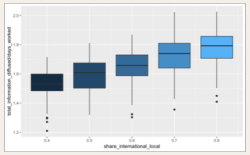
Assumptions

- A remote assessment is only shared with the requester. S/he shares the information with partners in the field.
- The overall accuracy of assessments follows a normal distribution with the correct value (need) as mean.





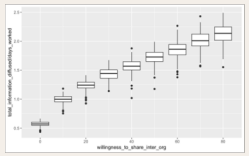
## Increasing the share of local staff



Assumptions

- Mean deployment length of local staff is on average twice as long as international staff.
- Local staff have the same qualifications as international staff

## Increasing willingness to share

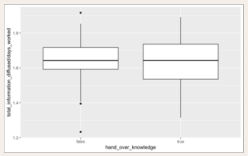


Assumptions

- Willingness to share information can be increased in a responsible manner.
- More Information is shared through social networks once compared to formal procedures.



## Implementing structured hand-overs



Assumptions

- Information or contacts are handed over to one colleague, the successor.
- The amount of information/contacts that is handed over depends on the deployment length of the new programme manager.



## Back-up: Additions to the model?

What aspect could/should be added to the information diffusion model to make it more accurate , comprehensive or useful.



## Back-up: shocks and social networks

- Once deployed, do you often share information in your social network.
- Once deployed, do you of share information with other organisations because it is agreed.
- Once deployed, do you experience 'shocks' that fundamentally change the needs in the disaster?

# L | OUTPUT FOCUS GROUP DISCUSSION

This study is conducted at 510, the data initiative of The Netherlands Red Cross. As part of the face validation of the study, the team members of 510 are asked to structurally reflect on the critical assumptions and main findings of the analysis. Appendix K discussed the set-up that was chosen to approach the face validation. This appendix provides the story line that is created based on the audio recordings of the validation session. This story line structures the discussion points by grouping them into general, strategy related or assumption related comments or remarks.

## General comments

Recurring element in the validation session was the observation that response operations in humanitarian disasters are in general very context specific. The researcher and its audience should consider that, as one of the participants puts it: *"We are talking about data in an industry that was previously only pertaining to the skill set of humans involved in the procedures"*. The effectiveness of a strategy might change according to an set of associated factors, factors that might be or might not be considered in this study. This highlights the need of an accurate parametrisations and consideration of the difference between disasters. In addition, the researcher and its audience should be aware of the elements that are not included in the study. Beside many cultural, historical and social dimensions these include the resources that are needed to implement the strategies. The following paragraphs discuss these points in the context of specific strategies and assumptions in greater detail and provide additional examples that were given by the participants.

## Discussing the strategies

The discussion mainly revolved around the increasing the share of local staff strategy, the changing publication method strategy and the increasing willingness to share information strategies.

**Increasing the share of local staff**

One of the participants discussed his experience with the share of local and international delegates in a response operation in Sint Maarten. This professional shared that he thinks that increasing the share of local staff would not have been very beneficial in this situation especially because of cultural and political reasons. This sparked a discussion about the benefits of international versus local delegates. The group discussed that local staff can provide the team with information that might be very difficult to obtain by an international delegate. At the other hand international delegates maybe able to get objective information because they are not caught up in the social and culture web that local staff is. They may be able to discuss topic that are taboo locally an experienced humanitarian added. In addition the point was raised that if there is more local staff there could be more problems that are related to culture and related to political issues. Tension can rise both as you increase or decrease the share of local vs international staff. In some case, however, you might not have an option to change the composition of the team. According to an experienced professional, this was the case in, for example, the context of East Timor where historically some groups of local staff grew in certain positions. He added that knowing whether the share of local people should be increased is finding

the right balance between local and international staff. Finding the right balance is very context specific. Often individuals or organisations do not really try to find a balance but stick to the status quo. He concluded that, certainly there is potential, but whether more or less works best depends on the local context.

Another point that were brought up in this discussion is the question of *"more local at which level"*. A participant shared: *"I think we have a tendency to think more local means more field based staff, but what about increasing the number of locals in senior management?"*.

**Changing publication method**
According to one of the participants, *"the question of the required sample size is one of the points that is most often discussed in the field"*. Her colleagues frequently questioned whether a bigger sample size was needed or that the current one was big enough. *"Some people say we are not a scientific institution and as 100% accuracy can never be reached we should have smaller sample sizes, others disagree."*

**Increasing willingness to share**
The same professional shared that she thinks increasing willingness to share information inter-organisational is especially a difficult strategy for the Red Cross because of political issues. She added that this also depends on the counterpart and the country in which the strategy is implemented. She mentioned that *"there are some very clear examples of case where we don't want to share"*. These include situations where we do not want to come through as part of the government. *"I have been in some very long conversation revolving around the question of whether we should or should not attend the meeting"*.

## Discussing the assumptions

The discussion on the assumptions many revolved around the assumption about the accuracy of assessments, the use of information as strategic asset and the difference between local and international staff.

**Representing the accuracy of assessments by a normal distribution**
Once confronted with the assumption that the overall accuracy of the assessments is represented by a normal distribution, the participants mentioned that this is also the distribution they would think of. One of the participants shared that *"within humanitarian aid we are not re-validating assessments. At least, I have never seen a valuation of an assessments, possibly because it is very difficult to do"*. As a result, he thinks that there is not a lot of data available to test this assumption. Another participant shared that, from her perspective many assessments are overestimated. She shared that *"beneficiaries know you are from an humanitarian organisations, if they over-estimate the situation then they receive more aid."* That is the reason why she uses proxies: *"we do not ask how much you earn, instead we ask how many cars one has. In the same way we do not ask how much damage was done to your house, we ask does your house have a roof"*. She added that whether a normal distribution is representative also depends on the type of assessment. Subsequently, she posed the question of how accurate a rapid assessment needs to be. *"I have never been in a situation where I gave relief items to people that did not need it. It is most important to know where the biggest needs are. You go there and continue your assessments along the way"*.

Relating to the use of remote imagery data one of the participants shared his experience with Missing Maps. He putted forward that various different volunteers use various different approaches to map areas. Especially, in difficult to map areas this causes problem as some volunteers add biases to the data. In cases where that are to many clouds we often decide to not use satellite imagery at all. To counter this

problem various validation methods are applied. In addition, it can be countered by providing better instructions. At the other hand, you do not want to give to many instructions because this might discourage volunteers. If we share data products we aim to share as much information on the methods that are used as possible.

**Strategic behaviour and the spread of false information**
On various moments during the discussion, participants shared points that related to strategic use of information. Some parties may purposely share biased information. Moreover, actors may share in-factual or false information. *"As the spread of false information affects your ability of diffuse factual information one should be aware of any false information being shared"*. One of the participants shared that this is the reason organisations in Congo are actively monitoring rumours and the spread of misinformation. Knowing that false information is spread might force you to choose other methods to share information.

**Differences local and international staff**
Once confronted with the assumption that there is no difference in the ability between local and international staff in terms of executing assessments, the participants shared that they think it is a fair assumption. Both for the accuracy of the assessment and for time needed to do an assessments there is no difference between international and local delegates.

## Suggested extensions to the model

While concluding the validation session, the researcher felt the need to ask whether there are any points, that were not discussed yet but could be useful additions to the model. The point that was raised after this question relates to the user experience of information products. One of the participants explained that the user experience, as perceived by the information user, can affect the diffusion of information. She stresses that, how well one is able to comprehend a piece of information depends on the information product and the level of skill and understanding of the user, this affects the likelihood that information is shared. Following this line of reasoning, it would be relevant to study how much information is retrieved from an information product and how this affects information sharing. One of the participants added that, in her opinion, continuously changing publication formats of, for example sit-reps, impede effective production, comprehension and use of information products.

# M | STRUCTURAL VALIDATION

To evaluate the effects of the ABMs assumptions two additional experiments are performed as part of the structural validation. The first experiment provides a sensitivity analysis of the assessment length variable. The second revolves around the assumption that accuracy of the assessment can be represented by a normal distribution with a mean that corresponds to the correct value. This experiment test the effect of using a skewed normal distribution and two bimodal distributions.

**Sensitivity analysis assessment length**

For the experiment conducted to test its sensitivity, the assessment length variable is increased from 4 to 12 with increments of 2. Each combination is replicated 50 times. Figure M.1 shows the results of sensitivity analysis. The figure shows that the variable is sensitive for changes in its parametrisation. The expected cause of this effect is that, as the assessment length is shorter the number of assessments a programme manager can perform increases. This leads to a higher number of information items that is shared. In turn, the higher number of information items leads to a lower relief gap and a lower number of programme managers that is needed in the disaster.

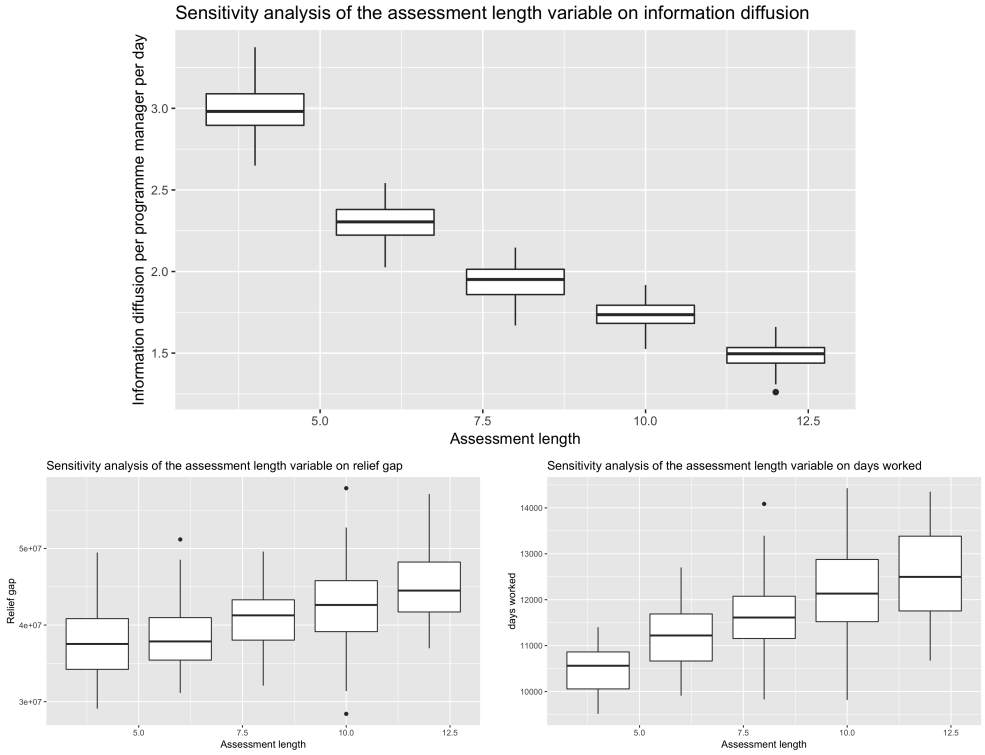



**Figure M.1:** Sensitivity analysis of the assessment length variable

This observation highlights an opportunity for further research. It is recommended to test the effect of changing the model in a way that a decrease in assessment length does not lead to more assessments. Moreover, given the sensitivity of the *assessment length* variable, it is advised to perform a sensitivity analysis on the *length*

*IM reporting cycle* variable as well. This is one of the other variables that determines when an assessment is performed. Lastly, this observation strengths to need to make the process by which programme managers use information to decide where to start a relief activity more realistic. The later forms the major recommendation for extension of the model.

**Representing the accuracy of assessments by alternative distributions**
To evaluate how the outcomes of the study are effected by the assumption that the accuracy of assessments can be represented by a normal distribution with as mean the correct value, the accuracy is assessments is represented with three alternative distributions. The alternative distributions are a left-skewed normal distribution, a bimodal distribution and left-skewed binomal distribution. For the left-skewed normal distribution the mean corresponds to 90% ground truth need. This distribution resembles assessments that are structurally underestimating the true value. The bimodal distribution has two peaks, one corresponding to 80% and one corresponding to 120% of the ground truth needs. This resembles the situation in which there are both assessment in use that structurally underestimate and overestimate the true needs. The last distribution is differs from the other binomial distribution that the structurally underestimating assessments out-way the overestimating once is a ratio of 3 to 1. All other variables, including the standard divisions, are equal to the reference scenario. Each combination of of variables is replicated 50 times.

Figures M.2, M.3 and M.4 show the effect of changing publication method from accuracy focused to time focused for the four different distributions on respectively information diffusion, relief gap and days worked. The top plot shows the effect under the normal assumption, the second the effect for the left-skewed normal distribution, the third the effect for the bimodal distribution and the bottom plots shows the effect for the left-skewed bimodal distribution. To gain an understanding of the effect of changing the accuracy assumption these plots should be evaluated, and that for all three KPIs.

Interpretation of the three figures leads to the conclusion that there is no significant effect of changing the accuracy distribution from a normal to bimodal distribution. For each figure there is no structural difference between the top and bottom two plots. Once taking a closer look to figure M.2, one sees that there is also no effect of changing the distribution on the diffusion of information. The four plots are comparable.

Close inspection of the effect on the relief gap shown in figure M.3 does suggest an effect of changing accuracy distribution. The relief gap for the two left-skewed distributions is slightly higher then the non-skewed distributions. This observation suggests that disasters in which assessments are used that structurally underestimate the true needs, yield higher relief gaps. Once taking a closer look at figure M.4, one can also see one differences between the boxplot bars. The bottom of the accuracy-focused publication method of the left-skewed normal distribution relates to a higher number of days worked once compared to the bottom of the accuracy-focused publication method of the non-skewed normal distribution. This is interpreted as, if you focus on getting a high accuracy but are structurally underestimating the needs, diffusing information and providing relief takes more time then when you are not underestimating the needs.

The four observations are inline with expectations. This strengthens the belief that the assumption that the accuracy of assessments can be represented by a normal distribution is justifiable. The model yields largely similar results once representing the accuracy by a normal distribution, compared to representing accuracy by an alternative distribution. Compared to the other distribution the normal distribution only leaves out small nuances in the final outcome. These differ-

ences in nuances are not per se more realistic. Once interested in these nuances, this study provides a standpoint for closer examination. When pursuing this research direction one is advised to use more sophisticated methods to assess significance, as the differences between effects of the distributions are small. Readers interested in a larger version of the figures shown in this appendix are advised to consult the R-script, data and images files that are published on this Github page: https://github.com/JasperCM/information-diffusion. This R-script also contains analysis of additional experiments that examine the effects of replacing the normal distribution assumption with other distributions. The results of these experiments are all inline with the conclusions discussed in this appendix.

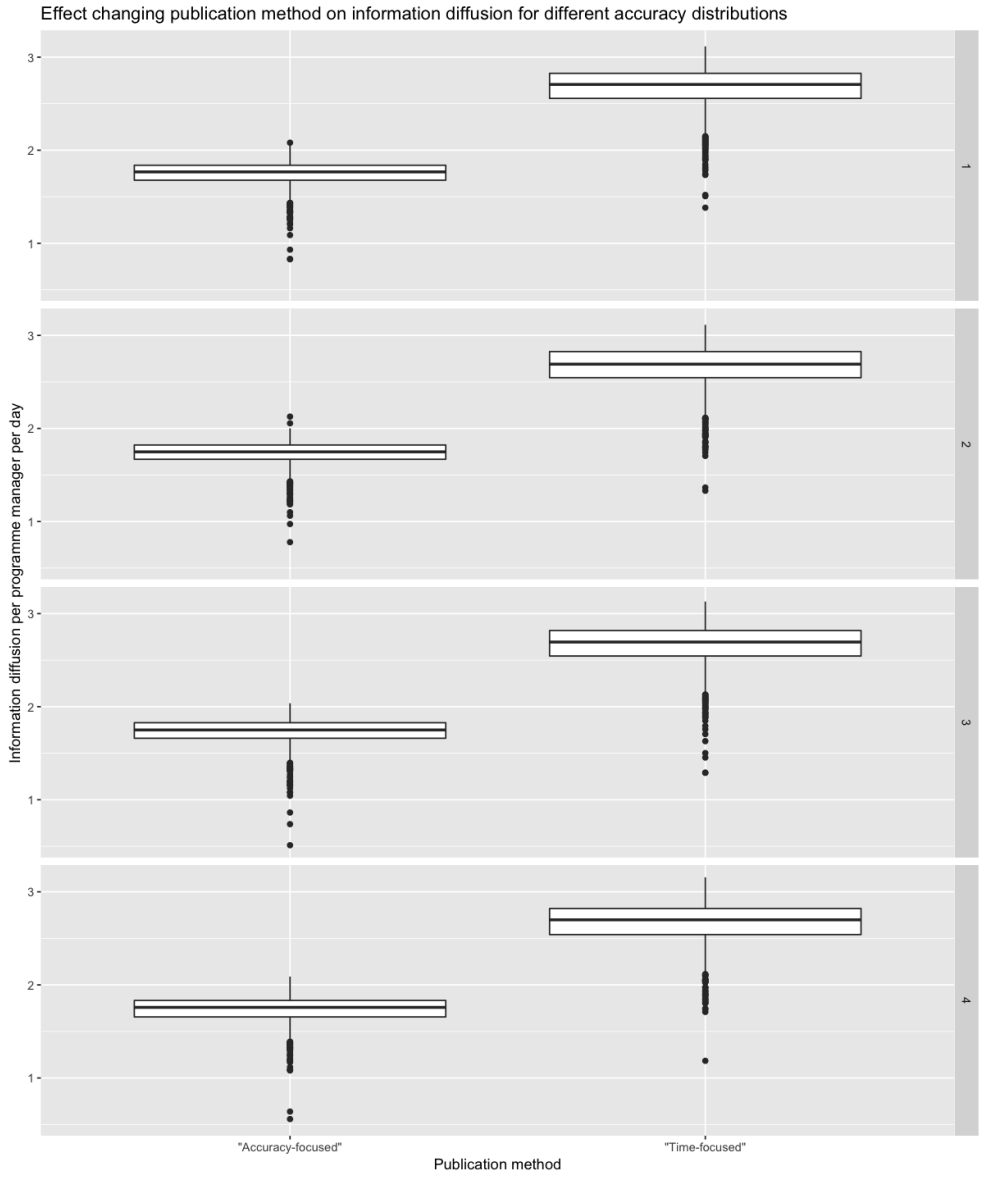



**Figure M.2:** This figure shows the effect of changing publication method from accuracy-focused to time-focused on the diffusion of information. The top plot shows the effect under the normal assumption, the second the effect for the left-skewed normal distribution, the third the effect for the bimodal distribution and the bottom plots shows the effect for the left-skewed bimodal distribution.

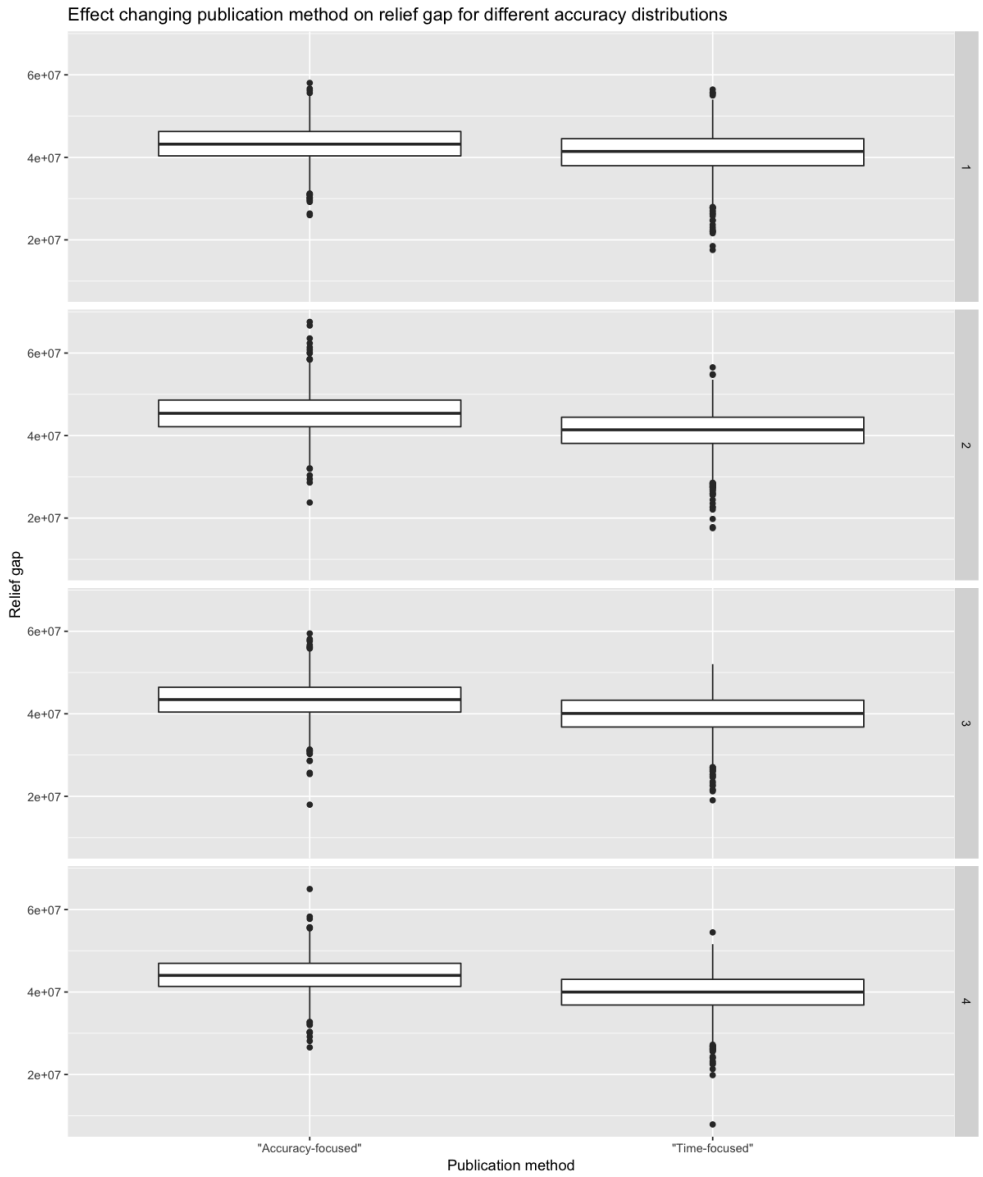



**Figure M.3:** This figure shows the effect of changing publication method from accuracy-focused to time-focused on the relief gap. The top plot shows the effect under the normal assumption, the second the effect for the left-skewed normal distribution, the third the effect for the bimodal distribution and the bottom plots shows the effect for the left-skewed bimodal distribution.

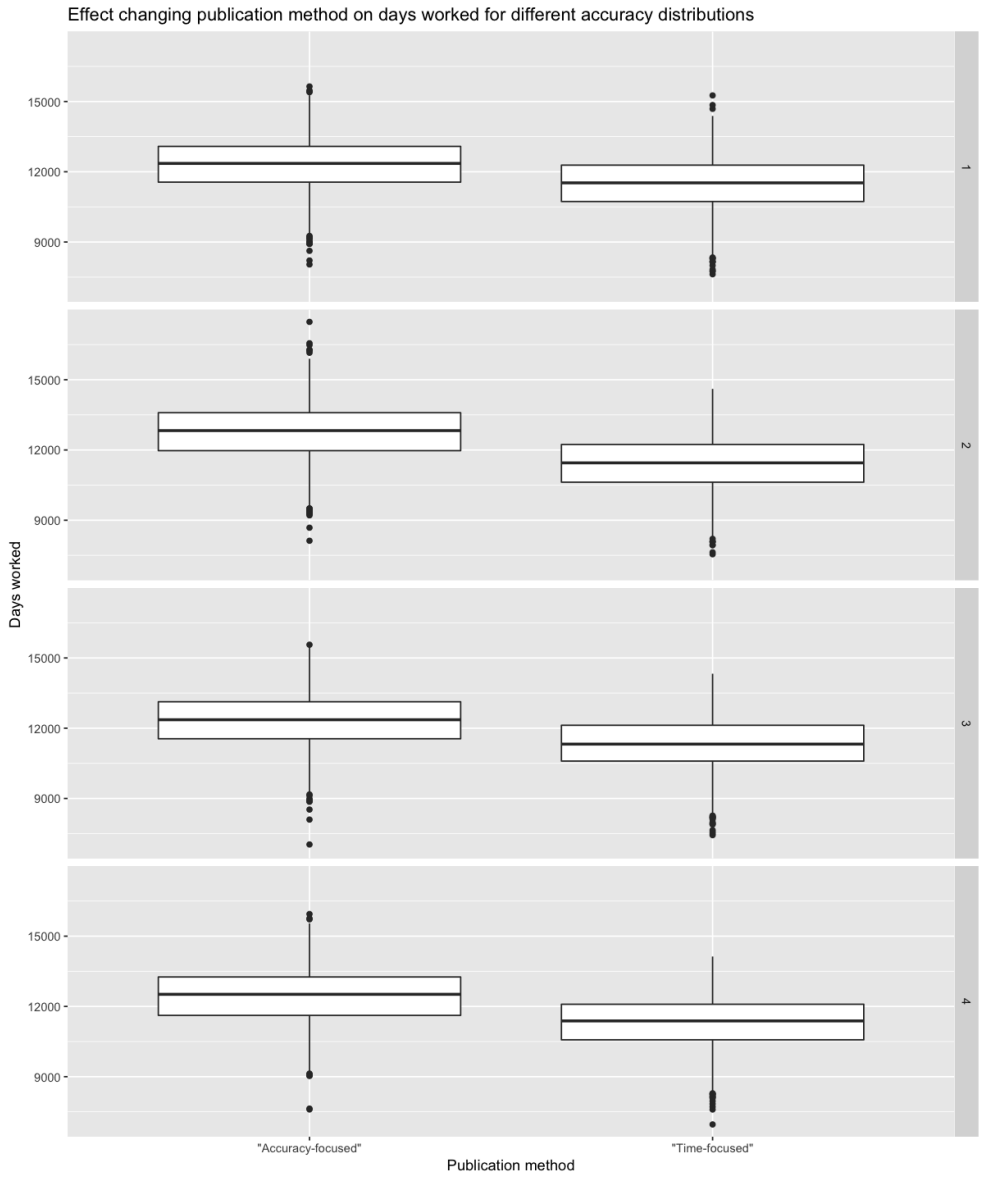



**Figure M.4:** This figure shows the effect of changing publication method from accuracy-focused to time-focused on the days worked. The top plot shows the effect under the normal assumption, the second the effect for the left-skewed normal distribution, the third the effect for the bimodal distribution and the bottom plots shows the effect for the left-skewed bimodal distribution.

# N REFLECTION ON BROADER USE OF THE APPROACH IN FUTURE RESEARCH

This study states that it provides the most generic model-based approach to evaluate information sharing strategies in complex, humanitarian disasters. A logical follow up question would be "could this approach also be used in other contexts"? The obvious, but slightly disappointing answer is that this is to be explored and other scholars are encouraged to try to answer this question. This appendix provides two examples of fields in which the approach could potentially be used along with a motivation of why it could be effective.

On an annual basis, multiple hurricanes and tropical storms ravage islands and countries in the Caribbean. An example of a hurricanes causing damage and taking lives is hurricane Irma. On the 6th of September 2017, the relatively powerful hurricane hit (amongst others) the island Saint Martin, ruining large parts of the island and causing an emergency that could be classified as a sudden-onset, natural disaster. Just as the complex emergencies analysed in this study, this disaster could be seen as series of shocks. Days after Irma made landfall, humanitarian relief to the islands was severely effected by a second hurricane, hurricanes Jose (KNMI, 2017). In addition, days after the hurricanes reports arrived of armed robberies and looting of Hotels (NRC, 2017).

With a different parametrisation, the model developed in this study could also be used for this case or other natural, sudden-on set disasters. This would require setting the length of disaster, the number of people affected, the willingness to share and number of shocks to and other variables to values that correspond to the situation at hand. An addition to the model that is worth considering, especially when analysing natural, sudden-on disasters is a component that would simulate the communication infrastructure by which information is shared. Adding is reliability and indeterminacy attributes to this infrastructure is advised. In the current version of the model a situation with no information sharing can be replicated. The model does, however, not allow for intermitted sharing.

Also outside the humanitarian sector there is a great number of other 'Global challenges' in which information diffuses in processes that show similarities to information diffusion in complex emergencies. Among these challenges multiple cases can be characterised as events that are affected by series of shocks about what information is shared in social networks. In 2015, the World Bank published a study named *'Shock Waves'*. This study explains how *"Poor people and poor countries are exposed and vulnerable to all types of climate-related shocks."* The shocks that are mentioned as examples in this study include crop failure from reduced rainfall, health shock and food price shocks due to drought or crop disease. According to the study, *"Climate change will worsen these shocks and stresses, contributing to a decoupling of economic growth and poverty reduction, thereby making it even harder to eradicate poverty in a sustainable manner"* (Hallegatte et al., 2015).

The World Bank study considers a number findings that are relevant in the relation to this research and that could trigger other scholars to apply an approach that is comparable to the one used here. As example, one could study the effects of

extreme weather events on information sharing about migration and the outbreak of violence. Perez Salazar, Diaz and Lopez conducted a study on the relationship between natural hazards and poverty. They designed a systemic model of natural hazards and poverty to help evaluate the agenda of the Mexican government. They conclude that *"In order to attend the systemic nature of natural and social systems interaction [...], it is required to move from agency – actions operating in closed silos - towards a systemic resilience building action. This implies that those actions to increase response and recovery capacity, as well those oriented to mitigation, will have to be designed in a transversal and holistic way"* (Perez Salazar et al., 2016). While their causal loop diagrams capture the main feedback loops in the system, they do not account for the way in which shocks, caused by the natural hazards that they study, change the system. The model developed for this study could extend the work of Perez Salazar et al. Where the patches in the developed model currently represent blocks in refugee camps, the same model could be used to represent communities in remote provinces suffering from extreme whether events. The current programme managers could then represent groups of people migrating, looking to create new livelihood opportunities and sharing information about their plans and well-being in social networks. According to Linke, Witmer, O'Loughlin, McCabe and Tir (2018), migrants in Kenya, who have relocated due to droughts and water shortages are more likely to be attacked outside of the home than those who have not reported moving for this reason. Their research raises the expectation of a connection between shocks caused by natural hazards and shocks in violence. A connection which existence and effects could be evaluated using approached developed for this study.

# O | RESEARCH POSTER

Figure O.1 shows a small version of the research poster that is designed to synthesise this research project. This poster is presented at at the Humanitarian Networks and Partnership Week 2019. A larger version of the poster can be found on this Github page: https://github.com/JasperCM/information-diffusion.

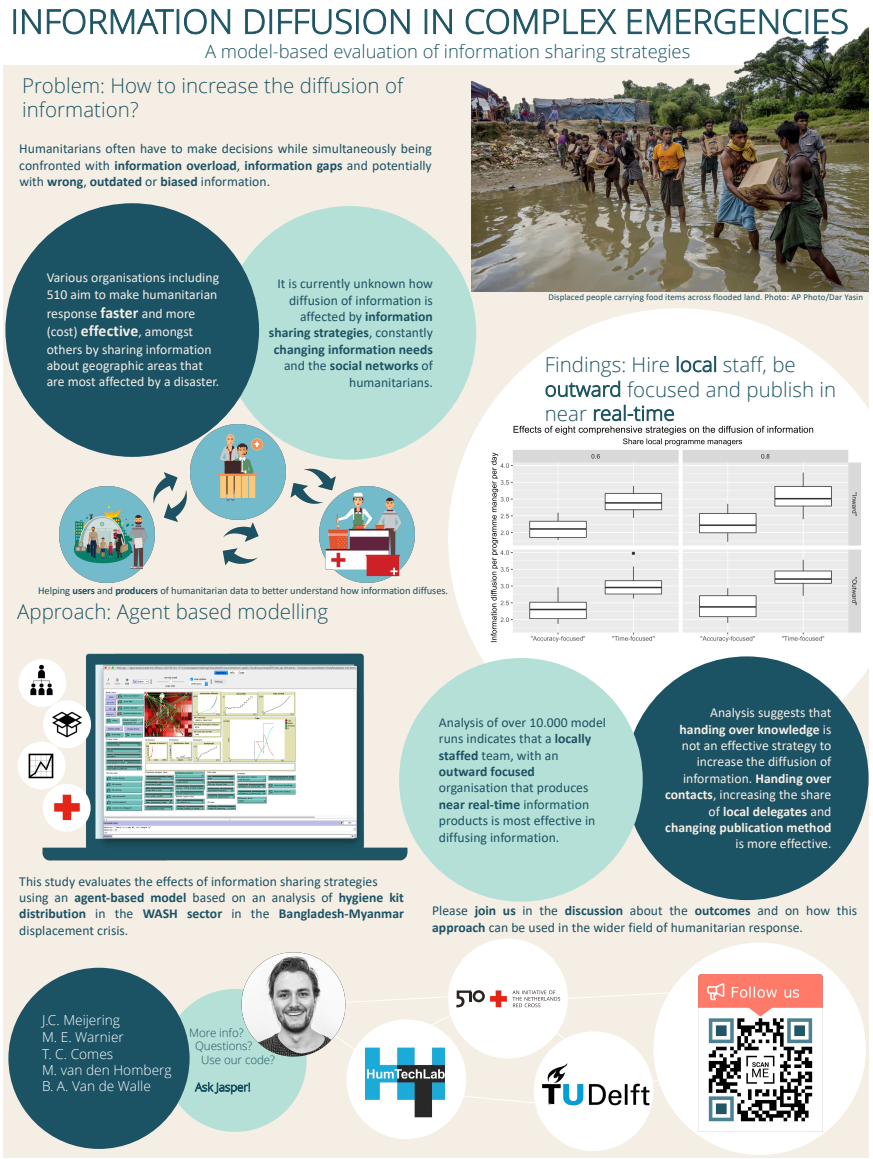



**Figure O.1:** Research poster synthesising the research project for the attendees of the Humanitarian Networks and Partnership Week 2019.