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Benefits and challenges of implementing emerging technologies in a humanitarian supply chain

MTTM05 Degree project in Engineering Logistics

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Preface

This thesis is written as the final project of my Master of Science within Industrial Engineering and Management, at the Faculty of Engineering LTH at Lund University. The specialisation of the master is Supply Chain Management. This project was initiated in the beginning of 2018 and conducted from March until September of 2018.

I would like to thank the people from Médecins Sans Frontières from all around the world that has shared their knowledge and experience of technology use in a humanitarian context. In particular I would like to thank Marpe Tanaka at MSF Sweden Innovation Unit for his support throughout the process of the thesis, from initiation until the end of the project. I would also like to thank my supervisor at the department of Engineering Logistics, Joakim Kembro, for his guidance and a lot of useful discussions during the course of the project.

Kajsa Salomonsson

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Abstract

Technology utilisation and implementation of new technologies are critical success factors for humanitarian supply chains and the possibility to improve humanitarian operations by the use of technology has been gaining increasing attention, especially since the 2010 Haiti earthquake. Despite this increase, the theory on emerging technologies within the humanitarian supply chain is still very limited, in particular there is a lack of studies providing a holistic perspective of technology development within the sector. This gap motivates the main purpose of this study: to investigate and compare opportunities and challenges of currently emerging technologies in the context of the humanitarian supply chain. Looking at multiple technologies creates an interesting overview, where larger influencing trends can be identified together with the main challenges that will have to be addressed in order to follow the technological development. Four types of technologies were selected as a representation of currently emerging technologies: three-dimensional printing, immersive technologies, unmanned aerial vehicles and Internet of Things. The benefits and challenges related to the implementation are first addressed through a structured literature review, mapping the existing theory. After this a multiple case study was conducted in collaboration with Médecins Sans Frontières Sweden Innovation Unit, in order to verify and add to the existing theory. The multiple case study included four cases, one per type of technology. The case study was conducted in two rounds. The first round was used to collect data from experts on respective technology, and the second round was used to verify the results from the first round by consulting supply chain experts not involved with the use of any of the technologies.

The study resulted in six ways that emerging technologies are expected to create benefits in humanitarian supply chains and three main challenges related to the implementation of emerging technologies. The ways in which benefits are created that are closest to reality, at least on a limited scale, are improved geographical assessment, increased access to supply, increased flexibility, and more efficient distribution. Further into the future increased visibility of resources as well as better tools for assessment are expected to gradually provide benefits. The main challenges that have to be tackled in order for humanitarian organisations to be able to implement innovations in their supply chain are improvement of IT and data management, communication and coordination within organisations as well as with external actors, and lastly how to collaborate with the commercial sector.

Keywords: Humanitarian logistics, humanitarian supply chain, emerging technologies, challenges, benefits, three-dimensional printing, unmanned aerial vehicles, internet of things, virtual reality

Abbreviations

AM – Additive Manufacturing
AR – Augmented reality
HO – Humanitarian Organisation
HSC – Humanitarian Supply Chain
IoT – Internet of Things
MSF – Médecins Sans Frontières
NGO – Non-Governmental Organisation
OC – Operational Centre
R1 – Round 1
R2 – Round 2
RQ1 – Research question 1
RQ2 – Research question 2
VR – Virtual reality

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1. Introduction

1.1 Background

The focus on humanitarian logistics is growing. From being an area struggling with recognition, humanitarian organisations are more and more focusing on their supply chains to improve operations (Van Wassenhove, 2006). Donors are also putting extra pressure on the situation as they are raising expectations and requirements, demanding efficiency, professionalism, accountability and visibility (Nurmala et al., 2017). Technology utilisation and implementation of new technology are critical success factors for humanitarian supply chains (HSCs) (Pettit and Beresford, 2009, Meredith, 1998) and the possibility to improve humanitarian operations by the use of technology has been gaining increasing attention, especially since the 2010 Haiti earthquake (Sandvik et al., 2014). Several pilot projects have been launched during the last years as a result, a few documented examples being Médecins Sans Frontières (MSF USA, 2017) and Red Cross (Johnson, 2017) using drones for mapping of disaster areas, 3D printing being used to mend pipes after an earthquake (Jones, 2017) and virtual reality (VR) technologies being used to prepare and educate aid workers (Agrawal, 2016). Scientific articles are also indicating an increasing interest in the academic world for investigating the potential of emerging technologies within the preparation and response to disasters, e.g. rapid prototyping (De la Torre et al., 2016) and three dimensional printing (Tatham et al., 2015), Internet of things (Yang et al., 2013) and drones (Sandvik and Lohne, 2014, Lichtman and Nair, 2015).

Despite an increasing focus on new technologies, humanitarian organisations (HOs) are facing challenges in the form of lack of skills in and commitment to technological development. In order to successfully adopt new technologies, humanitarian organisations need to foster a learning curve, and develop an innovative and technological culture (Kabra et al., 2017). This lack of technological culture is one of the areas where it is suggested that humanitarian organisations could learn from the commercial sector, as commercial organisations in general have more experience in the area of efficient implementation of technology (Nurmala et al., 2017). However commercial and humanitarian organisations do not necessarily benefit from all technologies to the same extent or in the same way, as they do not operate under the same supply chain conditions. While some emerging technologies might not yet be cost efficient or competitive enough to meet the requirements of the commercial markets, the requirements and competition in a humanitarian aid context are different. Taking 3D printing as an example, for a humanitarian mission lead times for supplies can range from one up to three months and therefore the possibility to manufacture necessary supplies on location would have an immense effect (Tatham et al., 2015), while in commercial supply chains demand and supply conditions are more stable and lead times are rarely of this length. The use of technology within HSC is therefore interesting also from the perspective of commercial supply chains, as humanitarian organisations have an incentive to move faster with the adoption of certain technologies, and have the potential to become a source of experience and expertise also outside of the humanitarian context.

1.2. Purpose and research questions

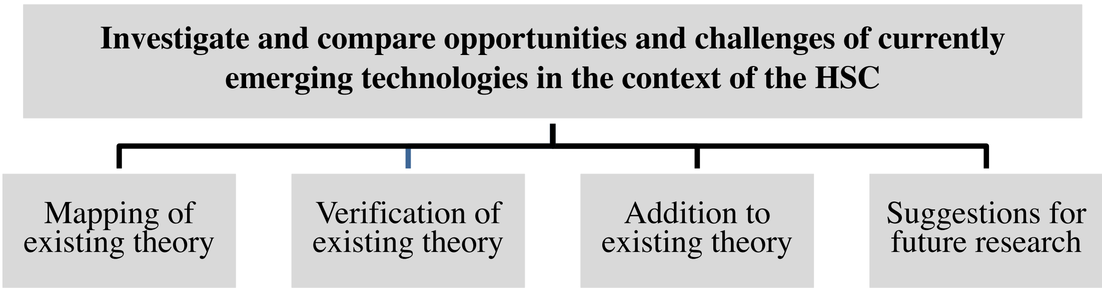

Figure 1. Illustration of the purposes of the study

The overall purpose of this study is to investigate and compare opportunities and challenges of currently emerging technologies in the context of the humanitarian supply chain. Looking at multiple technologies brings an interesting overview perspective, where larger influencing trends can be identified together with the main challenges that will have to be addressed in order to follow the technological development. As was addressed in the introduction, there has been a call for HOs to develop an innovative and technological culture. The aim is that this study should be useful and accessible for practitioners within HOs, contributing with a comprehensive overview of technological developments from a usefulness perspective. To the author's knowledge there is currently no study that has attempted to provide this type of holistic perspective of technology development within HSCs.

The main purpose is followed by several more specific purposes. First of all, one purpose is to provide a comprehensive overview of existing theory about benefits and challenges related to implementation of emerging technologies within the HSC. This will be done through a review of existing literature, mapping the documented knowledge related to a selection of emerging technologies within the humanitarian sector. Secondly, another purpose is to verify the existing theory identified through the literature review; to test the reality of the theory. This will be done through a case study in collaboration with MSF Sweden Innovation Unit, a part of the Médecins Sans Frontières (MSF) movement (English: Doctors Without Borders). As a part of this verification it will be investigated whether there are any gaps in existing theory, if possible these gaps will be filled by results from the case study. This addition to existing theory is an additional purpose. Lastly, the identified gaps that are not filled will serve as suggestions for future research and areas for developments, the provision of which is the last purpose. See Figure 1 for an illustration of the study purposes. Two research questions, RQ1 and RQ2, have been formulated in order to address the main purpose:

- *RQ1: In what ways can emerging technologies create benefits for humanitarian supply chains?*

"In what ways" refers to in which contexts, in which parts of the supply chain, in relation to which activities and for what beneficial purposes emerging technologies have the potential to play a role. The benefits should be assessed in relation to the compatibility of the technology and the context, and in relation to current as well as alternative solutions. The focus on benefits is useful from the perspective of the organisations. To raise awareness of the usefulness and possibility of a new technology to improve operations is a way to overcome potential resistance towards technology amongst practitioners (Kabra et al., 2017). In other words, in order to gain internal support to implement a new technology, the benefits need to be clear.

- *RQ2: What are the main challenges and barriers related to the implementation of these technologies?*

Although there are many interesting potential applications of emerging technologies within HSCs, new technologies can create hypes and expectations should be realistic. Benefits and opportunities need to be considered together with challenges related to the use of a specific technology. Challenges and barriers related to the potential benefits identified in RQ1 are therefore addressed by RQ2. See Figure 2 for illustration. Kembro et al. (2017) discuss the difference between challenges and barriers and arrive at the definition of "*a barrier as a factor which is likely too difficult to overcome or solve (…), whereas a challenge represents a complicating factor, which likely can be overcome or solved*". This definition will be used for RQ2.

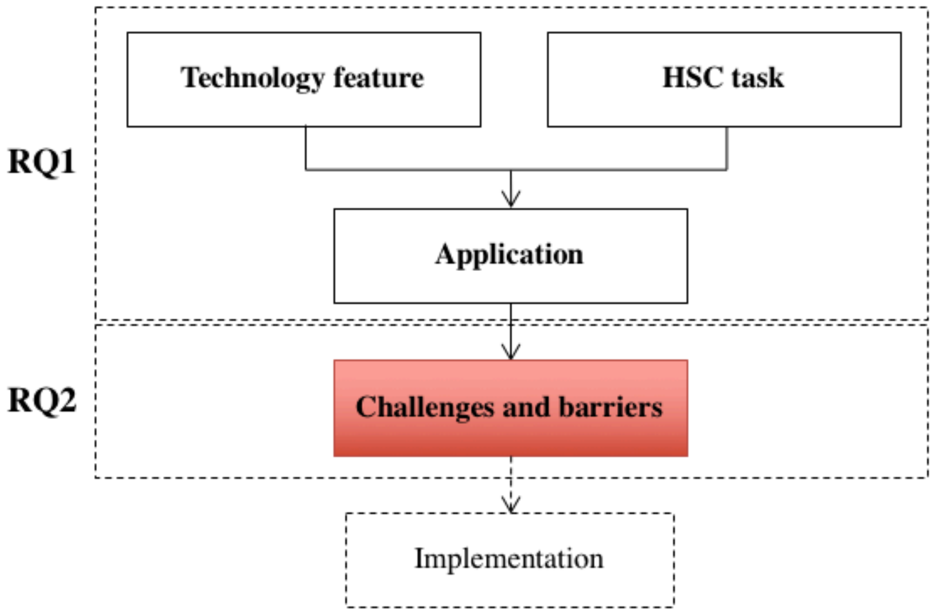

Figure 2. Illustration of research questions

1.3. Focus and delimitations

The focus of this study is the use of emerging technologies in the supply chain of humanitarian disaster relief operations. For this report, the term "humanitarian" will be used rather than the term "disaster relief". Day et al. (2012) points out that the difference between the usage of the terms humanitarian logistics and humanitarian supply chain management has been small within published research. The same authors arrive at the conclusion that there is in fact a difference, and defines it as humanitarian logistics being more tactical/operational/execution oriented compared to humanitarian supply chain management that is a broader system, the latter concept subsuming the first concept. This definition is also used for this report, considering humanitarian logistics as a part of the humanitarian supply chain (HSC). The study will investigate the adoption of emerging technologies from the perspective of international humanitarian non-governmental organisations (NGOs). The term used for these actors is humanitarian organisations (HOs) throughout the report. It should be kept in mind that there are many other perspectives and stakeholders in the context where HOs work, e.g. governments, the media, the private sector, donors and the final beneficiaries to name a few. Within disaster management there are four phases: mitigation, preparedness, response and rehabilitation (van Wassenhove, 2006). This study will limit the focus to the disaster preparedness and response phases, since it is usually in these scenarios international HOs operate. Technologies for mitigation and recovery are therefore not included in the primary scope.

Technology is a very broad concept and there are many definitions. Oxford Dictionaries (2018) defines technology as "*the application of scientific knowledge for practical purposes, especially in industry*" and BusinessDictionary (2018a) provides the definition "*the purposeful application of information in the design, production and utilization of goods and services, and in the organization of human activities*".
The focus of this study is "emerging" technologies. This is not necessarily the same as "new" technologies but can be technologies that have existed for some time but are not yet in use or still considered controversial. A common definition of emerging technologies is "*new technologies that are currently developing or will be developed over the next five to ten years, and which will substantially alter the business and social environment*" (BusinessDictionary, 2018b). This study will hence focus on technologies that have suggested potential for humanitarian supply chains but are not yet implemented beyond a trial setup, although they are expected to be within five to ten years.

1.4 Report outline

The report is divided into six sections. In this first section, some background information is provided as an introduction to the subject. The purpose and research questions are then presented, followed by focus and delimitations. The second section is Methodology, where the methods used to reach the purpose and reply to the research questions are presented, motivated and described. This section begins with a presentation of the research process. Following the process is section 2.1. Literature, where first the general review is described. The general review is conducted in order to develop the context of the study and elaborate on the models used for analysis. After the general review, the section moves on to the method for the structured literature review. Section 2.2. describes the method for the multiple case study.

After Methodology, the findings from the literature review are presented in Section 3. In the first sub-section (3.1) the context, i.e. everything related to the specific context of HSCs that might have an impact on technology adoption, is investigated. Beginning with the definition of disaster response and the humanitarian principles, moving on to the definition of the HSC with all related activities and some typical characteristics and challenges, ending with a description of technology use in the specific HSC context and implementation of innovations. The following sections (3.2-3.5) presents the findings from the structured literature review i.e. a mapping of existing theory, finishing with a summary and overview of all cases in relation to the HSC.

Section 4 contains the empirical findings. Section 5 contains a comparison of existing theory and empirical findings, as well as an analysis of the attributes of the technologies in order to arrive at the final conclusion in the last section.

2. Methodology

This section is divided in two parts. First the method to find information about the context (literature review) and mapping of existing theory (structured review) is presented in 2.1. Literature. In the second part, 2.2. Case study, the method for conducting the multiple case study is described. The research process is illustrated in Figure 3. The process is divided into five phases: Planning and preparations, Literature review, Case study: Round 1, Case study: Round 2 and Final analysis and conclusions. For each phase two types of activities are listed, Data collection and Analysis, together with the input required to launch the activities and the output resulting from the activities.

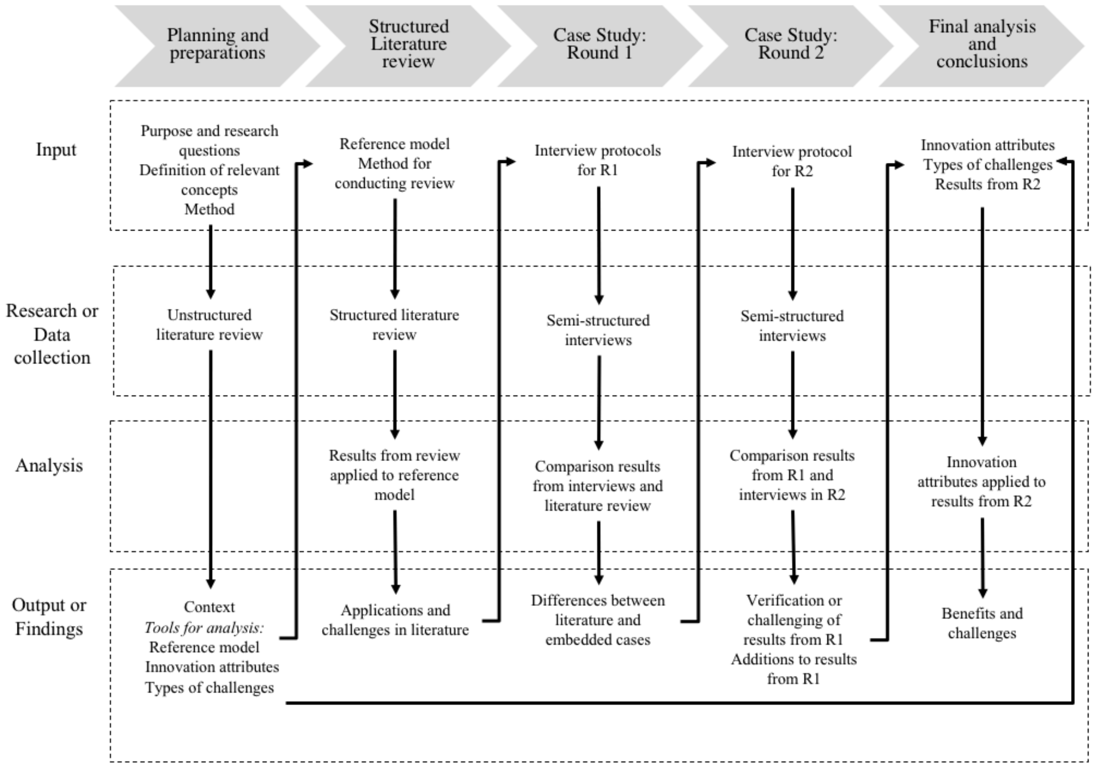

Figure 3. The research process.

2.1. Literature

The literature study is divided into two parts: a literature review and a structured review.

2.1.1. Literature review

Literature is reviewed in order to further develop the context and focus of the study, and to find suitable models to use for analysis of the study findings. For this purpose a structured approach is not considered necessary. Information is found through the use of relevant search terms combined until a useful source appear. Reference lists of key articles are used to further search for useful sources if necessary.

2.1.2. Structured review: Definitions and criteria

The approach for conducting structured literature reviews proposed by Durach et al. (2017) has been used. The approach is based on six general steps commonly used for systematic literature reviews, with added guidelines for supply chain management research.

The first step is the definition of purpose and scope of the review, including specifying the unit of analysis and defining relevant concepts. The unit of analysis for this review is "*the use of an emerging technology within the HSC*". Relevant concepts are defined previously in the introduction (section 1.3). In the second step criteria for inclusion/exclusion should be determined that makes it possible to identify whether a publication can provide information to build on the theoretical framework or not (Durach et al., 2017). See Table 1 for inclusion criteria. Since the scope is broad (several technologies) and limited resources available (time frame and resources of a master thesis) only publications with an explicit HSC focus have been included in this review.

Since the subject is emerging technologies, by definition of "emerging" applications and features of these technologies can be uncertain and experience rapid developments. Grey literature i.e. "the diverse and heterogeneous body of material available outside, and not subject to, traditional academic peer-review processes" (Adams et al., 2017), has therefore been included in this study. According to Adams et al. (2017) limited access to many forms of grey literature has historically been a barrier, but through digitalization the size and influence of many forms of grey literature is increasing. However, the heterogeneous nature and the very large selection of this type of literature make the assessment time-consuming and demanding. Due to the nature of this subject and the limited size of academic peer-reviewed material available, including grey literature is considered essential. The type of publications included in the review is therefore extended to include conference papers, consultancy reports, NGO reports and magazine articles, when the number of scientific articles for a certain technology type is not considered large enough to draw conclusions.

Table 1. Inclusion criteria for literature review

Type of criteria	**Criteria for inclusion**
Language	English
Timespan	2008-2018
Publication type	If initial sample is relatively large: Peer-reviewed article If initial sample is relatively limited: All types of articles, Conference paper, Consultancy report, NGO report
Subject	Proposed opportunity or challenge related to the use of an emerging technology within the HSC

2.1.3. Structured review: Data collection

In the third step of the review process proposed by Durach et al. (2017) one or several searches should be conducted in order to generate a sample of potentially relevant literature. The search terms should take into consideration the spread of definitions and terminology within SCM in order to generate an inclusive rather than exclusive sample. An initial sample was for this study retrieved with a building block strategy, i.e. several searches were conducted combining the search terms in Table 2. The databases used to conduct the searches were Web of Science Core Collection, Business Source Complete (EBSCOhost) and Scopus. A final search was conducted using Google. If the initial sample is relatively limited, citation pearl growing was used to find additional publications relevant to the subject.

Table 2. Search terms used, combined with Boolean operator AND.

Connection to inclusion criteria	**Search term**
Humanitarian context	humanitarian OR "disaster response" OR "emergency response" OR "disaster relief" OR "emergency relief"
Supply chain context	"supply chain" OR logistic* OR operation*
Emerging technology	"3D print*" OR "three dimensional print*" OR "additive manufacturing" OR "rapid prototyping" OR "rapid manufacturing"
	"virtual reality" OR "augmented reality" OR "immersive technolo*"
	drone* OR UAV* OR "unmanned aerial vehicle*" OR "unmanned aerial system*" OR UAS* OR "remotely piloted aircraft system*" OR RPAS OR "autonomous fleet*" OR "autonomous vehicle*"
	"internet of things" OR IoT OR "web of things"

In the next step the inclusion/exclusion criteria are applied to the retrieved sample, in order to reduce the sample to only include relevant, primary studies. This includes going beyond what is stated in the title and abstract of the study in order to determine relevance in relation to the theoretical framework (Durach et al., 2017).

2.1.4. Structured review: Data analysis and reporting

After collection, the data should be coded and analysed. Durach et al. (2017) proposes two parallel coding structures for supply chain management reviews, the first one covering the aspects of the theoretical framework, and the second one covering the ontological and epistemological characteristics e.g. research method, unit of analysis, data source, context, etc. See Appendix 1 for data extraction form used. After coding, the data is analysed and used to refine the initial theoretical framework. The last step is to report the findings of the review. The extracted data was analysed and reported in two ways; first recurring themes in the literature were identified and their frequency of occurrence reported, after this the extracted data was linked to the HSC. The purpose of identifying recurring themes and their frequency is linked to the first sub-purpose of the study: to map existing theory. It is also used to identify themes that are not well investigated, to find gaps that can serve as suggestions for future research which is another sub-purpose of the study. To link the data to the HSC a model of the supply chain and activities included was used, see Figure 6. All findings from the structured review can be found in Section 3, presented per type of technology.

2.2. Case study

2.2.1. Case study strategy

According to Yin (2014) there are three conditions related to the form of research questions, the control over behavioural events and the focus on contemporary events that distinguish the suitability of a research strategy. In general “how” and “why” questions are likely to favour a case study, experiment or historical study, “how many” and “how much” would favour a survey or archival analysis while “what” questions could lead to any type of strategy depending on the character of the questions. The level of control over behavioural events and the focus on contemporary or historical phenomena can determine whether an experiment is possible or not, and whether it is relevant to look into history. Due to the limited time frame and resources for this study an experiment is not possible. The exploratory nature of the research questions and the focus on very contemporary phenomena therefore makes the case study a suitable research approach following the reasoning presented by Yin (2014). The choice is further supported by Voss et al. (2002) presenting case studies as suitable for early, exploratory investigations and a possibility to generate new and creative insights, and Meredith (1998) stating that case studies are primarily useful for developing new theory or testing particular aspects of existing theory. The case method is according to these statements in line with the purpose of the study. Case studies are also argued to have high validity with practitioners (Voss et al., 2002), and since the aim is for this study to provide conclusions useful for practitioners this statement further supports the choice of strategy.

The weakness of case studies can be the influence of context and temporal dynamics, a tendency for construct error, poor validation and a lack of familiarity (Meredith, 1998). It has been argued that there is little basis for scientific generalization (Meredith, 1998, Yin, 2014). For this study, the arguments for a case study are however considered as stronger than the arguments against. Methods for handling potential factors of weakness are presented in section 2.3 Research quality.

2.2.2. Number of cases and Unit of analysis

The purpose of this study is to investigate and compare opportunities and challenges of currently emerging technologies, i.e. look at several technologies and draw conclusions on how they together will create opportunities and challenges. For this purpose a multiple case study is considered suitable, where each case focus on opportunities and challenges of one type of technology. Since the technologies are emerging and might not yet have been used or tested to a great extent, the potential related to their use rather than proven success is the focus. The unit of analysis is defined as "*the potential use of one type of emerging technology in a supply chain by a humanitarian NGO*".

2.2.3. Case selection

By looking at different technologies from the perspective of a single organisation, the opportunities and challenges become comparable and can be combined into an overview of what technological development can lead to in the near future. This is in line with the purpose of the study. The organisation referred to in the unit of analysis should therefore be the same in all selected cases. In order for the results to be transferrable to other organisations, the organisation from which the cases were selected had to be carefully considered. The organisation should be an international NGO that is currently running test projects with several emerging technologies. In order to get results that are generalizable for other HOs, the organisation should be present in a diverse range of disaster response contexts and conduct typical supply chain activities. The organisation should also be available and willing to take part in the study. An organisation that corresponds to these criteria is Médecins Sans Frontières (MSF) (English: Doctors Without Borders). As a medical humanitarian organisation MSF face a diverse range of both material and immaterial needs in the field, and they are present in all types of disasters as medical needs are not limited to a specific disaster context. Because of this presence in a broad range of disaster environments the benefits and challenges they experience as an organisation are considered likely to also apply to many other HOs. MSF is therefore selected as the organisation for the multiple case study.

The selected cases should be technologies that the organisation is some way focus on in a supply chain context by running pilot projects, or is looking into in order to launch pilot projects. The researcher needed to have access to information about the projects as well as one or several people involved. The final selection was based on discussions with MSF Sweden Innovation Unit, and general supply chain technology trends. Literature on technology trends for HSCs is very limited, but general supply chain technology trends can be argued relevant also for HSCs. Pettit and Beresford (2009) conclude that critical success factors in commercial supply chains are also applicable to the HSC. Following the same reasoning, although commercial supply chains and HSCs operate under different circumstances, the basic activities are in many aspects similar, and it is therefore likely that applications of emerging technologies in commercial supply chains could be applicable for HSCs as well. This is also the findings of Tatham et al. (2015) when it comes to three dimensional printing – the benefits of the technology in commercial supply chains are also applicable in the humanitarian context. To conclude, it is reasonable to assume that technologies with a great impact on general supply chains will also impact HSCs. Predictions from the Gartner Hype Cycle regarding how long it will take before technologies that are considered emerging reach "the plateau of productivity" i.e. the point of mainstream adoption, can be seen in Table 3. These predictions were used to decide whether a technology fell within the focus of this study, i.e. if they are expected to be implemented within five to ten years (from this study, 2018).

Table 3. Anticipated time to reach plateau of productivity.

Technology	**Years away from mainstream adoption**	
	General applications (Panetta, 2017)	Supply chain applications (Gartner, 2017)
3D printing	-	5-10
Autonomous vehicles	>10	-
UAVs/drones	2-5	-
Virtual Reality (VR)	2-5	-
Augmented Reality (AR)	5-10	-
IoT	2-5	5-10
Blockchain	5-10	>10
Artificial Intelligence	>10	>10

Through discussions with MSF Sweden Innovation Unit, four cases where selected for the multiple case study (see Table 4).

Table 4. Selected cases for the multiple case study

Case	**Type of technology**
1	Three-dimensional printing
2	Immersive technologies (VR/AR)
3	Unmanned Aerial Vehicles
4	Internet of Things

2.2.3.1. Background information on Médecins Sans Frontières

MSF was founded in 1971 by a group of doctors and journalists with the objective to create an independent medical organisation, delivering impartial emergency aid quickly and effectively. Today the organisation comprises more than 45 000 people from over

150 countries, bound together by the MSF charter. The primary objective is to provide high-quality medical aid to people in need all over the world. (Médecins Sans Frontières, 2018b) In 2017 MSF ran projects in over 72 countries, and had a total expenditure of 1 614 million euros (MSF International, 2018). The MSF movement consists of 24 national associations, each association is connected to an Operational Centre (OC). There are five OCs in total, based in Paris, Brussels, Barcelona, Geneva and Amsterdam. Supporting the operations of the organisation are three European Supply Centres: MSF Supply in Brussels, MSF Logistique in Bordeaux, and Amsterdam Procurement Unit in Amsterdam. (Médecins Sans Frontières, 2018a) Assistance to the field operations and certain needs assessments are provided from the headquarters. Logisticians in the field are responsible for communication tools, vehicles, power supply, water and sanitation, biomedical equipment as well as supply and storage of all medical and non-medical items needed in the various programs. (Médecins Sans Frontières, 2018a) When stocks need replenishing the first choice is to try to source locally, which can mean a delivery time between a few hours and up to a month. The second choice, if local purchase is not possible, is to place an order to one of the supply centres, where the delivery time can be several weeks. In an emergency situation, supplies that are kept specifically for that purpose are usually sent from one of the supply centres by air. MSF use and make a lot of kits which are pre-prepared for different needs and ready to be used in emergency situations, e.g. nutrition kits, rapid intervention surgical kits, and field hospital kits. (Médecins Sans Frontières, 2016) An air delivery of emergency supplies can be made within 24 hours, e.g. an emergency health kit containing everything required to provide 10 000 people with emergency health care for three months (Médecins Sans Frontières, 2018a).

2.2.3.2. Information on selected cases

Three-dimensional printing (or 3D printing) were the first technology that was selected as a case. The technology quickly came to mind as it has been mentioned quite frequently in various medias for applications in post-disaster scenarios. MSF in particular have received attention for a project in Jordan where 3D printing is used to print prosthetic limbs. Two interviews were conducted for this case. The first one was with the manager for a new project focusing on printing non-medical items in remote locations (I1). The second interview was with the project coordinator for the prothesis project in Amman (I2). See Table 5 for more details on the interviews.

Table 5. Details about interviews on three-dimensional printing

Interview	**I1**	**I2**
Date	2 May 2018	12 June 2018
Role of interviewee	Project manager	Project coordinator, supervising the project at a strategic level.
Location of interviewee	Toronto, Canada	Paris, France
Location of project	-	Amman, Jordan
Purpose of the project	Investigate whether 3D printing is suitable to print items temporarily that we cannot receive in a remote project easily or quickly. Generally non-medical items, logistical items.	To clinically investigate whether this technology could increase the access to a specific care i.e. the provision of prothesis and orthosis.
Duration and current status	Duration 1,5 y, currently in the early stages of organising and planning (May 2018). Nothing has yet been printed.	The project started in October 2016, and is still on-going
Context and environment	Focus is supply to remote places. It is considered both to have printers on a project level, or to keep it in a central location for projects to send requests.	Location of the project is Amman. It is a clinical project, completely surrounded by a team of experts.
Type of technology	Two types of printers are considered, a desktop size printer for remote locations or a larger version placed in a central, accessible location.	A desktop printer (an Ultimaker)

The second case that was selected was the use of immersive technologies (immersive technologies is used as a collective name for Virtual Reality and Augmented Reality). One interview was conducted for this case, with the team leader for a project on VR at the OC headquarters in Brussels (I3). See Table 6 for more information on the interview and project.

Table 6. Details about interviews on immersive technologies

Interview	**I3**
Date	20 June 2018
Role of interviewee	Strategy and program manager, but when I got this project on VR I was a Technical team leader.
Location of interviewee	Brussels, Belgium
Location of project	Brussels, Belgium
Purpose of the project	The first part of the project was to investigate how we could use VR and 3D printing in the design of our hospitals. This resulted in two products: a 3D printed mock-up of the hospital and an immersive virtual environment where you could go through the hospital, look at the equipment, look at the space, etc. The second part of the project was to use the material for training, briefing, and debriefing.
Duration and current status	A phase of the project is over. At this specific moment we don't work with VR, but we are still investigating where or how we could use it, to further develop what we already know. Right now we don't have the resources to further tackle this.
Context and environment	It was a pilot project, we did this retrospectively when the hospital was already in place, to have a feeling whether or not it would be something to consider for the future.
Type of technology	A head-mounted device was used to experience the virtual environment.

For the third case, the use of UAVs was selected. UAVs (or drones as they are also called) is a technology that is well known to the public, mostly for their use by the military and for video recording. The use of drones by HOs have been a subject of heavy discussions, where their relation to military applications have been argued as too strong and not compatible with the humanitarian values. Two interviews were conducted for the case of UAVs, the first one focused on mapping drones (I4) and the second one focused on cargo drones (I5). See Table 7 for details on the interviews.

Table 7. Details about interviews on UAVs

Interview	**I4**	**I5**
Date	16 May 2018	30 May 2018
Role of interviewee	Currently GIS e-health coordinator, before a GIS specialist in the field.	Work 70% outside MSF with development of drone technology and 30% with MSF in the Japan Innovation Unit.
Location of interviewee	London, UK	Bern, Switzerland
Location of project	Malawi	Various locations
Purpose of the project	To test a **mapping drone** and investigate how it could be useful for MSF. We also looked into how to formulate guidelines and standards for requesting and using the drone, how to share the drone.	The purpose of my work is to develop the **cargo drone** technology further and shorten the time until this technology becomes operational.
Duration and current status	I was testing the drone last year (2017), but the GIS officer in Malawi still has the drone, they could use it now. However we have had a lot of technical problems with this drone, so most of the time it is being repaired and not available to use.	It is not a project with clearly defined boundaries, we constantly do tests and pilots to develop the cargo drone technology and make it available for humanitarian organisations.
Context and environment	The pilot was done in Malawi, where we have different kinds of projects: emergency, non-emergency, floods, etc. We have a good relationship with the ministry of health and with the government in general, which makes it a suitable place for innovation.	The focus has been on transports for medical items to outreach, rural areas that are difficult to reach with other means of transport. We have done pilots in several countries where the nature and settings are different (e.g. Papua New Guinea, Peru, Dominican Republic, Madagascar).
Type of technology	An Ebee drone. It's light (700 g), discrete and silent. It's made in foam so it's really fragile. The pictures are nice, of high quality, but the drone is quite expensive.	We have had trials with different types of drones, trying to find which one that best suits the operations of a humanitarian organisation.

For the last case, the selected technology is Internet of Things. MSF dis not at the time of data collection for this study have a live project on IoT, but there where ongoing discussions about the technology and its future role within the organisation. Since it was a topic of discussions, IoT was considered suitable for inclusion as a case in this study. Two interviews were conducted, one with a responsible for operational applications in the OC Barcelona (I6), and one with a responsible for logistics innovation in the OC Paris (I7). See Table 8 for details on the interviews.

Table 8. Details on interviews on IoT

Interview	I6	I7
Date	29 May 2018	4 June 2018
Role of interviewee	Responsible the provision of applications to operations.	In charge of innovation within the logistic department.
Location of interviewee	Barcelona, Spain	Paris, France
Location of project	-	-
Purpose of the project	We don't have any IoT project today. It is a maturing technology, and with my knowledge of the MSF operations and my knowledge of IoT, I haven't noted any area of high operational added value for the technology so far.	We are having a workshop at the end of June (2018) with the purpose to introduce the concept of IoT to logisticians and understand how it could be useful for them. The final goal is to find a mission/country where we could launch a pilot project for IoT.
Duration and current status	-	Currently only this initial workshop is planned.

Two people were selected as supply chain experts for R2. One work at the Operational Centre Brussels (OCB) Headquarters as Supply Chain Officer and the other work at MSF Supply, the supply centre in Brussels, as Procurement Coordinator. Both have previous to their current roles several years of experience from working with supply and logistics for MSF in various projects in the field. The experts were selected because of their broad knowledge of MSF's supply chain and operations around the world, with a perspective from the field missions but also from a central headquarter level. None of them had been involved in any of the projects in R1.

2.2.4. Data collection

The case study will rely on primarily qualitative methods, as opposed to quantitative methods. A qualitative approach can be described as a way to understand the meaning individuals or groups ascribe to a phenomena or issue, and is suitable for exploratory studies (Creswell, 2014). Barratt et al. (2011) defines a qualitative case study as "*an empirical research that primarily uses contextually rich data from bounded real-world settings to investigate a focused phenomenon*", where the intent is to build and extend theories, and to explore and better understand emerging, contemporary phenomena or issues in their real-world settings. This intent is corresponding to the purpose of the study. The method used for qualitative data collection was interviews. Interviews were considered suitable as they are possible to do over a distance, by phone or over internet. Travelling to the people being interviewed was not considered possible due to limited time and resources, as well as the geographical distribution of the people being interviewed. All interviews were semi-structured. Semi-structured interviews are performed with the help of an interview protocol with pre-defined questions, but allows more flexibility than a structured interview as the researcher can follow-up with questions not indicated in the protocol and the interviewee is given the opportunity to develop certain areas that he or she has more to say about (Cohen and Crabtree, 2006). However, the semi-structured interview is still structured around the interview protocol and therefore provides results that are comparable. This data collection method allowed for flexibility, something that was considered necessary due to the exploratory nature of the study, where one purpose is to add to existing theory as well as find areas for future research.

Data for the case study was collected in two rounds, Round 1 (R1) and Round 2 (R2), where R2 was used as a verification of the results in R1. In R1, at least one person that had expert knowledge on each case was interviewed. Written documentation of the projects was used as source of secondary data if available. The interview protocols were based on the main themes and challenges resulting from the structured literature review. See Table 9 for the template that was used to create the interview protocol for each case. In R2, at least one person that is an expert within the supply chain activities for the selected organisation (MSF) was interviewed in order to verify and complement the results from R1. The interviews in R2 included less specific, more open-ended questions than the interviews in R1, in order to give the interviewees more space to focus on the areas they found important, interesting or surprising. The R2 interview protocol was based on a comparison of the results from the literature review and R1, with the reported results from R1 attached. If necessary specific follow-up questions or explanations were added to the interview protocol, in line with the semi-structured interview technique. See Table 10 for the structure of the interview protocol for R2. All interview protocols can be found in Appendix.

All interviews were recorded and transcribed. The transcription was used by the researcher to complete the interview protocol with all information transferred in the interview. The interview protocol completed with answers was then sent back to the interviewee for verification, and corrections were made if requested by the interviewee.

Table 9. Template for interview protocol, R1

Ref.	Section title	Motivation/relation to purpose
A	The interviewee	Provide context
B	The project	
C	Applications and related benefits and challenges from literature	Verify existing theory Addition to existing theory
D	Complementary applications or benefits	Addition to existing theory Suggestions for future research
E	General challenges and barriers from literature	Verify existing theory Addition to existing theory
F	Complementary challenges/barriers	Addition to existing theory Suggestions for future research
G	Comparison	Compare opportunities and challenges
H	More information	Find additional sources of information
I	End of interview	-

Table 10. Template for interview protocol, R2

Ref.	Section title	Motivation/relation to purpose
A	The interviewee	Provide context
B	3D printing	Verify results from R1 Addition to results from R1
C	UAVs	
D	Immersive technologies	
E	Internet of Things	
F	Comparison	Compare opportunities and challenges
G	More information	Find additional sources of information

2.2.5. Data analysis and reporting

The final results from R1, after approval from each participant in R1 on their respective replies, were gathered per case/technology in an Excel file. The results were at this first stage reported as replies to the questions in the interview protocol. These results were then compared to the data extracted from the literature review. Since the interview protocol is based on the results from the literature review, the comparison was straight-forward. If comments from the interviews diverged from what was stated in the literature, this was registered in a separate column in the data file. This comparison was not considered an analysis, the differences were noted and reported without any reasoning or drawing of conclusions by the researcher.

The Excel file including all results from R1, i.e. all replies from the interview in R1 together with notations of where these differ from the results of the literature review, was sent to the participants in R2. The comments from R2 were reported in an additional column in the main data file, a condensed version of these results for each case can be found in Section 4, Empirical findings.

The results obtained after R2 were analysed in order to verify and challenge the existing theory. Where the information in the literature and the information obtained in the case study diverge, possible reasons for this are discussed. The comparison of existing theory and empirical findings are transferred into five categories: 1) A2: Agree, relevant for now; 2) A1: Agree, relevant for future; 3) D: Disagree; 4) U: Unsure; 5) No comment. The four cases are also analysed with the help of five innovation attributes, see section 3.1.3.2. for definition. The tools for analysis are further described in the section 3.1. Context, and in section 3.1.4. their connection to the research questions are explained.

2.3. Research quality

Four tests commonly used to establish the quality of empirical research are proposed by Yin (2014): construct validity, internal validity, external validity and reliability. Internal validity relates to the establishment of a causal relationship where certain conditions lead to other conditions, and is therefore not applicable for exploratory studies, as they are not studying causal relationships. Construct validity relates to the establishment of correct operational measures for the concepts being studied. External validity relates to the establishment of domain to which a study's findings can be generalized. Reliability relates to demonstrating that the operations of a study can be repeated with the same results. Triangulation (multiple means of data collection) can be used to increase validity further (Voss et al., 2002).

Lincoln and Guba (1985) and Halldórsson and Aastrup (2003) argue that the conventional criteria of construct validity, internal validity, external validity and reliability are not optimal to measure trustworthiness for qualitative research. Instead the criteria of credibility, transferability, dependability and confirmability are proposed.

Credibility is parallel to the concept of internal validity, and it is determined by how well the reality corresponds to the researcher's representation of the same (Halldórsson and Aastrup, 2003). For the literature study this is tackled by searching several databases, using several synonymous search terms in a building block strategy. In the case study the second round (R2) serves as a verification of the results from each case, the results are cross-checked by supply chain experts not involved in any of the cases.

All interviewees in both rounds were also asked to verify the reported results from their respective interview, to make sure the interviews were not reported incorrectly.

The conventional term for transferability is external validity, determined by the extent to which a study is able to make general claims, "generalizability" (Halldórsson and Aastrup, 2003). Transferability is difficult to determine for this study, since the subject is highly time and context dependent. However this does not necessarily mean that knowledge acquired is of no relevance for other contexts or times (Halldórsson and Aastrup, 2003). A thick description of the context of the study can be provided in order to enable conclusions about whether the results could be applied in another context (Lincoln and Guba, 1985). The focus and delimitation, literature study and case description provide this.

Dependability deal with the stability of data over time, related to the notion of reliability (Halldórsson and Aastrup, 2003). This criterion can be achieved through an examination of documentation of processes and products of the study by an auditor (Lincoln and Guba, 1985). All methods and protocols for data collection in this study will be documented, making an audit possible.

Confirmability implies that the findings represent the results of the inquiry and not the researcher's bias (Halldórsson and Aastrup, 2003). An audit is suggested to establish confirmability, for which an audit trail is necessary (Lincoln and Guba, 1985). To make this possible, all the findings (both raw data and interpretations) of this study have been documented, enabling tracing.

3. Literature

3.1. Context

This first part of the literature section provides a description of the context of the study and outlines the focus in more detail. The models used for analysis, connecting the findings from the study with the context, will also be described in detail. The context can be divided into three sections, as illustrated in Figure 4. Section 3.1.1 will treat the disaster response context by defining what a disaster is, and the meaning of humanitarian aid. In section 3.1.2 the humanitarian supply chain and supply chain activities will be described in more detail, as well as characteristics and general challenges. Technology use and adoption of innovations will be treated in section 3.1.3. In section 3.1.4. the findings from previous sections will be summarized and combined.

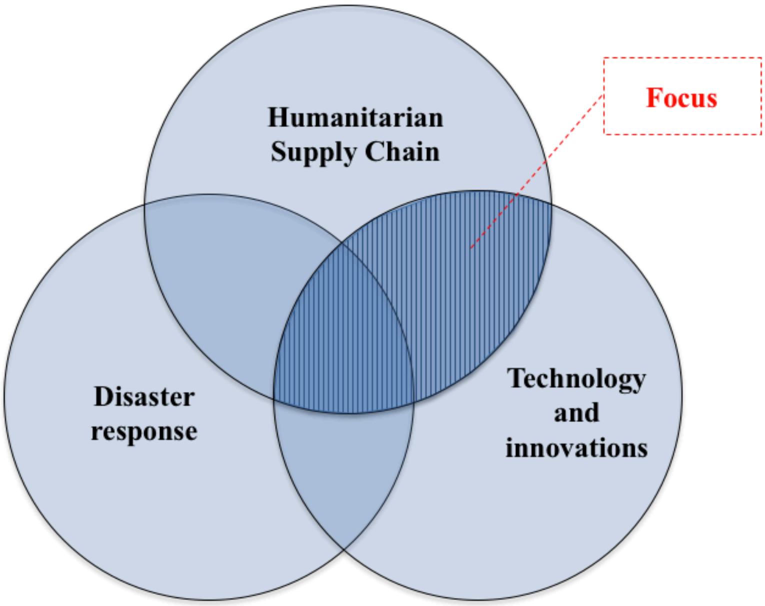

Figure 4. Illustration of the context of the study focus.

3.1.1. Disaster response

Hu A way to categorize disasters is to distinguish between natural and man-made, as well as slow-onset and sudden-onset disasters (Van Wassenhove, 2006). This is illustrated in Table 10. However, it gets complicated as some disasters evolve and create new types of crises, e.g. if a politically instable or conflict-prone area is hit by a natural disaster this can act as a catalyst for a political crisis (Omelicheva, 2011).

Table 10. Explaining disasters (Van Wassenhove, 2006)

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

Humanitarian disaster relief operations are conducted in the context of the humanitarian principles of humanity, impartiality, neutrality and independence, which are rooted in international humanitarian law (Heintze and Thielbörger, 2018). These principles are what define humanitarian aid and distinguishes it from activities of e.g. military, religious, political or ideological kind (ECHO, 2018). Humanity refers to the prevention and relief of all human suffering, and this is the general objective underpinning all humanitarian actions. Impartiality signifies to never discriminate based on nationality, race, religion, class or political opinions; priority should be given to cases where relief is most urgently needed. The principle of neutrality stands for not taking sides in any form of conflicts or disputes, and independence refers to autonomy from donors and authorities such as states or international organisation. The aim of these principles is to provide a humanitarian space, a humanitarian operating environment. However it should be noted that all actors operating in a humanitarian context do not share a commitment to the humanitarian principles, or interpret the principles in the same way (Heintze and Thielbörger, 2018). This divergence in interests and attitudes among actors providing disaster relief, often in combination with a very large number of different actors and stakeholders, represent a great challenge of disaster response.

3.1.2. The Humanitarian Supply Chain

3.1.2.1. Definition

A common definition of the HSC is "*the process of planning, implementing and controlling the efficient, cost-effective flow and storage of goods and materials, as well as related information, from point of origin to point of consumption for the purpose of meeting the end beneficiary's requirements*." (Thomas and Mizushima, 2005). It can be added to this definition that "*the function encompasses a range of activities, including preparedness, planning, procurement, transport, warehousing, tracking and tracing, and customs clearance*" (Jahre et al., 2016).

As mentioned in the method description (section 2.1.4.), in order to determine how the features of a technology relates to the activities and tasks of the HSC, a model of the supply chain is needed. This model will be used as an analytical tool for connecting the results of this study to the context. Blecken (2010) proposes a reference model that is considered to suit the study. The reference model is intended to serve as a basis for modelling and analysis of organisation specific supply chain processes for humanitarian organisations, see Figure 5.

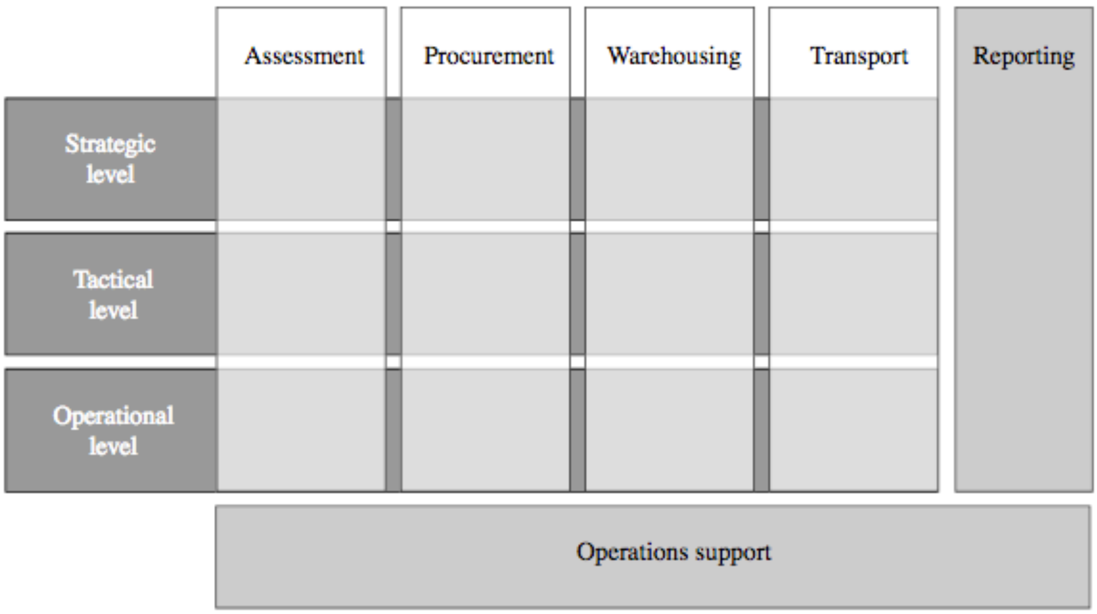

Figure 5. Reference task model framework (Blecken, 2010)

The model is structured around a planning dimension and a functional dimension, with operations support and reporting as supporting functions. Planning is done in three levels: the strategic, the tactical and the operational level. Task on the strategic level involve everything related to supply chain design for a strategic time horizon that stretches beyond two years. The tactical time horizon goes from six months to two years, and on this level the tasks revolve around optimisation of organisational processes and the entire supply chain. The decisions and constraints derived from the strategic level sets the restrictions. On the operational level everything that happens on a time horizon of six months is dealt with, comprising mainly supply chain execution tasks. The main objective is to run operations and optimize use of resources in line with what is decided on the strategic and tactical levels. (Blecken, 2010)

The functional dimension includes four categories: assessment, procurement, warehousing and transport. Assessment involves decisions regarding when to start a humanitarian operation, what the priorities should be and when to stop an operation. When a disaster strikes, the needs of the affected community have to be assessed as quickly and accurately as possible. The assessment also includes the transfer of information to various stakeholders such as the international community, donors and other actors present in a crisis. Procurement relates to the availability of resources necessary to meet operational requirements. On a strategic level this could mean long-term collaboration with suppliers and keeping track of appropriate laws and regulations, and on a tactical level to run yearly tenders and make sure pre-negotiated agreements are in place. The operational level includes order placement, expediting, and follow up and evaluation of suppliers (van Weele, 2014). The functions of warehousing include consolidations of products and better matching of supply and demand. Storing of supply enables an organisation to react quickly when demand arise, and can also come with economical gain, making it possible to purchase items of larger quantities which can reduce both cost per item and transport costs. However, warehousing is also related to operational costs and requires capital. (Bartholdi and Hackman, 2010) Consideration is needed on all planning levels in order to achieve the benefits of warehousing in a cost-effective manner. Transport relates to the spatial separation of supply and demand, and includes all deliveries within the network of the organisation. (Blecken, 2010) The objective is to manage all transports in an optimal manner, which depends on several factors such as mode choice, shipment size, location of warehouse, etc.

Supporting all other activities are the supporting functions (Blecken, 2010). Reporting includes everything that is related to the creation of external and internal reports. Internal reports are needed to monitor and document efficiency and effectiveness both during and after various operations. External reports are used e.g. to show to stakeholders how financial means are utilised and motivate further funding. Operations support refers to all activities required to enable humanitarian operations through planning, implementing and operating the basic infrastructures. This can be divided into two main categories: human resources (HR) and services and equipment.

As mention in the beginning of this section, the purpose of this model in the study is to connect technology features to the context, i.e. activities in the HSC. A technology can be used to execute supply chain tasks, but it can also have an effect on the tasks without being used in the execution. In order to fit the study an additional level is added to the planning dimension of the model, see Figure 6.

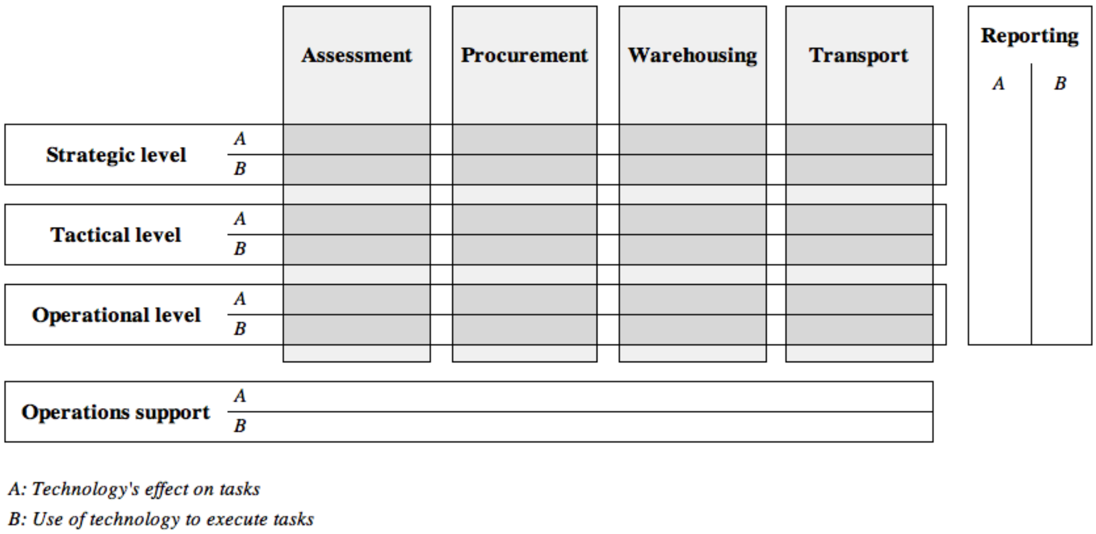

Figure 6. Reference model, modified from Blecken (2010)

3.1.2.2. Characteristics of the HSC

Day et al. (2012) have identified activities and attributes that distinguish humanitarian and disaster relief supply chains from other supply chains. The authors describe the high level of uncertainty as a major challenge for disaster response activities - uncertainty with respect to when a disaster strikes and how big the impact will be, but also what information that will be available, what funding will be available, and who will respond to the disaster with relief activities. As an effect of this uncertainty, the formation of the supply chain differs for different situations. The fact that the situation changes as time passes in the aftermath of a disaster, with a shift in priorities as effect, also adds uncertainty to the operations. This leads to high requirements on equipment amongst other things; humanitarian organisations require robust equipment that can be handled in and adapted to the changing conditions (Van Wassenhove, 2006). Another strong characteristic of a disaster is the urgency of the situation; the speed and quality of the relief activities might be a matter of life and death (Day et al., 2012). In order to pursue efficiency and effectiveness, and utilise limited resources to their fullest capacity, coordination and cooperation is necessary both within and between various actors. However, as mentioned above in section 3.1.1., a divergence in interests and attitudes among actors providing disaster relief, often in combination with a very large number of different actors and stakeholders, makes coordination and collaboration both complicated and complex.

The importance of preparedness as a means to improve the operational performance of the organisation, i.e. moving focus from operational and tactical planning to a strategic planning level, is acknowledged by many organisations in the humanitarian sector according to Jahre et al. (2016). However, few turn into action and only a small fraction of international aid is used to minimize disaster impact (Jahre et al., 2016). The format of donations can also be an issue. According to Day et al. (2012), the content of donations organisations get when the disaster strikes varies, and what is provided is not always what is most needed. Donors might feel they are contributing in a more concrete way by donating goods rather than money, but what is originally a good intention might in reality cause big issues as congestions arise and resources that would be better spent elsewhere are needed to manage unsolicited and often unwanted donations. To use resources as efficiently as possible, or register when they could be used better, is however not always straight forward. Performance measures are not well established in humanitarian organisations and HSCs, and can be complex to define. In a commercial logistics context the pursued objective is to minimize logistics costs, while in a humanitarian logistics context the objective is to minimize human suffering. Holguin-Veras et al. (2012) suggest the concept of social costs, i.e. the sum of logistic and deprivation costs, to formulate the humanitarian logistics objective. Depravation costs is in this context a metric that captures the loss of well-being (i.e. suffering) resulting from the lack of goods or a service. However the authors also point out the difficulties, computational as well as ethical, to estimate the cost of suffering. In general, factors such as difficulties to gather data, limited information technology, chaotic operating conditions, lack of motivation and general reluctance makes it challenging to measure all types of performance (Balcik and Haavisto, 2015). This in turn result in low incentives to use lessons learned, further complicated by a high turnover of staff (Van Wassenhove, 2006).

3.1.3 Technology and innovations

3.1.3.1. Technology use and challenges

Technology and how it can be used within the HSC is affected by several factors.
First off is the specific operational context - there are challenges related to technology transfer, i.e. the physical transfer of assets, know-how and/or technical knowledge from point of origin to point of destination due to operating conditions for humanitarian organisations. In their study on technology transfer of medical equipment, Ana Laura et al. (2016) detect several barriers, where the four most significant were difficult equipment implementation, uncertainty regarding local settings, absence or difficult compliance with standards and lack of continuous appropriate supply and servicing. Difficult equipment implementation relates to difficulties handling equipment as a complete "ecosystem", as arrivals of e.g. parts, complementary equipment and experts are misaligned. Continuous discovery of unplanned needs such as complementary products and running processes adds to this barrier. Uncertainty regarding differing local settings relates to differences when it comes to various variables (e.g. infrastructure, socio-economic factors, climate seasons, customs bureaucracy and political instability) that affect decisions regarding procurement and healthcare worldwide. The third factor, absence or difficult compliance with standards, protocols and guidelines, includes barriers that lack of standardization of equipment and processes lead to. The last factor, lack of continuous or appropriate supply and servicing, includes barriers related to uncertainties regarding continuous production and supply, reliance on local resources, and small manufacturers lacking capacity. All of these factors can be related to the conclusion by Van Wassenhove (2006) mentioned in the previous section about the need for robust equipment that can be handled in and adapted to changing conditions.

The organisational culture also affects the use of technology. As touched upon in the introduction to this report, there is a need to develop an innovative and technological culture in humanitarian organisations (Kabra et al., 2017). According to Kabra et al. (2017) HOs lack confidence and skills to adopt IT and they are far behind when it comes to building dynamic data and information processing capabilities, which are required to take advantage of modern technologies such as big data acquisition and evidence-based decision making. Balcik and Haavisto (2015) includes limited information technology as one of the challenges for measuring supply chain performance in a humanitarian setting, indicating the need to invest more in IT. A related remark is made by Blecken (2010), stating that time and accurate reporting is difficult to achieve due to the lack of appropriate IT systems. Özdamar and Ertem (2015) state in their study of humanitarian logistics models that the use of technology is not prevalent in HSCs, and the authors note that barriers for implementation of information systems relate more to the human way of doing things than lack of available technologies.

Lastly, there is the ethical aspect of technology use. Sandvik et al. (2014) argues that the deployment of technologies in the humanitarian field is not only a question of matching technology functionalities with specific problems or practices, there are also issues related to the humanitarian principles that requires consideration. By distributing relief in the form of monetary assets through mobile technology, what happens to those that do not have network coverage or access to a mobile phone? If technologies enable remoteness between humanitarians and the field, does that impact our understanding of humanity? How does the collection of sensitive data in a humanitarian context affect the imperative to "do no harm"? While emerging technologies have the potential to create great benefits and improvements for humanitarian operations, there is a need to also evaluate the dynamics that those technologies create and how they affect the humanitarian context (Sandvik et al., 2014).

The types of challenges related to technology use within the HSC are summarized in Table 11.

Table 11. Types of challenges related to technology use within the HSC

Type of challenge	Example
Operational	Equipment implementation, local settings, compliance with standards and access to appropriate supply and servicing
Organisational	Innovative and technological culture within HOs
Ethical	Effect of technologies on the humanitarian context

3.1.3.2. Implementation of innovations

In order to analyse and compare the benefits and challenges of emerging technologies, to connect the attributes of technologies to the context of the study, a tool for analysis is needed. Rogers (1983) define five key attributes of innovations that relate to the rate of adoption of an innovation by members of a social system. By identifying these attributes in relation to the context of the study, a suitable tool is obtained. The attributes of innovation are the following:

- *Relative advantage* is the advantage an innovation has compared to other available alternatives. The advantage can be of many forms e.g. increased economic profitability, increased social status, decreased risk for the user, etc. The relative advantage has a positive effect on the rate of adoption.
- *Compatibility* is how well an innovation corresponds to the needs, sociocultural values and beliefs, and already introduced ideas and experiences of the potential adopter. The compatibility, as perceived by the potential adopter, has a positive effect on the rate of adoption.
- *Complexity* is how difficult an innovation is to understand and use, and it has a negative effect on the rate of adoption.
- *Trialability* is the degree to which it is possible to try out the innovation on an experimental basis. If an innovation can be tested by the user, this has a positive effect on the rate of adoption.

- *Observability* is how visible the results of an innovation are, which is positively related to the adoption rate. For example, a software innovation usually has a slower adoption rate than a hardware innovation.

Table 12. Innovation attributes and their relation to adoption rate (Rogers, 1983)

Attribute	**Relation to adoption rate**
Relative advantage	Positive
Compatibility	Positive
Complexity	Negative
Trialability	Positive
Observability	Positive

Rogers (1983) adds to these five attributes that the *diffusion effect*, i.e. the cumulatively increasing degree of influence to adopt or reject an innovation by a social system, is affected by the degree of inter-connectedness in the social system. The closer the members of a social system are connected, the stronger is the diffusion effect and the rate of adoption increases. The concept of *overadoption* is also introduced, which is the adoption of an innovation that according to experts should be rejected. The reason for overadoption could be e.g. lack of knowledge about the innovation or the consequences of adoption, or inaccurate assessment of the compatibility of the innovation.

3.1.4. Summary: models to connect study and context

In section 3.1. the context have been explained. The models used for analysis, connecting the findings from the study with the context, have been described in detail. The place for the technologies in the HSC is determined with the extended HSC reference model (Figure 6). The applications that emerge from this matching of technology feature and HSC task are evaluated with the help of five innovation attributes (Table 12). The first two attributes in particular, Relative advantage and Compatibility, provides the answer to RQ1 of how the technologies are supposed to create benefits in this context. To address the challenges and barriers related to the use of the technologies (i.e. RQ2), all five attributes are considered from an operational, organisational and ethical point of view (see Table 11, types of challenges). This summary is illustrated in Figure 7.

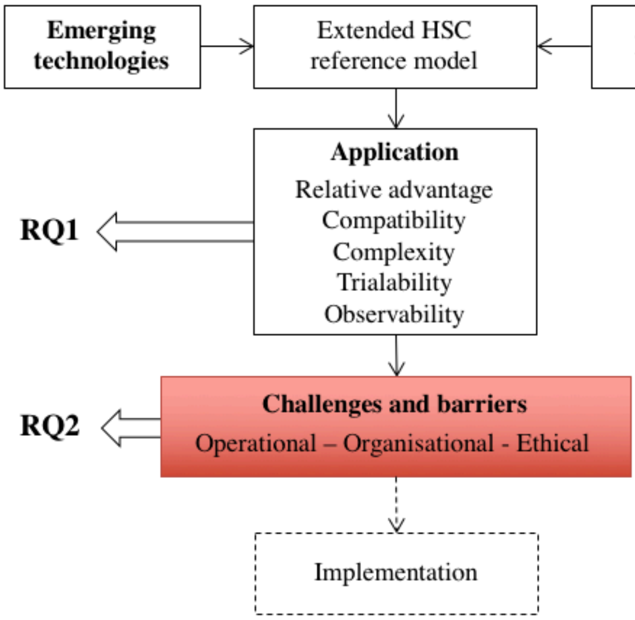

Figure 7. How the analytical tools are used to provide answers to the research questions.

3.2. Three-dimensional printing

3.2.1. Background to three-dimensional printing

Three-dimensional printing, also known as 3D printing or the more technical term Additive Manufacturing (AM), refers to methods where an object is manufactured from a 3D model and printed in thin slices, built layer by layer. The technology was first developed in 1989, but the numbers of 3D printers have grown exponentially the last few years (Noorani, 2017). There are various AM technologies suitable for different types of materials and objects. The quality of the manufactured object depends on several factors such as process used, material selection, thickness of printed layers, resolution of 3D model, etc. Examples of materials that can be used are polymers, metals, and ceramics. A 3D printer cannot print in air, so depending on the design of the printed item and the type of printer, more or less post-processing is needed to remove support material, i.e. material that holds up the final design (Noorani, 2017). Some advantages of 3D printing compared to other manufacturing methods are the possibility to manufacture very complex structures (e.g. for the purpose of design, or to create a lightweight version of an item by removing unnecessary material), and the possibility to very quickly develop a solution to a problem or customize and item without the need for specific tooling. It is also possible to print what would otherwise be several separate parts as one consolidated part, making the handling and instalment easier. 3D printing in supply chains is expected to reach mainstream adaptation within five to ten years (Gartner, 2017).

3.2.2. Structured review on three-dimensional printing

The initial sample of publications retrieved with the building block strategy for three-dimensional printing included 20 publications where seven publications were relevant for the subject, a relatively small sample. Not only peer-reviewed articles were therefore included as primary literature and citation pearl growing was used to find additional relevant articles, which resulted in two additional publications. See Table 13 for list of publications resulting from the review.

Table 13. Publications resulting from literature review on additive manufacturing

#	Title	Author(s)	Type of publication
1	Rapid Prototyping in Humanitarian Aid To Manufacture Last Mile Vehicles Spare Parts: An Implementation Plan	De la Torre et al. (2016)	Peer-reviewed article
2	3D Printing for Disaster Preparedness Making Life-saving Supplies On-Site, On-Demand, On-Time	Saripalle et al. (2016)	Conference paper
3	Three dimensional printing - a key tool for the humanitarian logistician?	Tatham et al. (2015)	Peer-reviewed article
4	Part of the solution	Thilmany (2010)	Article
5	3D opportunity for life - Additive manufacturing takes humanitarian action	Sniderman et al. (2016)	Consultancy report
6	3D printing humanitarian supplies in the field	James and James (2016)	Online article
7	Development of a Resilient 3-D Printer for Humanitarian Crisis Response	Savonen et al. (2018)	Peer-reviewed article
8	Shrinking the Supply Chain: Hyperlocal Manufacturing and 3D printing in Humanitarian Response	James and Gilman (2015)	NGO Report
9	3D Printing and Disaster Shelter Costs	Gregory et al. (2016)	Conference paper

Eight main themes are treated in the literature, as can be seen in Table 14. The themes are not explored to the same extent in all articles, and it should be mentioned that a few popular use cases are used as examples in several of the publications. “3D printing” is found to be used more commonly than “additive manufacturing” or “three dimensional printing”, therefore this will be the main term used for the technology.

Table 14. Relevant themes and their appearance in articles. Articles can treat several themes.

Theme of article	Included in article	# articles
3D printing used for spare parts	1, 2, 3, 5, 6, 8	6
3D printing used for low demand items	2, 3, 5, 6, 8	5
3D printing used for customized items	2, 3, 5, 6, 8	5
3D printing used for housing	2, 4, 9	3
General benefits of using 3D printing	2, 3, 5, 6, 7, 8	6
General challenges of using 3D printing	3, 5, 6, 7, 8	5
Design of 3D printer	7	1
Design of supply chain including 3D printer	1, 3, 5	3

The use of 3D printing for spare parts or replacement parts to repair broken equipment is the most commonly suggested application of the technology in the articles referred to in Table 13. There are two ways to use 3D printing in contrast to shipping a spare part from the manufacturer: either it is done in cooperation with the manufacturer that is consulted and sends the solution in the form of a three-dimensional model, or the manufacturer does not contribute in the replacement (De la Torre et al., 2016). In the second case a model of the required part would have to be created using reversed engineering. There are benefits both when it comes to efficiency and effectiveness related to involving the manufacturer for printing replacement parts according to De la Torre et al. (2016). For local manufacture of vehicle spare parts, the authors suggest an approach of close collaboration with the supplier from an early stage. It is suggested that the supplier is contacted as early on as possible, and that the supplier is involved in the selection of potential spare parts to print, i.e. it would be a partnership relating to the strategic level of procurement. The supply chain for spare parts has in general certain specific characteristics, such as a low and unpredictable demand combined with requirements of rapid availability when demand occurs, making the use of 3D printing beneficial (De la Torre et al., 2016). The possibility to manufacture spare parts in remote locations, or in general when conventional supply chains become difficult, allows for a higher level of self-sufficiency and can reduce both time and financial expenses while making more efficient use of transport and warehousing resources (Savonen et al., 2018, Tatham et al., 2015, De la Torre et al., 2016).

Similar to spare parts, the use of 3D printing for customized items benefits from the flexibility of the manufacturing method and the possibility to manufacture on location, close to the need. Sniderman et al. (2016) describes how in a disaster situation communication between relief providing organisations can be deficient, resulting in a lack of standardized tools and parts. This issue can be mitigated with the use of additive manufacturing, generating customized designs that suit the needs of the situation, making it possible to join the available resources. The authors use an example of water and sanitation issues after a natural disaster, where 3D printing can be used to manufacture a pipe fitting, adapted to the available pipes and with the possibility to add a customized bend or added extra features such as water filtration capabilities (Sniderman et al., 2016). James and James (2016) describe how they found improvised pipe connections such as metal fittings, bicycle tyre inner tubes or pushed-together pipes which often caused leakage, when arriving in Nepal after the earthquake in 2015. This issue could be addressed in less than a day by designing and printing a suitable fitting with a portable 3D printer, running off the battery of a car (James and James, 2016).

The speed of 3D printers is currently a barrier for its use as a way to manufacture large batches of items, if the time to manufacture is too long costs will be too high and/or the need will not be met in time (James and Gilman, 2015). When it comes to high demand items there are therefore usually more efficient production and delivery methods than 3D printing. The benefits of 3D printing come in when the demand for an item is low and/or uncertain, with the same logic as for spare parts. A recurring example in the literature (mentioned by Saripalle et al. (2016), James and James (2016) and Sniderman et al. (2016)) is the printing of umbilical cord clamps by the NGO Field Ready in a location where the clinics were not able to secure a supply, according to Saripalle et al. (2016) because the clamps were only available in bulk to a great cost. The clinics instead had to rely on personnel bringing these clamps in their personal luggage or use other less safe tools, before the opportunity to print the clamps was successfully introduced. Other examples of low demand items that could be suitable to print are special tools, rudimentary locks, learning tools, models for demonstration, rope clamps for shelters, pill dispensers, etc. (James and Gilman, 2015).

The last type of application found in the literature is 3D printing used for housing. To print buildings layer by layer with a 3D printer is presented as a low-cost and quick option to construct shelters or other necessary buildings (Saripalle et al., 2016, Thilmany, 2010). Gregory et al. (2016) attempt to compare the cost of 3D printing disaster shelter with conventional construction methods, however they have troubles finding accurate costs for 3D printed housing and does not include the cost or feasibility of transporting a printer to a disaster location. No actual use-cases or proof is found in the literature review of successful printing of houses in a post-disaster scenario.

Savonen et al. (2018) point out the need for a robust, transportable and easily deployable 3D printer to meet the contextual needs of humanitarian field operations. The authors define six key requirements that a printer should meet: it should make useful parts, function independently from infrastructure, be easily transported, be safe and easy to use, withstand harsh environments, and be procured for minimal cost. In their article Savonen et al. (2018) also present a new type of 3D- printer that is designed in order to meet all these requirements.

In general for 3D printing, the need to create local competence in order to manage the manufacturing process and related activities requires a significant investment, both in in the development of required processes and education of personnel (Tatham et al., 2015). Tatham et al. (2015) discuss a hub-and-spoke system as an alternative to providing local staff with all the necessary knowledge and skills to manage the design, printing and testing of items. The hub would be where all the design and testing activities are conducted, leading to a proven design that would only require printing, finishing tasks and limited testing at the spoke. A similar concept is also discussed by De la Torre et al. (2016) and Sniderman et al. (2016). Tatham et al. (2015) also bring up the possibility for the technology to create a new industry in remote locations with employment and income opportunities for the local population, eliminating the need for HOs to manage the 3D printing. Sniderman et al. (2016) point out the need for assessment of the level of 3D printing needed in order for organisations to ensure that capabilities and investments they make match the needs in the field. The level of need for 3D printing in specific situations needs to be assessed from project to project, and may also vary during a single mission. In conclusion, 3D printing would require assessment both on a longer-term, tactical level and on an operational level.

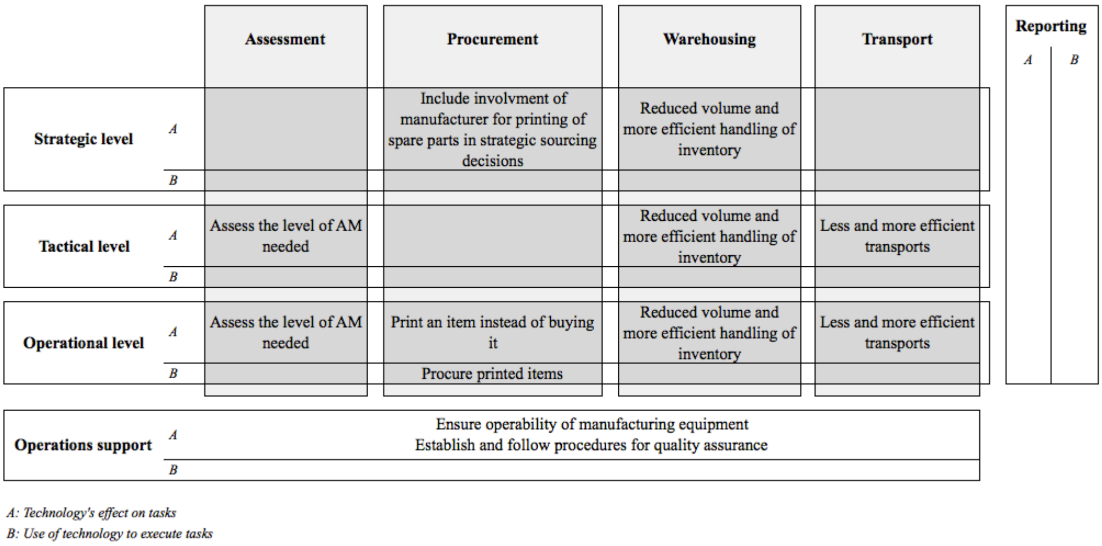

Figure 8. Findings from literature study on additive manufacturing incorporated in HSC reference model

3.3. Immersive technologies

3.3.1. Background to immersive technologies and mixed reality

Immersive technologies such as virtual reality (VR) and augmented reality (AR) are expected to drive competitive advantage for supply chains once reaching a high enough level of maturity. Virtual reality (VR) is a three-dimensional simulation of an environment, generated by a computer. The user experiences the simulation e.g. by wearing a pair of glasses or a helmet with a screen inside. How much the user can interact with the simulation depends on the equipment used. VR technology could be used in a supply chain context e.g. as a tool for education, preparation and social interaction (Gustafson-Pearce and Grant, 2017). The technology is expected to reach mainstream adaptation within two to five years (Panetta, 2017).

Augmented reality (AR) is a method where information is added as a virtual element to the physical reality in real-time. The information can be in visual, audio, or other forms, and the method can be supported by e.g. glasses, smartphones and tablets. (Stoltz et al., 2017) An application of AR within supply chain is e.g. improved order picking process in a warehouse as the picker could get visual information about what to pick, and which route to take in order to be as efficient as possible. The technology could also help train new personnel and to overcome language barriers. (Holger Glockner, 2014) AR is so far more common within e.g. the retail business and gaming than logistics operations, mainly due to the benefits the technology can provide with current level of maturity compared to existing logistics solutions (Stoltz et al., 2017). The technology is expected to reach mainstream adoption in five to ten years (Panetta, 2017).

3.3.2. Structured review

The initial sample of publications retrieved with the building block strategy for immersive technologies included 55 publications where five publications were relevant for the subject, a relatively small sample. Not only peer-reviewed articles were therefore included as primary literature. See Table 15 for a list of publications resulting from the review.

Table 15. Publications resulting from literature review on immersive technologies.

#	Title	Author(s) and publication year	Type of publication
1	Virtual Reality 360 Content Preservation for Disaster Relief	See et al. (2017)	Conference paper
2	Augmented Reality in Support of Disaster Response	Nunes et al. (2018)	Conference paper
3	Critical Facilities Virtual Environment for Emergency Responders	Wasfy and Gill (2012)	Conference paper
4	Managing humanitarian emergencies: Teaching and learning with a virtual humanitarian disaster tool	Ajinomoh et al. (2012)	Conference paper
5	State of Virtual Reality Based Disaster Preparedness and Response Training	Hsu et al. (2013)	Peer-reviewed article

Six main themes are treated in the literature, as can be seen in Table 16. It should be noted that four out of five publications are conference papers, only one peer-reviewed article is found.

Table 16. Relevant themes and their appearance in articles. Articles can treat several themes.

Theme of article	Included in article	# articles
Virtual Reality for training purposes	1, 3, 4, 5	4
Virtual Reality for recruitment purposes	1	1
Virtual Reality for content preservation	1	1
Augmented Reality to improve decision making abilities	2	1
General challenges of using virtual reality	1	1
General benefits of using virtual reality	1	1

The most commonly suggested application when it comes to immersive technologies in the articles referred to in Table 15 is to use VR for training purposes. Training in a virtual environment can be a way to overcome the issue of not having access to a specific environment or scenario during preparation (See et al., 2017, Wasfy and Gill, 2012, Hsu et al., 2013), while still being able to demonstrate complicated or complex conepts in a way that is easy to understand (Ajinomoh et al., 2012). Compared to alternatives such as real-life drills and simulations, training with the help of VR can reduce the time and cost burden as well as enable collaboration and ensure training consistency over geographical divides (Hsu et al., 2013). A virtual environment also allows for mistakes inexperienced personnell might make that could have severe consequences in an actual disaster scenario (Ajinomoh et al., 2012). The quality of the virtual environment is a key success factor, it is important that the content is as close to the reality as possible (See et al., 2017). The current state of the technology can therefore be a limiting factor, not providing a realistic enough experience (Hsu et al., 2013). Other challenges that are brought up in the literature is the current lack of familiarity for the technology (Hsu et al., 2013), and a risk of nausea for some users if a head-mount-device is used (See et al., 2017).

It is suggested by See et al. (2017) that VR could be used for assessment and demonstrations in a recruitment scenario. They also suggest that VR could be used in general for content preservation, preserving a very realistic view of a disaster scenario.

Nunes et al. (2018) focus on how AR could be used in support of disaster response. The conclusion is that from a supply chain perspective, AR could be used in most activities on an operative level to enable better decision making abilities and provide support or guiding by transmitting dynamic information through an AR interface. The technology is especially usefulf for tasks that makes it difficult to hold and manually interact with equipment for information systems. AR could also be used for training and preparedness purposes, as a way to demonstrate concepts, simulate scenarios or provide instructions. Figure 9 summarises how immersive technologies relate to the HSC according to the literature review.

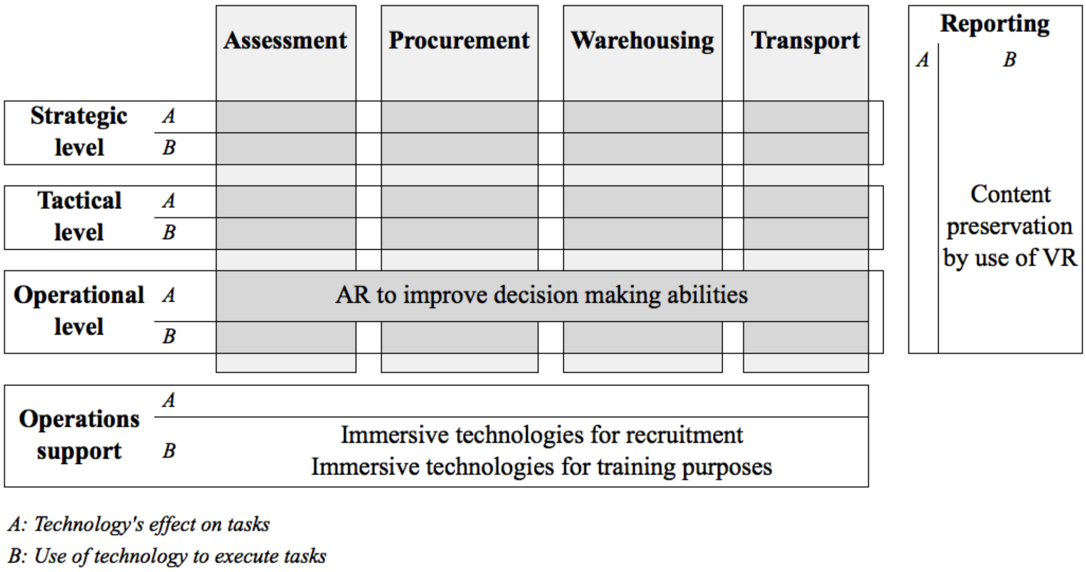

Figure 9. Relation between immersive technologies and the HSC according to the literature review

3.4. Unmanned Aerial Vehicles

3.4.1. Background on UAVs

Unmanned Aerial Vehicles are a type of autonomous vehicle. Autonomous vehicles can refer to both land-based vehicles such as cars or trucks, or aerial vehicles, also known as drones or UAVs. Autonomous vehicles are defined as "*those in which operation of the vehicle occurs without direct driver input to control the steering, acceleration, and braking and are designed so that the driver is not expected to constantly monitor the roadway while operating in self-driving mode*" (CAAT, 2018). The main supply chain focus is currently on autonomous vehicles in a closed environment, where e.g. UAVs could be used to save costs in warehouse inventory management, scanning barcodes, counting inventory and reducing the workload for employees in large distribution centres (O'Byrne, 2018). Investments in drone technology for last-mile deliveries are being made by company giants such as Amazon, but there are some challenges. First of all, it is a challenge to increase the payload so that drones are able to carry things that weigh more than 5 kg in a secure way (O'Byrne, 2018). Secondly there is the legal aspect of flying drones in an open environment, where various restrictions can apply depending on country and area. In the UK it is expected that unmanned traffic management solutions, required for UAVs to legally fly outside of the operators line of sight, will be developed by 2020 (Danaby, 2018). Autonomous vehicles are expected to be more than 10 years from the plateau of productivity while commercial UAVs are expected to reach the plateau within two to five years (Panetta, 2017).

3.4.2. Structured review

The initial sample of publications retrieved with the building block strategy for autonomous vehicles resulted in a relatively large sample, therefore only peer-reviewed articles were included as primary literature. See Table 17 for a list of publications resulting from the review.

Eight main themes are treated in the literature, as can be seen in Table 18. The use of autonomous vehicles for search and rescue operations was also detected as a recurring theme, however not included in Table 18 since it was judged as not directly related to supply chain operations. The only type of autonomous vehicle that is found in the relevant literature is the UAV, also called drone or less commonly RPAS (Remotely Piloted Aircraft System). The conclusion is that other types of autonomous vehicles, e.g. cars and trucks, are (quite expectedly) not considered particularly applicable for the HSC, and UAVs are the only types of autonomous vehicles that will be considered hereinafter.

Since the literature review resulted in a relatively large sample, even when only including peer-reviewed articles, the articles that mainly focus on "Facility location and resource management related to the use of UAVs" were not included as primary literature. The motivation for this selection is that for the purpose of this study there is no need to go into the practical details of the distribution network design, therefore data from the articles that mainly treat this subject is not extracted with the same level of detail as the primary literature. It is however noted in Figure 8 that using UAVs for distribution should be followed by an optimization of the distribution network on an operational level, and possibly an optimization of the design of the distribution network on a tactical and strategic level. A HSC considering the integration of UAVs in their distribution network should find it useful that there is a relatively large amount of articles treating this subject.

Table 17. Publications resulting from literature review on autonomous vehicles.

#	Title	Author(s) and publication year	Type of publication	Primary literature
1	Drone-borne GPR design: Propagation issues	Chandra and Tanzi (2018)	Peer-reviewed article	Yes
2	Flying maggots: a smart logistic solution to an enduring medical challenge	Tatham et al. (2017b)	Peer-reviewed article	Yes
3	Long-endurance remotely piloted aircraft systems (LE-RPAS) support for humanitarian logistic operations: The current position and the proposed way ahead	Tatham et al. (2017a)	Peer-reviewed article	Yes
4	Post-earthquake response by small UAV helicopters	Nedjati et al. (2016)	Peer-reviewed article	Yes
5	UAV Deployment Exercise for Mapping Purposes: Evaluation of Emergency Response Applications	Boccardo et al. (2015)	Peer-reviewed article	Yes
6	Development of an UAS for post-earthquake disaster surveying and its application in Ms7.0 Lushan Earthquake, Sichuan, China	Xu et al. (2014)	Peer-reviewed article	Yes
7	Radiation Mapping in Post-Disaster Environments Using an Autonomous Helicopter	Towler et al. (2012)	Peer-reviewed article	Yes
8	Cooperative use of unmanned sea surface and micro aerial vehicles at Hurricane Wilma	Murphy et al. (2008)	Peer-reviewed article	Yes
9	An investigation into the suitability of the use of unmanned aerial vehicle systems (UAVS) to support the initial needs assessment process in rapid onset humanitarian disasters	Tatham (2009)	Peer-reviewed article	Yes
10	Unmanned aerial vehicle-aided communications system for disaster recovery	Tuna et al. (2014)	Peer-reviewed article	Yes
11	An edge-based stochastic facility location problem in UAV-supported humanitarian relief logistics: a case study of Tehran earthquake	Golabi et al. (2017)	Peer-reviewed article	No
12	Drones for disaster response and relief operations: A continuous approximation model	Chowdhury et al. (2017)	Peer-reviewed article	No
13	A decision support system for coordinated disaster relief distribution	Fikar et al. (2016)	Peer-reviewed article	No
14	Hamiltonian dynamics and control of a joint autonomous land-air operation	Ivancevic and Yi (2016)	Peer-reviewed article	No
15	A drone fleet model for last-mile distribution in disaster relief operations	Reiner et al. (2018)	Peer-reviewed article	No
16	A constraint-based approach for planning unmanned aerial vehicle activities	Guettier and Lucas (2016)	Peer-reviewed article	No

Table 18. Relevant themes and their appearance in articles. Articles can treat several themes.

Theme	Included in article	# articles
Use of UAVs for deliveries	2, 4, 11, 12, 13, 15	6
Facility location and resource management related to the use of UAVs	4, 11, 12, 13, 14, 15, 16	7
Use of UAVs for geographical mapping	1, 3, 5, 6, 9, 16	6
Structural evaluation of buildings and other infrastructure	8	1
Use of UAVs for radiation mapping	7	1
Use of UAVs for communication	1, 10	2
Challenges of using UAVs	2, 3, 4, 5, 6, 9	6
Benefits of using UAVs	2, 3, 4, 5, 6, 9	6

There are two main applications for drones: mapping and deliveries. Boccardo et al. (2015) defines emergency mapping as the "*creation of maps, geo-information products and spatial analyses dedicated to providing situational awareness emergency management and immediate crisis information for response by means of extraction of reference (pre-event) and crisis (post-event) geographic information/data*". UAVs can be used in order to create an overview of a situation, e.g. generate real-time and high-resolution maps (Chandra and Tanzi, 2018, Tatham, 2009), evaluate damage on infrastructure (Murphy et al., 2008), assess supply routes (Tatham et al., 2017a, Xu et al., 2014), and count the number of people in a population (Boccardo et al., 2015). The main challenges related to mapping drones are legal restrictions or potential permissions required to fly in a specific area and altitude, how to keep the generated data secure and make sure it is not used for the wrong purpose, and to make sure people does not experience the drone as hostile (especially in areas where there have been military drones) (Chandra and Tanzi, 2018, Tatham et al., 2017a).

The use of UAVs for deliveries is presented as a way to increase access to inaccessible locations, e.g. geographically remote locations (Tatham et al., 2017b) or locations that becomes difficult to reach after a disaster due to collapsed roads etc. (Nedjati et al., 2016). Challenges include legal restrictions (Nedjati et al., 2016), potential conflicts between UAVs and commercial flights (Tatham et al., 2017b), and the current state of the technology leading to payload and duration limitations (Reiner et al., 2018, Chowdhury et al., 2017). A concern of increasing the "distance" between relief providers and beneficiaries, i.e. loosing the actual human-to-human contact, is discussed by Tatham et al. (2017b) as a potential negative effect of using UAVs for deliveries. The authors point out the importance of establishing trusted relationships and communication channels between relief providers and the community in order to avoid this issue.

Apart from mapping and deliveries, the use of UAVs for deployment of ad-hoc communication networks is suggested (Chandra and Tanzi, 2018, Tuna et al., 2014). A UAV could work as a mobile access point extending the communication network in areas where no regular network is present or where the network is temporarily not functioning for some reason. Tuna et al. (2014) present in their study a UAV-aided communications system that is successfully tested and feasible to deploy in a post-disaster scenario. The main challenge according to the authors is the limited flight endurance of the drones, possibly solved by using enough UAVs to let them land and recharge in an alternate manner.

Regarding issues related to the connection of UAVs to military applications, the opinions differ. Some, e.g. Chandra and Tanzi (2018), say that the military affiliations of UAVs generate social challenges; people can be scared, hostile and/or feel uncomfortable with having drones fly above them. Others, e.g. Tatham et al. (2017b), state that the humanitarian relief community is supportive towards the use of UAVs despite their military roots, however also stating that further work is needed to fully understand community engagement, benefits, challenges, and implications of integrating UAVs in the supply chain.

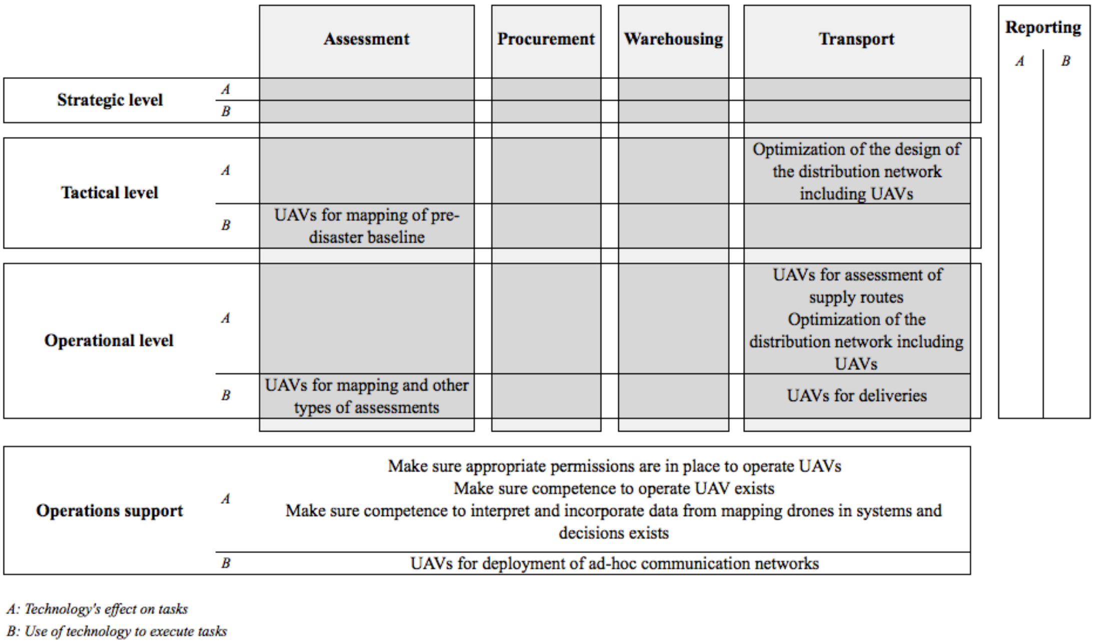

Figure 10. Relation between autonomous vehicles and the HSC according to the literature review

3.5 Internet of Things

3.5.1. Background on IoT

Internet of things (IoT) is the concept where objects are connected to a network where they are provided with a unique identifier and can transfer data without interaction with a human or a computer. The International Telecommunication Union (ITU) defines IoT as "*a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies*" (ITU, 2018). Possible applications of IoT within logistics include tracing of objects throughout the supply chain, monitoring and control of environmental parameters, and monitoring of stock levels. (Atzori et al., 2010) However there is a need to address the issue of data security in the cloud of things, which is a challenge due to the scale of deployment, the mobility of the things and their relatively low complexity (Bandyopadhyay and Sen, 2011). IoT platforms are expected to reach general mainstream adoption within two to five years (Panetta, 2017), while for supply chain purposes IoT is expected to be five to ten years away from the plateau of productivity (Gartner, 2017).

3.5.2. Structured review

The initial sample of publications retrieved with the building block strategy for IoT included 44 publications where six publications were relevant for the subject, a relatively small sample. Not only peer-reviewed articles were therefore included as primary literature. See Table 19 for a list of publications resulting from the review.

Table 19. Publications resulting from literature review on IoT.

#	Title	Author(s)	Type of publication
1	Development of an intelligent disaster information-integrated platform for radiation monitoring	Tzu-Husan and Der-Cherng (2015)	Peer-reviewed article
2	Developing an Integration Framework for Crowdsourcing and Internet of Things with Applications for Disaster Response	Dubey et al. (2015)	Conference paper
3	Implementing mission critical services and applications on top of heterogeneous networks	Sedlar et al. (2014)	Conference paper
4	How the Internet of things technology enhances emergency response operations	Yang et al. (2013)	Peer-reviewed article
5	Resource management system for crisis response & management	Du et al. (2016)	Conference paper
6	Architecture Design of Internet of Things in Logistics Management for Emergency Response	Xu et al. (2013)	Conference paper

Six main themes were detected in the literature, as can be seen in Table 20. It should be noted that only two of the publications are articles published in academic journals. The article by Yang et al. (2013) provides a good introduction to how IoT technology might be used within emergency management in order to create benefits, as can be seen in Table 20 they cover all detected themes.

Table 20. Relevant themes and their appearance in articles. Articles can treat several themes.

Theme of article	Included in article	# articles
IoT to enhance situational awareness	1, 4, 6	3
IoT to enable visibility of resources	4, 5, 6	3
IoT to improve resource allocation	4	1
IoT to improve inter- and intra-organisational cooperation	1, 4, 6	2
General challenges related to IoT	2, 3, 4, 6	4
General benefits related to IoT	4, 6	2

IoT to enhance situational awareness refers to the ability of the IoT technology to provide an assessment of a situation by presenting data gathered by various “things” in a comprehensive manner to the emergency personnel (Yang et al., 2013). Tzu-Husan and Der-Cherng (2015) presents an IoT supported platform for radiation monitoring as an example of IoT providing situational awareness, pointing out that in addition to providing real-time information to the emergency responders the platform can be used for disaster information dissemination to the public. Apart from providing an overview of a situation, IoT can enable real-time visibility of the various resources of an organisation (Du et al., 2016, Xu et al., 2013). Combining situational awareness and visibility of resources allows for improved resource allocation, allocating the often limited resources in the most efficient way possible with the help of IoT (Yang et al., 2013).

Sharing of information and resources is a key success factor for emergency relief operations (Yang et al., 2013). By allowing access to an IoT platform to multiple actors within the same organisation or between organisations, the technology can also be used to improve cooperation in a disaster situation where a lot of actors are present (Xu et al., 2013).

General challenges related to IoT include the configuration, update and maintenance of devices for the network (Tzu-Husan and Der-Cherng, 2015). A specific challenge for post-disaster scenarios or the general operational conditions for humanitarian work is that connectivity might be an issue (Du et al., 2016). Even if available communication systems are functioning, it might be required to update or adopt a new communication system if the current one does not allow for the throughput necessary for IoT applications (Sedlar et al., 2014). An IoT platform must be able to handle large amounts of data (Tzu-Husan and Der-Cherng, 2015) in a secure manner (Yang et al., 2013, Xu et al., 2013, Dubey et al., 2015). For IoT to be as beneficial as possible trust needs to be established for the technology (Dubey et al., 2015), however acceptance and trust issues towards IoT might be an issue and should be investigated further (Yang et al., 2013).

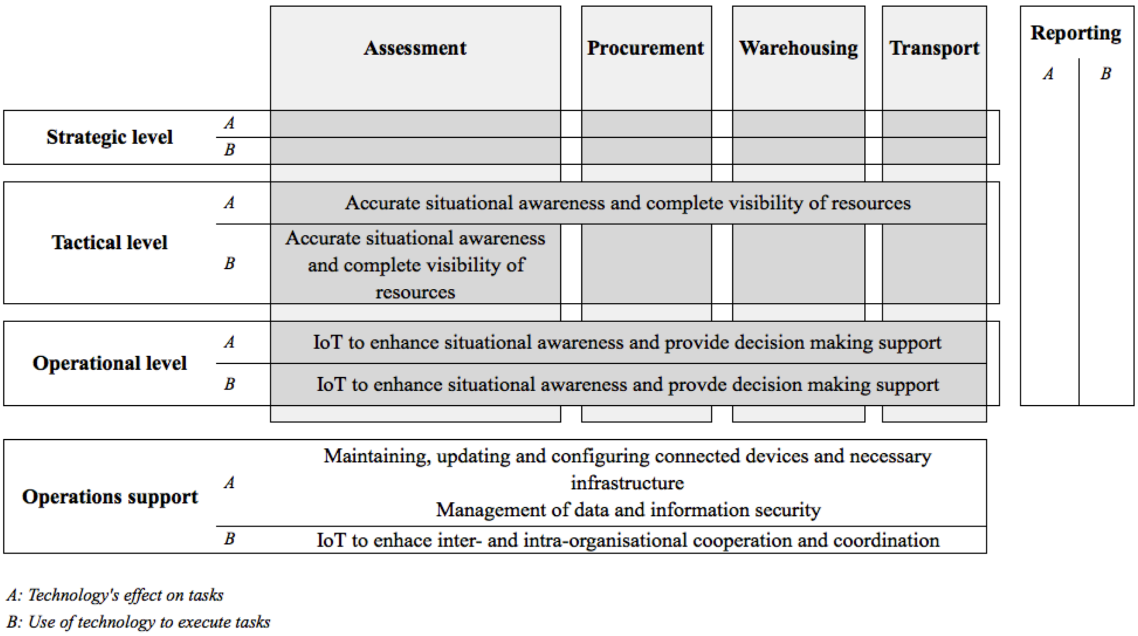

Figure 11. Relation between IoT and the HSC according to the literature review

3.6. Summary: Technologies in relation to the HSC

In Table 21 the relations between the technologies and the supply chain activities are summarized. In addition to the division between execution of tasks and effect on task, the effect on tasks is divided into positive effect and challenging effect/added tasks.

Table 21. Summary of relation between the technologies and the HSC.

	Assessment	Procurement	Warehousing	Transport	Op. support	Reporting
Technology used to execute tasks						
3D printing		X				
VR					X	X
AR						
UAVs	X			X	X	
IoT	X	X	X	X	X	
Technology has positive effect on tasks						
3D printing		X	X	X		
VR						
AR	X	X	X	X		
UAVs				X		
IoT	X	X	X	X		
Technology has a challenging effect on tasks/adds tasks						
3D printing	X	X			X	
VR						
AR						
UAVs				X	X	
IoT					X	

4. Empirical findings

4.1 Three-dimensional printing

For a summary of the findings from R1 and R2, see table 22. In the first project (I1) no distinction is made between spare parts, low demand items and customized items at the point of the interview (May 2018). All types of items that can be manufactured with the machine and material on hand will be considered for printing, with the limitation of non-invasive objects, external to the human body i.e. nothing that needs to be sterile. To begin with the focus will be on small, simple items to try out the technology which is similar to the approach in many of the publications from the literature review (e.g. Tatham et al. (2015)). The focus is on mitigating instead of avoiding long lead times, to use the technology as a complement to the supply chain without replacing any of the current steps. This means that when a need arise that cannot be covered with available stock or local procurement, an order will be placed to the current supplier but while waiting for the delivery a replacement item would be manufactured with the 3D printer. The result should be less downtime for equipment or less stockouts, depending on the type of item, leading to a higher service level in the field. It could also reduce transport and generate savings if emergency requests and shipments could be avoided. With this setup, none of the savings related to the import and management of printing material compared to finished goods (that are discussed in the literature) would be realised since the printing does not replace any of the steps in the supply chain.

Table 22. Summary of findings from R1 and R2. The minus sign indicates that there were no comments for that specific subject.

Literature	R1 I1	R1 I2	R2
3D printing is suitable for spare parts	At this point no difference is made between these categories. No supply chain activities will be replaced. No contact with original supplier. Otherwise comments correspond to literature.	-	Cost analysis recommended Challenge: guarantee requires original spare part
3D printing is suitable for manufacture of low demand items		-	Cost analysis recommended Suitable for specific, one-time needs
3D printing is suitable for manufacture of customized items		Corresponds to literature. A reverse innovation tendency is experienced	Cost analysis recommended Challenge: moving further from standardization
3D printing is suitable for housing	Not really relevant for MSF	-	Cost analysis recommended Could be relevant to look into
Design of supply chain including 3D printer	Different set-ups are still considered.	Remote expertise is used for design activities and externally managed shop used for printing	Printer most useful on country level
Design of 3D printer	No real need to transport printer for short term needs, therefore challenges related to robustness and self-sufficiency are less critical	Rely on manufacturing hub to avoid this task	Agree with I1
General challenges of using 3D printing	Corresponds	By relying on manufacturing hub, a lot of the challenges are manged by the hub	-
General benefits of using 3D printing	Mitigating instead of avoiding long lead times No comparison of import of printing material vs. finished goods	Does not agree to benefits related to import procedures	Agrees to benefits related to import procedures
Additional applications	-	-	3D printing for prototypes and demonstrations
Additional benefits	-	-	-
Additional challenges	Relationship to original supplier and copyright issues	-	Involvement of original supplier a good idea

In I1 the setup is primarily motivated as a way to move slowly and reducing the risk of copyright issues with suppliers. Another related concern raised during R2 is that sometimes the suppliers do not give any guarantee to a machine if the spare part is not original, which could be an issue when using printed parts. The possibility to collaborate with the original manufacturer for printing of spare parts is something that have been discussed as an ideal scenario for the future according to I1. The participants in R2 agree that it would be a good idea to involve some of the suppliers that the organisation have strategic partnerships with in the discussion and testing of 3D printing. In the literature, copyright or guarantee issues are not discussed but to involve original manufacturers in the printing process is mentioned as a possibility. The motivation for supplier involvement in the literature, letting the original manufacturers supply the specifications and/or 3D model ready to print, is rather one of efficiency and effectiveness than risk mitigation.

It could be argued that the use of the 3D printer in I2 is rather related to medical than supply chain activities, but since the issue is the provision of a physical item needed in order to provide a specific type of care, the supply chain relation is motivated. The project has been successful so far, the 3D printer in combination with a 3D scanner is according to I2 a way for MSF to provide something that the organisation can't provide in another way. The project has received positive attention.
"With the difficult context we are experiencing we are daring a lot, and hence we have a certain advantage in the world of prosthesis and now a lot of conventional movements they want to collaborate with us (...). We experience a kind of reverse innovation tendency right now." – I2

Two set-ups are discussed for the future in I2, see Option A and B in Figure 10. In both scenarios the design would be done remotely i.e. not at the place of need, and then the options are between printing locally or centrally in connection to one of the European logistics centres. In either of the cases the printing would be managed by an external actor, a 3D printing shop or a Fab Lab (a place for digital fabrication such as 3D printing). The 3D scanner as an enabler to use remote design expertise is highlighted as a critical success factor by I2. *"We are not experts in prosthesis, and we are not experts in 3D printers, so it's smarter to collaborate with others who are" – I2*. With option B in I2, i.e. printing managed centrally, the advantages related to production close to the need are lost. This is motivated by the fact that for rehabilitation purposes (where prothesis is used) it is not a matter of hours for the supply to arrive, so the reduction of lead time you would gain by having the printer very close to the patient is not an obvious advantage. *"It might be interesting e.g. if you are talking about a population that is on the way, running. In that case it would mean critical added value if the prothesis could be delivered as soon as possible. It depends on the population, it's not compulsory that everything is made within a few hours." – I2*. The other benefits related to reduction of import related complications, by having the printer in the same country as the need, are questioned in I2 with the motivation that if import is difficult or expensive for medical supplies, import of a 3D printer would be just as complicated. However the participants in R2 rather agree with the results from the literature review that there are import related benefits. First of all because the lead time in general should be as short as possible, and a big share of the lead time today is import so in order to decrease lead times a printer would be most useful on a country level. Secondly, since a printer is only imported once any complications related to that process should be manageable, and after that import of raw material for printing instead of finished goods should be easier and less expensive.

In I1 the discussed set-up is to have both the printer and design process in the same country as the need, possibly with remote help with the design. At the point of the interview it was not decided if a printer should be located centrally in the country, answering to needs of more remote places by managing the manufacturing process, or if the remote locations would have their own printers. The benefits of having the printer centrally located are better access to expertise, more suitable manufacturing locations to choose from, facilitated supply of printing material, and so on. It would be easier to motivate and maintain a more advanced printer in a central location, in the remote locations a simpler model would be more suitable. I1 comments that if it became more common with local 3D printing businesses, and cities MSF operate in would have a 3D printing workshop that delivers with high quality and reliability, then perhaps printing is not something MSF would actually do themselves. That would be a good scenario since money would be spent locally, fostering local businesses, and MSF wouldn't have to handle the printing process and everything that comes with it.

The supply chain designs discussed in literature are mainly similar to the set-up discussed in I1 (e.g. James and James (2016)) or option A in I2 (e.g. De la Torre et al. (2016)). The possibility to use local printing shops is also discussed as a good scenario for the future when 3D printing becomes a more widely spread technology.

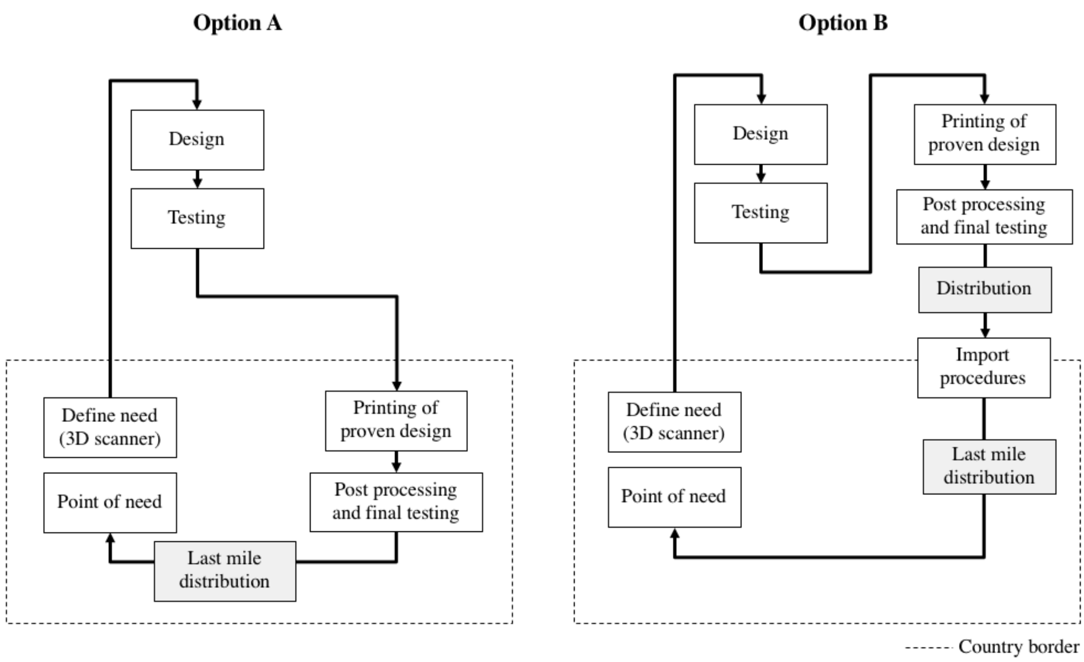

Figure 12. Illustration of the two options for design and distribution of prothesis discussed in I2

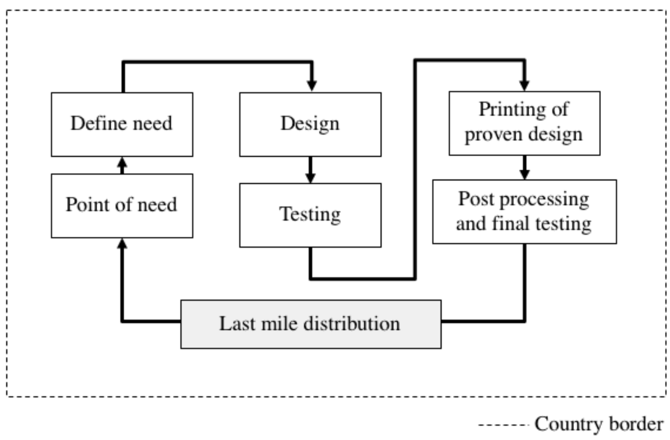

Figure 13. Illustration of the set-up discussed in I1

During R2 a concern is raised by one participant regarding the possibility to manufacture customized items with 3D printing, and how this might interfere with the aim to standardize as many needs as possible. A majority of the needs in the field are recurring, and for those needs there is a value in standardizing in order to save time and cost, be more efficient. There needs to be a definition for the cases where this technology would be a good solution, when there is a one-time need or a situation that is so rare there is no value in standardization. Printing of customized items should not be used as a quick fix. This is a general concern, as in none of the projects in R1 moving further from standardization would be an issue, in I1 because printed items only act as temporary replacements and in I2 because the a prothesis clearly has to be customized and adopted to each individual's needs. The other participant in R2 also comments that even though there is an aim to work with standardized equipment, this is not feasible in reality because missions are so different, whether it comes to temperature, the level of humidity, the security, the activities, the level of health care in the country, etc.

A general comment from R2 is that a cost analysis would be a reasonable approach, and should be quite straight forward to do, in order to find out which items should be printed, and which should be bought. The analysis would have to be done on item and country level, starting somewhere where fairly detailed demand data is available and including all factors and related costs e.g. transport, quality, life time, lead time, available supply, import, etc.

To use 3D printing for housing is dismissed in I1 as something unrealistic for several reasons. These types of printers are very large, and they usually use some sort of cement, so getting both printer and material into place would be heavy and difficult from a logistics perspective. To build with cement also requires a lot of water, which might be an issue. According to I1 it would be difficult to motivate this application for the short-term housing and building applications that are needed in MSF when there is the option of e.g. tents. The participants in R2 are a bit more positive, again arguing for a proper cost analysis to compare alternatives. To use 3D printing for parts in modular construction projects is also brought up as an interesting alternative, which would not require the type of large printer that prints a whole house layer by layer. The application of 3D printing could in that case rather be considered printing of customized items, used in the construction of buildings.

Key takeaways:

- Use 3D printing as a complement to the existing supply chain while the technology is still developing
- Opportunity for collaboration with external actors with technical expertise when the operational context makes MSF more daring

4.2 Immersive technologies

In the first round, one person was interviewed regarding immersive technologies. For details about the interview see Section 2.2.3. For a summary of the findings from R1 and R2, see table 23.

Table 23. Summary of findings in R1 and R2. The minus sign indicates that there were no comments for that specific subject.

	R1	
Literature	I3	**R2**
VR is suitable for training purposes	Agree	MSF should follow the development and adapt to new standards, but it's not realistic or necessary to be the first movers.
VR is suitable for recruitment purposes	Not sure	
VR is suitable for content preservation	Unclear benefits	More visual ways to share content have benefits: save time and better explain a scenario.
AR to improve decision making abilities	Not at this point Challenge: lack of connectivity	-
General challenges of using VR	Haven't collected enough feedback to tell	-
General benefits of using VR	-	-
Additional applications	Collaboration, demonstration and communication	Agree
Additional benefits	Bridge language, cultural and professional barriers	
Additional challenges	Lack of connectivity for AR	Organisational challenge: innovative communication

The participant in R1 agree with the literature that VR could be useful for training since it is very visual, making it easy to grasp concepts and scenarios that are demonstrated. During I3, the participant also points out that this can be particularly useful when you are working with people from different cultures that speak different languages and might have different professional backgrounds, as is often the case for humanitarian organisations. This benefit is not found in the literature review and is therefore noted as an additional benefit in Table 23. VR for recruitment was not a part of the project but the interviewee comments that it depends on how it would be used. As a communication tool in the recruitment process the virtual environment could be used to demonstrate something, better describe the work in question. However, in order to be able to interact with the virtual environment, which might be needed to assess the skills of an applicant, the VR that they created would need a lot more development. It should be noted that even though the project was considered successful and the interviewee in I3 thinks that VR would be suitable for training and demonstrations, they do not focus on it at the moment due to lack of resources. The participants in the second round share the opinion that MSF does not have to be the first movers when it comes to using VR for training or recruitment, they think the organisation is not ready to take on this type of technology on a larger scale. MSF should follow the development of the technology as it matures, when VR is something that people start to expect the organisation should be prepared and ready to adopt the technology.

VR for content preservation or reporting was not something that was directly discussed in I3, and the interviewee does not see the added value compared to e.g. recording a video. VR training material was created by using 360 videos of actual construction processes, but according to the interviewee it was just documentation for training purposes and not a way to record results or create a report. The participants in R2 are more positive, the same way as VR can improve training by visualising complex scenarios for people with various backgrounds the technology could be a way to create better, more visual reports. An example is given from the Ebola outbreak in 2014, where the first returning MSF employee was lacking words and had troubles describing how dramatic the situation actually was during the debriefing back in the headquarters. It is suggested that a VR element could help in grasping the idea of the context, improve your understanding of the supply chain constraints and the emotional constraints of your staff. However, it is also brought up as a challenge that MSF as an organisation is not very innovative when it comes to ways to communicate. There is a tendency to rely too much on text for communication and reporting when sometimes more visual or auditory ways of transferring information would save time for the sender as well as be easier for the receiver to understand and process. In conclusion, there are organisational challenges to tackle probably before VR could be used for reporting and content preservation. Since this is a challenge that could be applicable for all immersive technologies, innovative communication is noted as an organisational challenge in Table 23 under "Additional challenges".

AR was not part of the project in I3, and the interviewee does not think that it would be relevant for MSF to look into AR applications in the field at this point. The main reason for this is issues with connectivity, the current level of connectivity in the field is limited and it would be unrealistic to incorporate AR in that operational context. This challenge is not found in the literature review, therefore it is noted in Table 23.

Key takeaways:

- Do not try to lead the technological development
- Innovation when it comes to communication is a general organisational challenge
- Visual ways to communicate can bridge language, cultural and professional barriers

4.3 Unmanned Aerial Vehicles

For a summary of the findings from R1 and R2, see table 24. I5 have been involved in several trials of cargo drones, both with MSF and other organisations. In Papua New Guinea (2014) there was an MSF project on tuberculosis, a disease that requires long term treatment of patients with follow-ups and medication. The poor condition of the dirt roads after the rain season, as well as the locations of some of the communities that required access by boat or through the jungle, made access to the remote health centres and communities a challenge. The objective of the project was to use UAVs to tackle this challenge. The UAVs were supposed to pick up tuberculosis samples from the remote areas and bring them to a central laboratory for testing, as well as delivering results and treatments back to the remote areas. The project was successful in the sense that the deliveries were possible to carry out in a shorter amount of time and with less risks with the UAV compared to with a car. It was also successful in the sense that the local communities had no objections towards the use of UAVs, indicating acceptability and support of the technology. However it was noted that the limited flight range of the UAV used in this project posed a considerable constraint as it was required to land and recharge/change batteries between origin and destination, a less than optimal solution.

Table 24. Summary of findings in R1 and R2. The minus sign indicates that there were no comments for that specific subject.

Literature	R1		R2
	I4	I5	
UAVs are suitable for deliveries	-	Agree	Payload limitation affects how related it is to the job of a logistician
UAVs are suitable for mapping and assessment	Agree	-	Assessment of transport routes - issue of reach with the mapping drone
UAVs are suitable for communication	-	-	-
General challenges of using UAVs	Agree that attitudes towards drones might be a challenge. Other challenges correspond	Ethics and attitudes towards drones are not really concerns Other challenges correspond	Agree with R1
General benefits of using UAVs	Correspond	Correspond	-
Additional applications	-	-	-
Additional benefits	-	-	-
Additional challenges	Fragility of the drone	-	-

According to I5 there is a clear need for drone deliveries since it would enable deliveries that cannot be done today, e.g. deliveries to areas that can only be reached by boat or where there is a lack of roads either temporary or permanently, as in the case of Papua New Guinea. In addition to this there are other types of deliveries, e.g. supply of smaller quantities on demand if there is an unplanned stockout or a very specific need that you don't have supplies in stock for. Drones could work as a complement to the supply chain, making it more flexible. By sending drones instead of using other forms of delivery (motorbike, car, helicopter, etc.) savings can be generated and time saved. Currently the more refined, advanced and well performing drone models still requires more or less professional pilots, the objective is to be able to train a field logistician or local staff to operate the vehicle. The equipment should be easy enough to handle so that people with very little training could both launch and receive a drone delivery. The interviewee estimates that this level of operability might need an additional 1,5-2 years of development, however in areas where you would have a very high added value the deployment will probably go faster since it might be reasonable to hire a pilot or accept a higher cost. The price of transport drones that are available on the commercial market have in general been a bit high for an organisation like MSF, taking the (lack of) robustness of the equipment into consideration. For some available solutions you need a high flight frequency in order to get a good price per flight, which MSF for the moment do not have in the outreach areas. Since what is available on the commercial market does not really meet the requirements of an organisation like MSF, I5 is now working on developing the technology to make it more suitable and available to humanitarian organisations.

The cargo drone that is currently under development will be able to carry a weight of 2 kg and volume of 15 l. The interviewee says that there is a demand for drones that can carry more cargo but argues that it makes sense to start with this type of smaller platforms. It is a technical challenge to do deliveries of larger size, and it might also create an import challenge when larger batteries are required. A lot of the medical needs in rural areas can also be satisfied with quite small deliveries, motivating the usefulness of smaller cargo drones. This payload limitation was the main thing that the respondents in R2 reacted on, stating that there might be some very specific projects where it could be useful, but it would not really be related to the work of a logistician. Deliveries of 2 kg is very end-user focused, it is more related to something the medical staff would handle. Otherwise the interviewees in R2 agree that there are useful applications for cargo drones e.g. deliveries to unreachable areas, ad-hoc complementary deliveries with food to your staff, etc. without the security risks of road transport. I5 thinks that initially UAVs will probably be used as a complement to the existing supply chain at first, used to transport low volume cargo with high value to outreach areas. As the technology develops the drones will increase in size, and deliveries will move on to more mundane things in rural areas. Lastly drone deliveries will take place in more populated areas such as cities.

The interviewee I4 agree with what is stated about mapping drones in the literature; drones could be useful for e.g. road assessment, location of critical facilities and population count in refugee camps. The testing of the mapping drone described in Table 20 was during a period of yearly flooding in southern Malawi. During the flooding the team has limited access to the area, so they wanted to use photos from above in order to see where the highest levels of water were, where it was possible to access the flooded area, how to reach certain places and health facilities. The project was successful as they were able to photograph the area with the UAV and use the output to inform the team how to get into the area. Investigations of the usefulness of mapping drones are still ongoing within the organisation, but the conclusion from this case according to I4 is that the technology can be useful and help in similar situations. It provides a quick, flexible and non-expensive way to get an overview of geographical areas, but it is pointed out during the interview that it can be a challenge to know how to process, analyse and use the information. A participant in R2 agrees on this; while advanced, high-resolution maps are nice to have it is not always clear how they should be used to improve operations and it might not be the first thing you prioritise to invest in. Another comment from R2 was that transport routes quite often are very long, so there could be an issue of reach with the mapping drone if it is intended for assessment of transport routes.

The UAV that was used in Malawi was fit for the purpose of testing in the sense that it was easy to use even with limited practice and provided high quality images. However the model was expensive and quite fragile, which became an issue as it had to be repaired several times. I4 suggests that it should be investigated how high image resolution that is actually required for the needs of MSF, and that a cheaper, more robust mapping UAV could be a better fit for the organisation. The alternative to mapping UAVs would be satellite images, a solution that is less flexible, more expensive, more exposed to risk of clouds, and it takes time to order and receive the images which risks making the material outdated when it arrives. However, even if it is relatively easy to learn how to use a mapping UAV it requires an operator with some sort of training as well as legal permissions to operate it, so in some cases it could be cheaper and quicker to order satellite images than to send a drone operator.

Regarding attitudes towards drones, I4 brings up that this might be a challenge within MSF where some people have a negative view on drones and an official decision needs to be made regarding whether MSF should work with drones or not. I5 states that even though people had concerns in the beginning, now they are accepting drones because the technology is needed. Regarding the people receiving aid, they can differentiate between military and non-military drones and most people are getting used to drones for purposes other than military. The perception is changing, but it is important to always speak with the local population in the area before starting to operate drones in order to be transparent and explain the purpose and benefits.

Both participants in R1 agree that regulations, operating standards and permissions for operating UAVs are a challenge, sometimes because more regulations are required and sometimes because the permissions are difficult to get. Coordination and operating standards are necessary, otherwise dangerous situations might occur after a disaster where drones might interfere with planes, helicopters, etc (I5). Authorization to operate the UAV is brought up as the primary issue in I4, depending on where you are various permits might be required in order to operate the drone and in some cases this can put a stop to a planned assessment. In order to be able to use drone after a disaster it is suggested by I4 that all permissions need to be in place before the actual disaster, requiring a certain level of preparedness.

To use UAVs for deployment of ad-hoc communication networks was not specifically commented during any of the rounds and will therefore not be elaborated on further.

Key takeaways:

- Drones are suitable for deliveries, but the technology needs some more development to optimize its performance
- Drones are suitable for assessment
- Legal issues can act as barriers

4.4 Internet of Things

For a summary of the findings from R1 and R2, see table 25. Regarding IoT for cooperation and collaboration purposes, participants in R1 and R2 agree that there is a variety of factors that make both inter- and intra-organisational cooperation difficult (also discussed as general challenge in Section 3.1), and these factors would remain even if IoT could be utilized to share information more efficiently. When it comes to the other applications that are suggested, it is too early for the participants in R1 to tell much about neither their benefits nor specific challenges since a lot of factors are unsure and further investigations are required regarding possible set-up of a potential network, configuration of connected devices, requirements on existing systems, etc. At the point of the interviews (May/June 2018) no project on IoT had yet been launched or even clearly defined. The suggested applications are instead discussed from their potential usefulness in general terms. Regarding applying IoT for situational awareness I7 comments that e.g. warning systems for natural disasters could be outside the scope of MSF's work since they usually arrive after a disaster and are supposed to be a temporary addition to the local healthcare. Visibility of resources is the application that both participants in R1 are most positive towards, they agree with the literature that this could be interesting for things like stock levels, temperature sensing or fleet management but are not sure whether IoT should be the technical solution. IoT for allocation of resources would be yet another step that first requires at least some level of visibility of resources in place. According to I6 and I7 it is too early to tell whether IoT would be useful for this type of application, but I7 points out that a there have been discussions within the department of some sort of automated allocation of resources particularly in the context of vaccines where the ordering is a real issue.

Table 25. Summary of findings in R1 and R2. The minus sign indicates that there were no comments for that specific subject.

Literature	R1		R2
	I6	I7	
IoT could enhance cooperation	General challenges with cooperation, or reasons that cooperation is not happening, would remain even if IoT could be used to make collaboration more efficient	Agree with I6	Agree with R1
IoT could be used for situational awareness	Too early to tell	Could be outside the scope of what MSF do	-
IoT could enable visibility of resources	Interesting to look into	Interesting to look into	-
IoT could be used for allocation of resources	Too early to tell	Too early to tell	-
General challenges of using IoT	Agree or too early to tell	Challenge of connectivity: use dedicated network for IoT	-
General benefits of using IoT	-	-	-
Additional applications	-	-	-
Additional benefits	-	-	-
Additional challenges	In general: be aware of the "buzz" factor, ensure technology is fit for purpose	Evaluate usefulness of technology	Maturity of the organisation

For the challenges found in the literature, a lot of them depend on how the IoT network is set up and used, therefore it is too early to completely reject a potential issue or really tell how big of a challenge it would entail. For example, the importance of data security depends on what data that is gathered. The GPS location of a car can be sensitive for security reasons, but something like the level of water in a tank in a refugee camp, is not very sensitive (I7). Regarding the issue of connectivity required to establish a network of things, I6 agrees that connectivity is a big issue for the organisation fundamentally. There is an ongoing international project on data exchange, but it is moving slowly and involves a lot of challenges since in some areas even getting a cellular signal can be difficult (I6). In I7 the option of using a dedicated network for IoT was discussed, there is an on-going discussion with a company that provides this sort of solution and installs antennas for their own dedicated IoT network. An interesting workaround for the challenge of having access to a reliable internet connection, not mentioned in the literature.

The "buzz" factor is brought up as a general challenge for deployment of new technologies (I6), or the risk of deploying a new technology "just for fun" without making sure it is answering to an actual operational need (I7). A comment from I7 correspond to what is discussed in section 3.1.3. about overadoption of innovations:

"We frequently get all excited about new technologies, and we forget that there needs to be an application. If the application doesn't have value for our operations, then we actually loose respect of the technology (...). That puts us then into dangerous situation where we become late adopters because we have been burned by unsuccessful implementations." (I7)

The participants in R2 both bring up the maturity of the organisation as a challenge, suggesting that there are gaps to fill when it comes to data management and systems before MSF would be ready to implement something like IoT. However the importance to invest in competence and systems to enable e.g. more visibility of resources is also emphasized. In other words, it is important to increase the level of maturity.

"*Today we have difficulties getting KPI:s in an automated way, our ERP system require a lot of time and manual work just in order to get the data we want to analyse. I believe that there are a lot of basic things we need get in place. I don't know if IoT would be the solution here or something simpler to increase atomization, data handling, etc." (R2)*

Key takeaways:

- Make sure the technology is useful before implementing it
- Visibility of resources could be an interesting application
- Update of systems and data management would be necessary before something more advanced, like IoT, could be added in the most effective way

4.5. Comparative comments from R2

The participants in R2 were asked at the end of their interviews which technology they believed could bring the greatest benefits for MSF, and which technology they saw as furthest from implementation. Both participants were positive towards 3D printing, but the opinions on UAVs diverge. The first participant focuses on the feasibility of conducting pilots:

"3D printing has quite a clear scope, e.g. with spare parts it should be possible to do a fairly quick economic analysis of which articles that would possible to print, and in which country it would be most beneficial to print them. Then we buy a printer and do a pilot in a suitable country, see where that takes us. It sounds pretty straightforward, and the same goes for drones. We do pilots with drones already, we will continue with that and develop our understanding of the benefits. There is not a huge investment related to drones, so it's reasonable to go for an approach of learning by doing."

The other participant enhances the usefulness of three-dimensional printing, but does not see the value of adding drones to the supply chain operations:

"I would say the 3D printing is the technology I can see would bring the greatest benefits. We often have machines or things that are not working because we miss one

spare part, one small thing, or the machine is broken for whatever reason. We have activities in remote locations, so this technology would help us to be more efficient, a way to be faster. In terms of supply chain and operations I would see this as something that would be convenient. The drones are interesting, but I think the supply chain added value is not yet mature enough so that I see an immediate benefit."

Regarding immersive technologies the participants agree that the adoption of immersive technologies is rather about following the technological development in order to not lag behind and be perceived as out-of-date when it comes to training and communication methods, than meeting an urgent supply chain need. It is pointed out that in terms of running pilot projects, it should be quite straight forward as the technology has a clear scope and is possible to try on a limited scale. IoT is the technology that the participants in R2 consider to be furthest from implementation. The reason for this is partly because the required data infrastructure is not in place, but also that the scope of the technology and the boundaries of what it could do is less clear. It is complex and therefore it would be more difficult both to implement and pilot. As one participant expresses it:

"We don't have the basics yet, it's like giving a Ferrari to someone who just knows how to ride a bicycle. You need a certain level of maturity and MSF is still old school when it comes to IT. (...) I think IoT is way too advanced for us at this stage."

However, the fact that IoT might be difficult to implement and too advanced for the organisation at this point does not mean that the technology should be dismissed. The other participant highlight that the proposed benefits are substantial, and how the applications most likely will become increasingly important in the coming years:

"There are reasons such as increasing legal requirements on traceability, which makes it important for us to focus on these kinds of things and make sure we invest in competence. I believe the applications that are proposed for IoT are the ones that could bring the greatest benefits compared to the other technologies, while it is also the technology that would be most difficult to implement and integrate."

5. Analysis and discussion

5.1. Comparison of theory and empirical findings

The findings from the case study are compared to the findings from literature (see Table 21). If the empirical findings lead to the conclusion that the theory is reasonable and currently relevant, this area is marked with A2 (Agree, relevant now) in the matrix Table 25. If the empirical findings indicate that the theory is reasonable, but there are still considerable developments required in order for the theory to be relevant, this cell is marked with A1 (Agree, for the future). In the case that the empirical findings are in explicit contrast to the theory, this area is marked with D (Disagree). Some areas of the theory were discussed without any conclusion in the empirical study, mainly because too little information was available to make a grounded statement. These areas are marked with a U (Unsure). Lastly, some areas were not commented on in the empirical study. These cells are marked with a minus sign (No comments).

Table 25. The results from the literature review in relation to the results from the case study. The table is based on Table 21.

	Assessment	Procurement	Warehousing	Transport	Op. support	Reporting
Technology used to execute tasks						
3D printing		A1				
VR					A1	U
AR						
UAVs	A2			A2	U	
IoT	U	U	U	U	D	
Technology has positive effect on tasks						
3D printing		A2	-	-		
VR						
AR	U	U	U	U		
UAVs				A2		
IoT	U	U	U	U		
Technology has a challenging effect on tasks/adds tasks						
3D printing	A2	A2			A2	
VR						
AR						
UAVs				-	A2	
IoT					U	

A1	Agree, for the future
A2	Agree, relevant now
D	Disagree
U	Unsure
-	No comment

Regarding the theory on IoT and AR and their place in the supply chain presented in the literature, the case study does not bring any clear conclusions. The exception is the statement that IoT could be used for collaboration purposes, where the empirical findings indicates barriers to collaboration making this application unrealistic. Apart from this, the empirical findings neither verifies nor dismisses the statements in theory, due to lack of information and experience. Considering that the theory on IoT and AR was very limited to begin with, this indicates that both these technologies are areas for further research.

Assessment

It is clear from both literature and empirical findings that UAVs are relevant to use for mapping and assessment purposes. The implementation of 3D printing requiring specific assessment, adding a challenge to this activity, is also confirmed by the case study.

Procurement
Regarding positive effects on procurement, the case study confirms that 3D printing can be a way to avoid procurement of finished goods. This is positive in the sense that savings can be generated, both monetary and time savings. As with the case of prosthesis, 3D printing can be a way to obtain items that would not be available otherwise. Also the challenges found in the theory related in particular to the involvement of original manufacturers for printing of spare parts, are confirmed in the case study. Regarding the use of 3D printing to execute procurement tasks, i.e. to procure printed items, this was confirmed as something very interesting in the empirical study, however not relevant for the moment.

Warehousing
Activities related to warehousing were not elaborated on in the empirical study.

Transport
The use of UAVs for deliveries was confirmed as feasible in the case study. The positive effect that mapping drones can have on transport operations was also confirmed. The challenge to optimize the transportation network with regards to the use of drones was not elaborated on, drones for deliveries were primarily discussed as a complement to the supply chain in the case study.

Operations support
VR might be used as a means of communication, however this should not be considered a priority at the moment according to the empirical findings. Regarding the use of UAVs for deployment of communication networks no empirical conclusions were made. The use of IoT to enable collaboration was dismissed as unrealistic. Challenging effects on operations support that the implementation of both 3D printing and UAVs would lead to are confirmed in the case study.

5.2. Analysis of technology attributes
The innovation attributes for all cases are combined in Table 26. By summarizing the attributes in one table the strengths and weaknesses of each technology can be compared. The appearance of question marks in the column of a technology indicates the areas that require further investigation before implementation.

Table 26. Summary of innovation attributes

Technology	IoT	UAVs		Immersive technologies		3D printing	
Application	All	Mapping	Deliveries	Communication (VR)	Decision making (AR)	All except housing	Housing
Relative advantage	**?**	**P**	**P**	**P**	**?**	**P+**	**N-**
Compatibility	**N-**	**?**	**?**	**N**	**N-**	**?**	**N-**
Complexity	**N**	**P+**	**P+**	**P**	**P**	**P+**	**P+**
Trialability	**N**	**P+**	**P+**	**P**	**N-**	**P(+)**	**N**
Observability	**N**	**P+**	**P+**	**?**	**?**	**P+**	**P+**

P	Positive impact
P+	Strong positive impact
N	Negative impact
N-	Strong negative impact
?	Need further investigation

For 3D printing all attributes are considered to have a positive impact except the compatibility. The compatibility might have a negative impact since the use of technology would be something new, requiring new competences, new procedures for quality control, etc. How strong this negative impact is, or whether the impact is negative at all depends on the specifications and requirements of the printed item. The attribute is marked with a question mark to indicate that further investigations are needed. Trialability of 3D printing have been highlighted as having a positive effect, since it is an independent system possible to try on a very limited scale, but due to the challenges of compatibility the strong positive impact is not a given. 3D printing of housing differs from other applications of the technology, as the relative advantage compared to traditional construction methods is considered to have a strong negative impact, and the trialability is complicated due to the size of the equipment. This application could be relevant for an organisation of which the operational conditions are more compatible with this type of larger equipment for construction. Alternatively, it could be relevant if it could be proven to have a relative advantage in a specific context but to define this context more information is needed.

For immersive technology the attribute standing in the way of implementation is compatibility. If the technology is not compatible with the needs of the organisation this will stand in the way of implementation.

For UAVs the attributes of complexity, trialability and observability all have a positive impact on the adoption. The technology also has a clear relative advantage compared to alternatives: it is a flexible, relatively cheap technology that does not require any infrastructure or a pilot (at least not one that goes with the vehicle). The big question is the compatibility. Ethically it needs to be ensured that the technology goes well the principles of a humanitarian organisation, that is does not scare local populations and end up causing more harm than good. Still, this is a challenge for the launching of the technology but can be expected to be resolved be demonstration of relative advantage. The same goes for the organisational challenge of interorganisational approval. Left is the matching with the operational conditions, where it has to be ensured that the relative advantage is greater than the difficulties to operate UAVs (including acquiring necessary permissions).

For IoT the relative advantage is unclear, it would depend on the setup of the network, the application, the scope of the application and the context of the application. More concrete use cases would be needed, and they need to be compared to alternative solutions rather than current situation. However maybe more importantly, the low level of compatibility has a very negative impact on the possibility of adoption. It should be investigated what the next development should be, what can be done with current system and what the actual need is. The complexity will decrease as IoT become more common, not only in supply chains but in other contexts and business sectors. If people get used to the technology, in the workplace or as an individuals, and useful applications emerge it will most likely make the level of perceived complexity decrease. The impact is therefore set to the first level of negative, and it is assumed that this will partly solve itself when mainstream adoption approaches. The observability is set to having a negative effect on the adoption rate, but there are ways to make the technology more visible. As with software in general, the addition of dashboards or similar functions help in the visualisation and interpretation of data.
There are a lot of factors that negatively affect the motivation to adopt the IoT technology. The comment from I6 in R1 regarding the risk of too early, unsuccessful implementation leading to unnecessary costs and negative attitudes toward the technology within the organisation, should be considered. Since there already seems to exist difficulties with the information systems, where the existing systems leave a lot to desire, it is logical to focus on getting the basic requirements in place before looking at innovative, not yet well-proven solutions. The conclusion is that, while it is relevant to follow the development of the technology, when it comes to IoT MSF and organisations with similar preconditions should wait until it the technology is more mature and tested in environments that are more predictable and controlled.

5.2.1 Three-dimensional printing

The attributes of 3D printing of spare parts and low demand items are grouped together since they share similarities. The relative advantage is about the possibility to postpone the point of decision as much as possible by manufacturing a part locally, an advantage especially when the demand is unsure since stock levels then can be greatly reduced. The lead time aspect is another major advantage of 3D printing, a reduction is possible both when it comes to delivery from the warehouse where the spare part otherwise would be stocked, or if the spare part would have to be ordered from a supplier, the additional time it takes to receive the part from the supplier. The relative advantage compared to three alternatives, keeping stock centrally, keeping stock locally and keeping no stock, is illustrated in Figure 14. The dimension of the relative advantage, or which of the categories (spare parts or low demand items) that has the greatest relative advantage depends on the type of demand and type of supply available. In general spare parts should benefit more from these advantages than low demand items since the lack of a spare part could cause downtime for some critical equipment or vehicle.

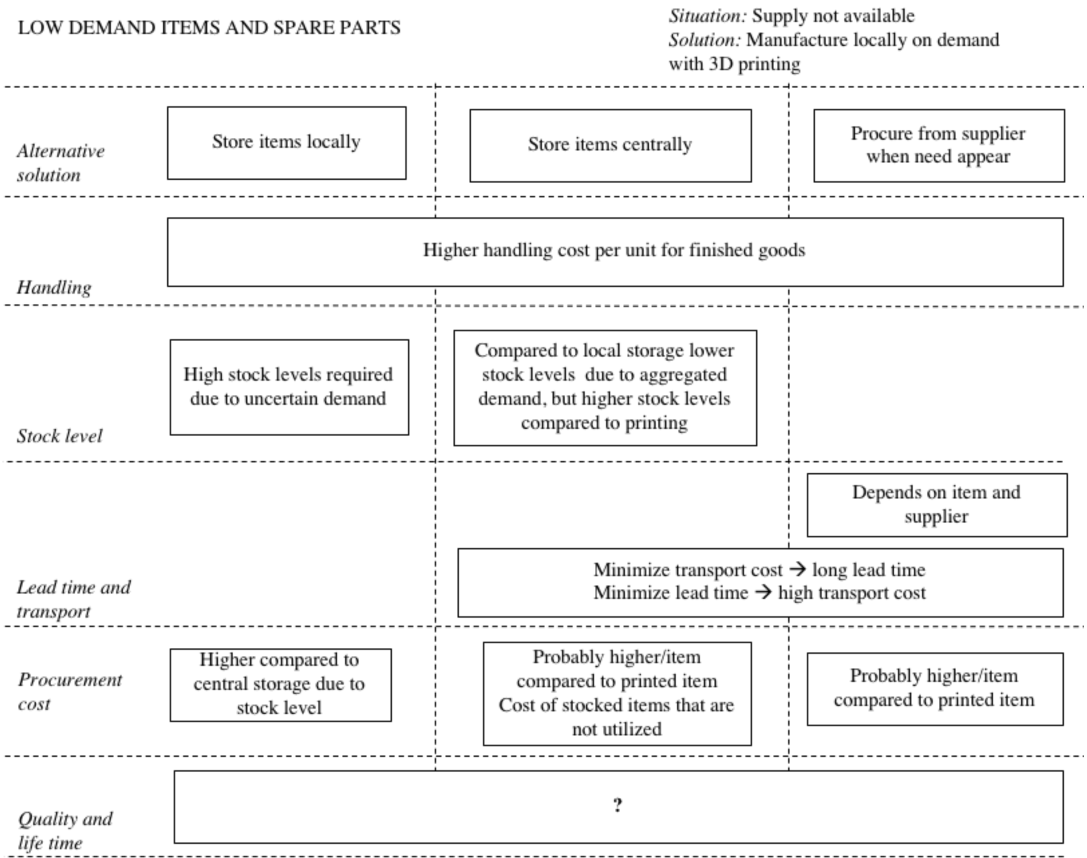

Figure 14. Relative advantage of printing spare parts and low demand items

For printing of customized items, the relative advantage is different. Spare parts and low demand items are possible to store, but customized items are in general not stored. The advantage of 3D printing becomes the possibility to be close to the need - making it easier to both make and try out the customized design, and if needed make modifications. The reduced need to import finished items is also a greater advantage for customized goods in general, since they are items without an article number, a clear specification, etc. possibly complicating import procedures. However, for customized non-medical items it might be more realistic to consider the alternative as the use of non-customized items (or nothing at all) i.e. items that are less adapted to the need, with a lower performance as result. This was the case in the example with printing of water pipe fittings (see section 4.1, p.26), the customized pipe fitting was replacing less than optimal solutions that caused the pipes to leak. The relative advantage could therefore be considered to be access to adapted solutions.

When it comes to compatibility, as was pointed out in R2, it has to be evaluated on item and country level whether the printing of something is compatible with needs, previously taken decisions, available equipment, available supply, demand, and any other factor that might influence the decision. There are most likely some locations where the environmental conditions would make it impossible to assure the quality of printed items. 3D printing is not similar to anything MSF would do regularly in the field today, in that sense it is not compatible with current operations, competence or processes. The investments required to include 3D printing more regularly in projects would vary greatly depending on the type of items that should be manufactured, and the type of setup (including the option to manage design and main testing remotely). In conclusion, there are many factors that influence the level of compatibility but it can also be assumed (from both literature and case study, in particular comparative comments from R2) that there will be scenarios where this technology will prove itself useful. No issue is detected when it comes to compatibility with organisational values. The compatibility can therefore in general be considered high *as long as* the level of 3D printing needed is carefully assessed and the capabilities and investments that are made matches this level. It is reasonable to expect that more advanced spare parts, or items in general, will still be manufactured in a controlled environment by experts and with specialist equipment. It is not realistic to have a very large, expensive printer capable of e.g. printing in metal within the organisation for MSF – that would be incompatible with competence or core mission. The ideal situation would be if 3D printing became more widely available, and printing shops could help with necessary designs or ready designs could be sent to shops that just printed. This would be preferred both because it's supporting the local economy and because MSF would be able to concentrate on their core activities.

Regarding customized items, it is questioned in R2 whether increasing the access to customized items is compatible with the general aim to standardize solutions to achieve efficiency and facilitate maintenance. This is a valid point, but as the other participant in R2 points out the operational context varies greatly and 100% standardization will never be possible. A definition of scenarios where customized items are suitable is reasonable, and when something customized is designed there should be a way to save and re-use this design – if the need appears to be recurring the design could then be used to create a standardized solution. In the case of pipe fittings (or similar), where it is likely that small modifications in measurements will be needed to adapt it to available infrastructure, a reasonable approach would be to have a database of standard designs and step-by-step instructions for how to modify these to suit a specific situation.

The level of complexity is considered to be relatively low. To decide which items are suitable to print and the creation or modification of computerized 3D models requires some level of expertise, also when 3D scanner is involved. Nevertheless, the principle is easy to understand without the knowledge of any technical details, the complexity of the technology is therefore not considered to have any negative impact on adoption. The level of observability is also high, both the actual equipment, the process and result is very observable.

Trialability is considered to be high. The printer itself requires an investment, but a simple and affordable model is considered suitable for the purpose of a trial. This affects the type of items that could be printed, however since it is also reasonable to do a trial with simple items (literature and R1) it should be compatible with the trial. The technology does not require integration with the organisation to be tested, it could therefore be tested on a small scare with relatively small and simple items, without any great investments or risks. Testing the technology, proving the usefulness of the concept is therefore considered relatively straight-forward. The approach suggested as most useful in the feedback from R2, to have a printer and decide what to print on a country level, is considered reasonable. The possibility to conduct trials together with an external partner should be considered for more projects than the one involving prothesis and orthosis in Jordan. Collaboration with external partners could lower the threshold to the technology as well as give better results. Especially for housing, a collaboration setup seems like the only scenario where MSF would try 3D printing of this size. For spare parts it would also be appropriate with trials in collaboration with the original manufacturer. For customized items there is no issues of copyright or guarantees (as opposed to spare parts), in that sense they would be easiest to try without involvement of existing supplier.

In the case of printing of housing, the relative advantage is according to literature low cost and speed (though statements are not very founded). The practical requirements of this application, i.e. the need to acquire and manage a specific printer and the printing material, are significant disadvantages and makes it incompatible with the operational context. The advantage compared to other solutions is questioned, suggesting that other solutions (tents, modular solutions, conventional construction methods) are more suitable for MSF's needs. Trialability for housing is lower compared to the other applications, due to cost of printer and required efforts to transport printer and printing material. In conclusion, housing is at this stage not promising as an application.

An additional application is suggested in R2, the use of 3D printing for prototypes and demonstrations. When used for this application 3D printing plays a very similar role as VR for demonstration, and 3D printing was actually also used in the VR project for constructing a prototype that was included in addition to the virtual environment to demonstrate the hospital. The innovation attributes for this application are rather similar to the attributes of "VR for demonstration, simulation and communication", therefore see Table 28 below for details on how the adoption rate is likely to be affected by the attributes of the innovation.

Table 27. Innovation attributes for applications of additive manufacturing

Attribute	3D printing of spare parts and low demand items	3D printing of customized items	3D printing of housing
Relative advantage	Reduced stock levels and/or reduce lead times, reduced need to transport. Save costs, alternatively increase access to items	Possible to manufacture items adapted to the need – increase access to better solutions	Low
Compatibility	High – if level of 3D printing needed is thoroughly assessed and investments and capabilities match	Incompatible with aim to standardize Incompatible with level of competence	Low
Complexity	Low	Low	Low
Trialability	High	High	Low –require investment in large equipment
Observability	High	High	High

Challenges for adoption of 3D printing for MSF:

- Involve supplier(s), find mutually beneficial way to collaborate
- Quality control – how?

5.2.2 Immersive technologies

The relative advantage of using VR in training and recruitment needs to be further investigated. It is clear that there are certain advantages compared to real life simulation exercises or field studies, such as increased flexibility when it comes to time, resources and location, and the subsequent opportunity to save costs and resources. The question is whether the VR option keep the same level of quality as a simulation or real-life exercise, which according to results from the literature study is a direct function of the fidelity of the VR material. If instead comparing VR with other alternatives such as photo, video or animated material they have the same ingredient of flexibility, but it is suggested that VR would be closest to the reality. Once again, the level of fidelity of the VR content would play a crucial part as well as the degree to which it is possible to interact with the environment. To fully understand the relative advantage, it should be further investigated how close to the reality the VR would have to be in order to provide better learning than the other alternatives.

Compatibility includes how well an innovation correspond to current practices, how easy it would be to adopt the innovation. Considering that VR require equipment that at this point is not very common, e.g. if comparing with the computer screen required to watch a video, it is not fully compatible with current practices. Neither does it seem to be fully compatible with the needs of MSF, or at least not compatible with the priorities of the organisation. Even though the participant in R1 said that the VR project was considered successful and the technology useful, the project was not developed further and no new projects or initiatives to continue the evaluation of the technology are launched or planned due to lack of resources. In other words, this is not the project with highest priority in the department at the moment. The participants in R2 agreed that while the technology seems to have some strengths MSF should not try to push or prioritise this, but rather wait for the development of the technology and adapt if VR for training and recruitment becomes the norm. The need to adopt VR is talked about as something that MSF has to do in order to follow technological development rather than something coming from an actual need within the organisation.

The level of complexity for training and recruitment with VR would be low, since there seems to be no trouble for any of the participants in this study to grasp to concept. The level of trialability depends on how advanced the VR is. If no element of interaction is included (as was the case in the project that was looked into for this study) material could e.g. be recorded with a camera without much effort. In this case the trialability would be high, since it would be relatively easy to try out the concept on a limited scale without great costs or investments. If the possibility to interact with the virtual environment should be included in the material, a lot more development is necessary. The investment of a lot of resources in this type of development could be difficult to motivate for an organisation like MSF where the activities need to be motivated by the core mission of the organisation – to provide medical assistance to people in need. Again, it becomes a question of compatibility with the needs of the organisation.

The observability of a new method of training or recruitment is low, since it is difficult to exactly see and measure the effect this type of technology would have on the quality of the training (corresponds to results from R2).

The relative advantage of VR for content preservation/reporting compared to other visual ways of preserving content and report results is questioned in R1, could not a regular video do the same job as a VR experience? The comments from R2 relate mostly to the lack of visual ways of reporting within the organisation, there would be benefits in using more visual material to explain certain situations than what is currently the practice. It is not clear how strong the relative advantage of VR being more immersive than e.g. a video would be. Regarding the attribute of compatibility, it would be a challenge to move from very little innovation when it comes to communication to a quite advanced solution, i.e. to go directly from relying mostly on text and verbal transmission of information to VR.

The application of VR as a communication, demonstration and simulation tool was suggested as an additional application during the interviews, however it seems more suitable to aggregate the other VR applications to these activities since they describe the role a VR element would have in all above mentioned activities. The attributes of VR discussed above are summarised in Table 25.

The advantage of AR would in theory be increased access to up-to-date information in a very visual and comprehensive manner. It is pointed out earlier in this report, in the introduction to immersive technologies that "*AR is so far more common within e.g. the retail business and gaming than logistics operations, mainly due to the benefits the technology can provide with current level of maturity compared to existing logistics solutions*" (p.12). The same source concludes that AR is promising but not yet mature enough for usage in warehouses (Stoltz et al., 2017). In the literature on AR within disaster response some specific factors for this context are emphasised, such as the need for experts to collaborate in real-time after a disaster (Nunes et al., 2018), which gives the benefits of AR added importance. However the disaster context also place added requirements on the AR equipment, and negative aspects such as limited battery power and uncomfortable equipment (Stoltz et al., 2017) are less acceptable. The AR platform for disaster relief operations presented by Nunes et al. (2018) was not directly compared with any alternatives, which makes the relative benefits of the platform difficult to assure.

In addition to this, it is clear from the interview that the use of AR is not compatible with either the operational context where there are issues of connectivity, or current practices as it would require a) innovation when it comes to communication, something that is indicated as difficult in general, and b) information to be transferred to data in a specific format quickly. Conclusions from discussions on IoT is that efficient data management in general is a struggle within MSF, but data management and IT is also discussed as a general challenge within humanitarian logistics in section 3.1. This incompatibility further makes the possibility of a trial low.

Table 28. Innovation attributes for applications of immersive technologies

Attribute	**VR/3D printing as a simulation, demonstration and communication tool**	**AR for decision making**
Relative advantage	More realistic than photo, video, etc. Easier to grasp complex concepts in 3D than 2D Bridge gaps in communication	Not ensured.
Compatibility	Not a priority Far from current practices Would require new equipment	Low – not compatible with operational context or current practices
Complexity	Low - easy to understand	Low – easy to understand
Trialability	Without interaction – High With interaction - Low	Low - require decision data in specific format linked to AR device
Observability	Innovation itself is very visible – but difficult to measure performance improvement as a result of innovation	Low – can't actually see results

Challenges for adoption of immersive technologies for MSF

- General challenge to be innovative when it comes to communication
- Keep track of development of technology, be ready to adopt when it is mature enough

5.2.3. Unmanned Aerial Vehicles

The relative advantage of cargo drones is not completely clear, as the discussed payload limitation of 2 kg makes it difficult to compare to current delivery modes according to the participants in R2. The payload limitation of 2 kg came from R1 where this was the specification of the UAV that was under development, but the participants in R2 did not fully agree with I5 that this was a delivery size that would be useful in a lot of MSF projects. For the purpose of the literature review, the exact payloads where not deemed relevant and was therefore not investigated in detail. However due to the differing views of what a suitable payload for MSF could be, a comparison of payload limitations that are indicated in publications resulting from the literature review becomes interesting. These payloads are presented below, see Table 29 and 30. It is clear from these tables that a maximum payload of 2 kg is limited also in comparison to other studies and what is available on the market. However, the reason for developing a new UAV model was that none of the models available on the market suited the needs of MSF when it came to cost, durability, and level of expertise required to operate the vehicle. The payload limitation can be viewed as a reasonable trade-off for these other factors for the moment, and for a phase of testing. Nevertheless it is clear that for the future it will be relevant to develop a UAV model that can carry a larger load.

Table 29. Payload in publications from literature review that treat the theme "Use of UAVs for deliveries"

#	Max payload of UAV used	Reference
2	5,5 kg	Tatham et al. (2017b)
4	22,7 kg	Nedjati et al. (2016)
11	22,7 kg	Golabi et al. (2017)
12	100 kg	Chowdhury et al. (2017)
13	-	Fikar et al. (2016)
15	0,5-2,5 kg	Reiner et al. (2018)

Table 30. Categorization of UAV models by Nedjati et al. (2016)

Type	Maximum payload	Dimensions
Large-scale UAV helicopters	< 3000 kg	15 m length, 4 m height
Medium-scale UAV helicopters	< 25 kg	3 m length, 1 m height
Small-scale UAV helicopters	Approx. 10 kg	2 m length, < 1 m height
Mini-scale UAV helicopters	< 5 kg	Not indicated
Microscale UAV helicopters	0 kg	< 20 cm length
Multi-rotor UAV	Approx. 1,5 kg	Not indicated

The relative advantage of mapping drones over the closest alternative, satellite images, is clear – it is cheaper, faster, more flexible, and more accurate. There is a need for someone who knows how to operate the drone, but since knowing what to do with the resulting material is pointed out as the greater challenge the need for expertise does not disappear if satellite images are used. Compatibility with the needs of the organisation and whether the added value is great enough to motivate the investment in expertise and technology should be further investigated. Other ways to conduct assessment might be enough in some cases, and the complementary effect of the UAV low. However, a logical assumption is that there are also situations where the added value would be very high, e.g.

- very urgent situations where there is no time to wait for assessment from other sources
- volatile situations where change happen quickly and information become inaccurate
- assessment of disconnected areas that cannot be reached by other means of communication
- situations where assessment otherwise would take up more time and resources, where mapping UAVs could streamline the process

The situations where the added value is greatest, including limitations of the UAV such as reach, should be identified and used to further investigate usefulness as well as develop procedures for the use of UAVs for assessment purposes.

The compliance of UAVs with organisational values, as well as the attitudes towards UAVs globally in the countries where MSF is working needs to be further investigated and continuously evaluated as UAVs are piloted. According to the interviews, the UAVs do bring added value and would be able to enable deliveries that are currently not possible, and friendly UAVs are in general possible to distinguish from military ones. Considering these results, it is reasonable to expect that UAVs will be accepted both by the organisation and the beneficiaries. However if the concept of delivery by UAV is more integrated as a part of the supply chain, not only complementing but replacing some of the current delivery modes, the point made by Sandvik et al. (2014) regarding a concern for increasing distance between providers and receivers of aid should be considered.

All types of UAVs should be quite straight forward to pilot in the sense that they can be deployed in very limited and controlled manner. There is no obvious economy of scale or huge investment required in the beginning, but the UAVs can essentially be tested one at the time in one project at the time to a limited cost. The attribute of trialability is therefore set to high. Even though the technical details are complicated and complex, it is relatively easy to understand the concept of UAVs and their functionalities, and the results from both mapping and cargo drones are easy to observe. The attribute of complexity is therefore set to low, and observability is set to high.

Table 31. Innovation attributes for UAV applications

Attribute	UAV for mapping	UAV for deliveries
Relative advantage	Cheaper, quicker, faster, more flexible than alternative satellite images Better overview, more accurate than if no images are available	Unmanned, possibly cheaper, no need for roads Advantage would be greater if the payload capacity increased
Compatibility	Consistent with existing values to operate drones? Consistent with existing needs? Need further investigation	Consisting with existing values? Consistent with existing needs? Need further investigation
Complexity	Low	Low
Trialability	High	High
Observability	High	High

Challenges for adoption of UAVs for MSF:

- Define cases where mapping drones provide enough added value to motivate the use of mapping drones
- Define cases where cargo drones provide enough added value to motivate deployment as a function of the capacity of the drone, requirements for operating the drone, all related costs, and demand for the services of the drone
- Ensure acceptance of UAV operations, within and outside of the organisation
- Legal issues and regulations can act as barriers in some cases, due to the fact that an organisation like MSF probably has very little influence over these things in most of the countries they operate in.

5.2.4. Internet of Things

The deployment of IoT could make both the generation of and reaction to various forms of data more efficient. Except for maybe the use of IoT for cooperation within or between organisations, where general challenges of cooperation would stand in the way for improvements by technological means, the applications that resulted from the literature review on IoT could be interesting for an organisation like MSF according to the interviews. However, it is possible that for the needs of the organisation these applications could be achieved with simpler means than deployment of IoT, and it is pointed out in R1 that they are not sure IoT would be the right technology. The additional challenges resulting from R1 relate to the evaluation of the usefulness of the technology, but it is important to also look at the usefulness in relation to other solutions i.e. the relative advantage. For example, increased visibility of resources could be achieved by implementing radio-frequency identification (RFID) tags that would facilitate tracking of individual items throughout the supply chain without going all the way to IoT. It is probable that there are quite a bit of efficiency measures that could be taken before IoT would be relevant and realistic. These measures should be investigated and the relative advantage of IoT should be evaluated in relation to those alternative arrangements. With that said, the application that would be most suitable for an organisation like MSF is probably to use IoT to increase visibility and tracking of high value resources such as vaccines or vehicles. IoT for cooperation purposes is problematized above, and IoT for situational awareness is not clearly within the scope of an organisation like MSF. Automated allocation of resources requires visibility of the concerned resources, making increased visibility the application with highest relevance.

There are several ways in which the attribute of compatibility is not fulfilled. In order to integrate IoT in the current data management systems, those systems would most likely require some sort of update or modification i.e. there would be an issue of compatibility with current practices. There is also the issue of connectivity that is brought up both for IoT (and previously for AR applications), which makes IoT incompatible with the operational context in the field. The idea to deploy a dedicated network for IoT would be a way to work around the issue of connectivity, but if the deployment of a new, dedicated network is required it still makes the technology incompatible with operational context and current practices. It could also be reasonable to question the feasibility of this type of action, it is reasonable to assume that there are some countries where this would not be possible. The compatibility with the purpose of MSF to provide medical aid can also be questioned - to install permanent infrastructure enabling deployment of IoT, is that compatible with the mission of the organisation? Is it a sustainable solution? Lastly, in R2 both participants talked about the maturity of the organisation when it comes to data management and systems as an issue, this would also add to the incompatibility of the technology on an organisational level. The low level of compatibility in several ways leads to the conclusion that it would be difficult to test the technology and conduct a pilot i.e. the level of trialability is low.

IoT has a high level of complexity – it requires quite a bit of knowledge to fully grasp the concept and its possibilities, for the more technical details it takes even more expertise. Just like the traditional internet, it would not be necessary to understand all the technical details or even fully grasp the concept in order to use it, but according to the defined attributes of innovation this complexity will slow down the rate of adoption for IoT. It is not obvious how the technology is best applied, and it will take time to realise this. In Table 3 it is stated that IoT is expected to reach mainstream adoption for supply chains within five to ten years, but taking into consideration that humanitarian organisations in general, MSF being one of them, are lagging behind when it comes to information systems (section 3.1) it is reasonable to expect that HOs will be at least in the later part of that spectrum, in particular for applications in the field.

Observability is in general low for innovations of software characteristics, this is the case for IoT where the result of adoption would be the ability of objects to communicate with each other and generate data, something that is not necessarily very observable.

Table 32. Innovation attributes for IoT applications

Attribute	**IoT**
Relative advantage	Possibility of increased efficiency when "things" communicate, both for generation of information and reaction to information, but relative advantage to alternative measures is unclear and needs further investigation
Compatibility	Low - not compatible with operational context or current practices
Complexity	High – difficult to grasp concept
Trialability	Currently low due to low compatibility
Observability	Low – output is data

The challenge for adoption of IoTs for MSF:

- Investigate relative advantage
- Investigate state of current information systems. Is IoT something that could facilitate improved data management, or would it require improved data management?

6. Conclusion

The overall purpose of this study was to investigate and compare opportunities and challenges of currently emerging technologies in the context of the HSC. As a first step, existing documented knowledge was investigated and mapped through a literature review. The results were presented as the quantity and types of publications available, as well the identified themes together with their frequency of appearance in order to map the existing theory. The second goal, to verify that the existing theory is reasonable, was partly fulfilled through the performance of a multiple case study in collaboration with Médecins Sans Frontières and comparison of the empirical findings with theory. The purpose was only partly fulfilled since there were some areas where not enough empirical data was available to draw conclusions. In the cases where these gaps corresponded to very limited theory, this was noted as areas for future research. Addition to existing theory is fulfilled through the response to the research questions in section 7.1 and 7.2 below. The last goal, to provide suggestions for future research, will be addressed at the end of this section.

6.1. How emerging technologies create benefits

Currently emerging technologies are able to create benefits for humanitarian supply chains in several ways. The conclusions are listed in the order they are likely to happen.

Geographical assessment

UAVs with mapping abilities will be able to conduct more and more intelligent assessments as the technology develops in the coming years, but already now they are ready to replace satellite images as a cheaper, more flexible and higher-quality alternative.

Increased access to supply

HOs can expect an increased access to supply with the help of emerging technologies, i.e. organisations will have access to a wider range of items in a wider range of locations. The technologies that play a crucial part here are 3D printing and UAVs with the ability to carry cargo. 3D printers managed internally by HOs will make it possible to manufacture items in locations where supply is not available due to e.g. lack of local suppliers and inadequate infrastructure for distribution, either temporary or permanently. This type of local manufacture is currently possible on a limited scale, but as the technology develops and related business models emerge benefits will become stronger. In the future, the 3D printing technology is expected to increase local supply by creating a new type of flexible manufacturing industry worldwide. Cargo UAVs will be able to increase supply access by transporting goods to locations that cannot be reached by other means of transport, but also by transporting goods that cannot be kept in certain locations due to abilities at the location (e.g. requirements such as temperature controlling or security related issues at the location), or economic reasons (e.g. the item having a high value and low demand, making it too expensive to store at multiple locations). Currently the payload and endurance of cargo drones are a limiting factors, but these are expected to increase gradually. The relative advantage of increased access to supply is large for humanitarian operations in remote areas and certain post-disaster scenarios, making the benefits valuable even though they are limited or comes with a higher cost. It is due to this relative advantage reasonable for HOs to take the lead when it comes to the implementation of these types of technologies.

Increased flexibility

3D printing and cargo drones also contribute to the flexibility of the supply chain. 3D printing can be used to manufacture a temporary solution while waiting for supply to be delivered, in case there is an unexpected stockout or deliveries are delayed. The relative advantage of this can be great in a HSC context where delivery lead times normally are long, and unexpected delays can occur e.g. in the import process. Cargo drones can be used to increase flexibility of deliveries locally. For example, if there is an unexpected stockout between two regular deliveries but the item is available within the range of a drone flight, it could be delivered directly when the need occur.

More efficient distribution

Positive effects for transport and warehousing activities is the third category of benefits where three-dimensional printing and UAVs play important roles. Replacing distribution of finished goods with distribution of printing material has a lot of benefits such as more efficient handling, lower stock levels regarding volume, value and stock keeping units, as well as more efficient import procedures. The greatest benefits would be achieved for items where the demand is unsure and stock risks being left unused. However for these benefits to be realised, a certain volume of goods need to be printed instead of bought and stored as finished goods. This benefit will therefore come after the increased access to supply and increased flexibility. For the last mile distribution to the end-user, assessment of routes with mapping drones makes it easier to select the optimal route not only when roads are damaged, but also taking into account traffic jams, local accidents, etc. The use of cargo drones can also make the last mile distribution more efficient, allowing some smaller, possible urgent, deliveries to be made without a driver and leaving deliveries that can be efficiently grouped together in larger batches to be sent with a driver.

Increased visibility

Increased visibility of resources is further from the reality than the previously mentioned benefits. Emerging technologies such as IoT and AR promises this type of benefit, however the relative advantage for both IoT and AR was found to be unclear, meaning that there may be other existing solutions that is found to be better. Even so, some degree of increase of visibility can be expected and is very relevant for HSCs if striving for transparency. It is probable that supply chains in more controlled environments, e.g. most commercial supply chains, will move faster in the area of resource visibility because it is an easier task for more predictable supply chains, with less variable parts. As soon as items arrive in the field there will in general be issues with tracking of resources. Notwithstanding, HSCs can't be too behind since stakeholders will get used to new standards and demand increased transparency.

Gradually: better tools for assessment
Better geographical assessment with the help of mapping drones has already been brought up, but further into the future better tools for additional types of assessments are expected. Assuming increased visibility of resources (see above), better assessment will be possible as a consequence. An increased level of automated data is expected, which leads to data being more up to date, enabling better assessment. Exactly how AR can be used is still unsure, but the technology is expected to allow for better transfer of information and as a consequence improved decision making at some level of the supply chain. IoT might be involved with the automatic creation of data in the future but before then we will probably see simpler solutions as steps in the IoT direction. Compared to conventional supply chains, HSCs are less compatible with automatic data generation as HSCs in general have less fixed parts of the supply chain. In conclusion, other types of organisations or companies are expected to take the lead when it comes to tools for more advanced assessment, and the tools will be adapted for the humanitarian context as the technologies matures.

6.2. Challenges related to the implementation of emerging technologies

There are several challenges related to the implementation of emerging technologies. Since the technologies are still maturing, what might look at a barrier at this stage is not necessarily a barrier when it is time for implementation. In conclusion, all issues found in this study are considered challenges rather than barriers. The general challenges are presented here in decreasing order of importance.

Data/IT management
A recurring challenge related to several types of emerging technologies is the management of data and information technology. A lot of technological advances and technology trends occur in the domain of IT, and in order to be able to benefit from these developments humanitarian organisations need to improve the way that they are collecting and managing data. For the cases in this study, particularly the feasibility of implementing IoT is affected by the lack of sufficient data infrastructure. Considering other emerging technologies that were not included in the focus of this study there are several that are highly based on IT, e.g. blockchain, artificial intelligence, big data and machine learning. Even though these examples are far away from reaching maturity, development of competence within IT should be considered a high priority in order to follow the technological development in the future.

Communication and collaboration
This challenge refers to communication and collaboration within and between HOs. Several times for different technologies the issue of collaboration both with others and within the organisation comes up. IoT for inter- and intra-organisational cooperation is dismissed as an unrealistic application as there are too many complications when it comes to collaboration. In relation to immersive technologies as a means of communication the conclusion from the empirical study is that there are organisational challenges when it comes to communication that need to be solved before it is even an option to be innovative. This challenge is not surprising, and it is brought up already in the context section (3.1) that collaboration between actors in a humanitarian context is difficult due to a number of reasons. The challenge being well known does not make it less important to work on a solution, and the conclusion from this study is that issues with collaboration and communication can have a negative effect on the possibility to implement new technologies.

How to collaborate with the commercial sector

To collaborate with the commercial sector can come with ethical challenges, and if the consequences of a collaboration are not thoroughly evaluated and considered it could lead to a compromise of the commitment to the humanitarian principles. However collaborations should not be dismissed. In the case of 3D printing MSF experience a tendency of reverse innovation, where the specific operational context of the organisation attracts actors from other sectors that are interested in collaboration. Technologies that are not mature enough for a commercial sector might have a stronger relative advantage in a humanitarian context, which could be a win-win for both parties involved. The requirements on companies to work with corporate social responsibility are also increasing – is this something that could be utilized by HOs or is it always problematic? In particular collaboration with IT companies – could this be explored in order to cover the generally weak point of IT and data management within HOs? By addressing the challenge and working out a solution for how to collaborate more with the commercial sector and using the expert knowledge of this sector, HOs have great opportunities to yield more benefits from emerging technologies in the future.

6.3. Suggestions for future research

Throughout the study, several areas that would be suitable for future research are detected. The following suggestions are considered most relevant:

- Involve one or several suppliers in an investigation of the feasibility of 3D printing of spare parts in the field. What are the attitudes amongst original manufacturers? How could quality be assured? How could warranties be kept? How could copyright issues be solved?
- Development of a decision model for of 3D printing of items, based on an economic cost analysis
- Attitudes towards drones – a thorough investigation
- Investigate the relative advantage of AR in HSCs
- Investigate the relative advantage of IoT in HSCs
- The subject of communication – what are the technologies currently used? Is there a need to be more innovative?
- Investigate how to collaborate with commercial sector without compromising the humanitarian values

References

ADAMS, R. J., SMART, P. & HUFF, A. S. 2017. Shades of Grey: Guidelines for Working with the Grey Literature in Systematic Reviews for Management and Organizational Studies. *International Journal of Management Reviews,* 19**,** 432-454.

AGRAWAL, J. 2016. *How virtual reality can help during disasters [Infographic]* [Online]. TechCo. Available: https://tech.co/virtual-reality-help-disasters-2016-11 [Accessed 23 March 2018].

AJINOMOH, O., DOW, L., MILLER, A., GORDON-GIBSON, A. & BURT, E. Managing humanitarian emergencies: Teaching and learning with a virtual humanitarian disaster tool. CSEDU 2012 - Proceedings of the 4th International Conference on Computer Supported Education, 2012. 55-64.

ANA LAURA, R. S., LINDA, S. G. L. W., RICHARD, G. & HAN, B. 2016. Systemic barriers and enablers in humanitarian technology transfer. *Journal of Humanitarian Logistics and Supply Chain Management***,** 46.

ATZORI, L., IERA, A. & MORABITO, G. 2010. The Internet of Things: A survey. *Computer Networks,* 54**,** 2787-2805.

BALCIK, D. B. & HAAVISTO, I. 2015. Measuring humanitarian supply chain performance in a multi-goal context. *Journal of Humanitarian Logistics and Supply Chain Management***,** 300.

BANDYOPADHYAY, D. & SEN, J. 2011. Internet of Things: Applications and Challenges in Technology and Standardization.

BARRATT, M., CHOI, T. Y. & LI, M. 2011. Qualitative case studies in operations management: Trends, research outcomes, and future research implications. *Journal of Operations Management,* 29**,** 329-342.

BARTHOLDI, J. J. & HACKMAN, S. T. 2010. *Warehouse & distribution science*, Atlanta, GA: The Supply Chain and Logistics Institute, School of Industrial and Systems Engineering, Georgia Institute of Technology, 2006-.

BLECKEN, A. 2010. Supply chain process modelling for humanitarian organizations. *International Journal of Physical Distribution & Logistics Management,* 40**,** 675-692.

BOCCARDO, P., CHIABRANDO, F., DUTTO, F., TONOLO, F. G. & LINGUA, A. 2015. UAV Deployment Exercise for Mapping Purposes: Evaluation of Emergency Response Applications. *Sensors,* 15**,** 15717-15737.

BOWCOTT, O. 2017. *Laws for safe use of driverless cars to be ready by 2021* [Online]. Available: https://www.theguardian.com/law/2017/dec/14/laws-safe-use-driverless-cars-ready-2021-law-commission [Accessed 5 Sep 2018].

BUSINESSDICTIONARY. 2018a. *Definition technology* [Online]. Available: http://www.businessdictionary.com/definition/technology.html [Accessed 5 April 2018].

BUSINESSDICTIONARY. 2018b. *What are emerging technologies? Definition and meaning* [Online]. Available: http://www.businessdictionary.com/definition/emerging-technologies.html [Accessed 18 March 2018].

CAAT. 2018. *Automated and Connected Vehicles* [Online]. Available: http://autocaat.org/Technologies/Automated_and_Connected_Vehicles/ [Accessed 2 Sep 2018].

CHANDRA, M. & TANZI, T. J. 2018. Drone-borne GPR design: Propagation issues. *Comptes Rendus Physique,* 19**,** 72-84.
CHOWDHURY, S., EMELOGU, A., MARUFUZZAMAN, M., NURRE, S. G. & BIAN, L. K. 2017. Drones for disaster response and relief operations: A continuous approximation model. *International Journal of Production Economics,* 188**,** 167-184.
COHEN, D. & CRABTREE, B. 2006. *Qualitative Research Guidelines Project* [Online]. Available: http://www.qualres.org/HomeSemi-3629.html [Accessed 1 oct 2018].
CRESWELL, J. W. 2014. *Research design : qualitative, quantitative, and mixed methods approaches*, Los Angeles, Calif. : SAGE, cop. 2014
Fourth edition, international student edition.
DANABY, M. 2018. *Comment: Innovation beyond drones - transforming the supply chain* [Online]. Available: https://www.supplychaindigital.com/technology/comment-innovation-beyond-drones-transforming-supply-chain [Accessed 2 Sep 2018].
DAY, J. M., MELNYK, S. A., LARSON, P. D., DAVIS, E. W. & WHYBARK, D. C. 2012. Humanitarian and Disaster Relief Supply Chains: A Matter of Life and Death. *Journal of Supply Chain Management,* 48**,** 21-36.
DE LA TORRE, N., ESPINOSA, M. M. & DOMÍNGUEZ, M. 2016. Rapid Prototyping in Humanitarian Aid To Manufacture Last Mile Vehicles Spare Parts: An Implementation Plan. *Human Factors and Ergonomics in Manufacturing & Service Industries,* 26**,** 533.
DU, P., CHEN, J. & SUN, Z. Resource management system for crisis response & management. Proceedings of the International ISCRAM Conference, 2016.
DUBEY, R., LUO, Z., XU, M. & WAMBA, S. F. 2015. Developing an Integration Framework for Crowdsourcing and Internet of Things with Applications for Disaster Response. IEEE.
DURACH, C. F., KEMBRO, J. & WIELAND, A. 2017. A New Paradigm for Systematic Literature Reviews in Supply Chain Management. *Journal of Supply Chain Management,* 53**,** 67-85.
ECHO. 2018. *Humanitarian principles* [Online]. European Civil Protection and Humanitarian Aid Operations. Available: https://ec.europa.eu/echo/who/humanitarian-aid-and-civil-protection/humanitarian-principles_en [Accessed 2 Sep 2018].
FIKAR, C., GRONALT, M. & HIRSCH, P. 2016. A decision support system for coordinated disaster relief distribution. *Expert Systems with Applications,* 57**,** 104-116.
GARTNER. 2017. *Gartner's Hype Cycle Reveals the Digitalization of the Supply Chain* [Online]. Available: https://www.gartner.com/en/newsroom/press-releases/2017-09-11-gartner-hype-cycle-reveals-the-digitalization-of-the-supply-chain [Accessed 5 Sep 2018].
GOLABI, M., SHAVARANI, S. & IZBIRAK, G. 2017. An edge-based stochastic facility location problem in UAV-supported humanitarian relief logistics: a case study of Tehran earthquake. *Natural Hazards,* 87**,** 1545.
GREGORY, M., HAMEEDALDEEN, S. A., INTUMU, L. M., SPAKOUSKY, J. J., TOMS, J. B. & STEENHUIS, H. J. 2016. 3D Printing and Disaster Shelter Costs. *In:* KOCAOGLU, D. F., ANDERSON, T. R., DAIM, T. U., KOZANOGLU, D. C., NIWA,

K. & PERMAN, G. (eds.) *Portland International Conference on Management of Engineering and Technology.* New York: Ieee.
GUETTIER, C. & LUCAS, F. 2016. A constraint-based approach for planning unmanned aerial vehicle activities. *Knowledge Engineering Review,* 31**,** 486-497.
GUSTAFSON-PEARCE, O. & GRANT, S. B. 2017. Supply Chain Learning Using a 3D Virtual World Environment. *In:* CAMPANA, G., HOWLETT, R. J., SETCHI, R. & CIMATTI, B. (eds.) *Sustainable Design and Manufacturing 2017.* Berlin: Springer-Verlag Berlin.
HALLDÓRSSON, Á. & AASTRUP, J. 2003. Quality criteria for qualitative inquiries in logistics. *European Journal of Operational Research,* 144**,** 321-332.
HEINTZE, H.-J. & THIELBÖRGER, P. 2018. *International Humanitarian Action. [Elektronisk resurs] : NOHA Textbook*, Cham : Springer International Publishing : Imprint: Springer, 2018.
HOLGER GLOCKNER, K. J., JOHANNES MAHN, BJÖRN THEIS 2014. Augmented reality in logistics: Changing the way we see logistics - a DHL perspective.
HOLGUIN-VERAS, J., JALLER, M., VAN WASSENHOVE, L. N., PEREZ, N. & WACHTENDORF, T. 2012. On the unique features of post-disaster humanitarian logistics. *Journal of Operations Management,* 30**,** 494-506.
HSU, E. B., LI, Y., BAYRAM, J. D., LEVINSON, D., YANG, S. & MONAHAN, C. 2013. State of Virtual Reality Based Disaster Preparedness and Response Training. *PLoS Currents*.
ITU. 2018. *ITU-T Recommendation database* [Online]. Available: http://handle.itu.int/11.1002/1000/11559 [Accessed 19 March 2018].
IVANCEVIC, V. & YI, Y. 2016. Hamiltonian dynamics and control of a joint autonomous land-air operation. *Nonlinear Dynamics,* 84**,** 1853-1865.
JAHRE, M., PAZIRANDEH, A. & VAN WASSENHOVE, L. 2016. Defining logistics preparedness: a framework and research agenda. *Journal of Humanitarian Logistics and Supply Chain Management,* 6**,** 372-398.
JAMES, E. & GILMAN, D. 2015. Shrinking the Supply Chain: Hyperlocal Manufacturing and 3D printing in Humanitarian Response.
JAMES, E. & JAMES, L. 2016. 3D printing humanitarian supplies in the field. Available: https://odihpn.org/magazine/3d-printing-humanitarian-supplies-in-the-field/.
JOHNSON, E. M. 2017. *Red Cross launches first U.S. drone program for disasters* [Online]. Reuters. Available: https://www.reuters.com/article/us-storm-harvey-redcross-drones/red-cross-launches-first-u-s-drone-program-for-disasters-idUSKCN1BI2X9 [Accessed 23 March 2018].
JONES, S. 2017. *When disaster strikes, it's time to fly in the 3D printers* [Online]. Available: https://www.theguardian.com/global-development/2015/dec/30/disaster-emergency-3d-printing-humanitarian-relief-nepal-earthquake [Accessed 23 March 2018].
KABRA, G., RAMESH, A., AKHTAR, P. & DASH, M. K. 2017. Understanding behavioural intention to use information technology: Insights from humanitarian practitioners. *Telematics and Informatics,* 34**,** 1250-1261.
KEMBRO, J., OLHAGER, J. & NÄSLUND, D. 2017. Information sharing across multiple supply chain tiers: A Delphi study on antecedents. *International Journal of Production Economics,* 193**,** 77-86.

KSHETRI, N. 2017. Can Blockchain Strengthen the Internet of Things? *IT Professional, IT Prof.*, 68.
LICHTMAN, A. & NAIR, M. 2015. Humanitarian uses of drones and satellite imagery analysis: the promises and perils. *AMA Journal Of Ethics,* 17, 931-937.
LINCOLN, Y. S. & GUBA, E. G. 1985. *Naturalistic inquiry*, Beverly Hills, Calif. : Sage, cop. 1985.
MÉDECINS SANS FRONTIÈRES. 2018a. *How we work* [Online]. Available: https://www.msf.org/how-we-work [Accessed 31 Aug 2018].
MÉDECINS SANS FRONTIÈRES. 2018b. *Who we are* [Online]. Available: https://www.msf.org/who-we-are [Accessed 31 aug 2018].
MÉDECINS SANS FRONTIÈRES, A. 2016. *The MSF Supply Chain* [Online]. Available: https://www.youtube.com/watch?time_continue=15&v=lYiAxPi44I0 [Accessed 31 Aug 2018].
MEREDITH, J. 1998. Building operations management theory through case and field research. *Journal of Operations Management,* 16, 441-454.
MORABITO, V. 2017. *Business Innovation Through Blockchain. [Elektronisk resurs] : The B^3 Perspective*, Cham : Springer International Publishing : Imprint: Springer, 2017.
MSF INTERNATIONAL 2018. International financial report 2017. *In:* GAJARDO, M., LEBAILLY, G. & LEVERY, A. (eds.).
MSF USA. 2017. *Drones as humanitarian tools* [Online]. Available: http://www.doctorswithoutborders.org/article/drones-humanitarian-tools [Accessed 23 March 2018].
MURPHY, R. R., STEIMLE, E., GRIFFIN, C., CULLINS, C., HALL, M. & PRATT, K. 2008. Cooperative use of unmanned sea surface and micro aerial vehicles at Hurricane Wilma. *Journal of Field Robotics,* 25, 164.
NEDJATI, A., VIZVARI, B. & IZBIRAK, G. 2016. Post-earthquake response by small UAV helicopters. *Natural Hazards,* 80, 1669-1688.
NOORANI, R. 2017. *3D printing : technology, applications, and selection*, Boca Raton, FL : CRC Press, Taylor & Francis Group, 2017.
NUNES, I. L., LUCAS, R., CORREIA, N. & SIMÕES-MARQUES, M. 2018. *Augmented Reality in Support of Disaster Response*, Springer Verlag.
NURMALA, N., DE LEEUW, S. & DULLAERT, W. 2017. Humanitarian-business partnerships in managing humanitarian logistics. *Supply Chain Management-an International Journal,* 22, 82-94.
O'BYRNE, R. 2018. *The Future of Drones in Logistics: Thinking Inside the Box* [Online]. Available: https://www.logisticsbureau.com/drones-in-distribution-thinking-inside-the-box/ [Accessed 2 Sep 2018].
OMELICHEVA, M. Y. 2011. Natural Disasters: Triggers of Political Instability? *International Interactions,* 37, 441-465.
OXFORD DICTIONARIES. 2018. *Definition of technology in English* [Online]. Available: https://en.oxforddictionaries.com/definition/technology [Accessed 5 April 2018].
ÖZDAMAR, L. & ERTEM, M. A. 2015. Models, solutions and enabling technologies in humanitarian logistics. *European Journal of Operational Research,* 244, 55-65.

PANETTA, K. 2017. *Top Trends in the Gartner Hype Cycle for Emerging Technologies, 2017* [Online]. Available: https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/ [Accessed 20 March 2018].
PETTIT, S. & BERESFORD, A. 2009. Critical success factors in the context of humanitarian aid supply chains. *International Journal of Physical Distribution & Logistics Management*, 450.
REINER, G., RABTA, B., WANKMUELLER, C. & REINER, G. 2018. A drone fleet model for last-mile distribution in disaster relief operations. *International journal of disaster risk reduction,* 28, 107-112.
ROGERS, E. M. 1983. *Diffusion of innovations*, New York : Free Press, 1983
3. ed.
SANDVIK, K. B., GABRIELSEN JUMBERT, M., KARLSRUD, J. & KAUFMANN, M. 2014. Humanitarian technology: a critical research agenda. *International Review of the Red Cross,* 96, 219-242.
SANDVIK, K. B. & LOHNE, K. 2014. The Rise of the Humanitarian Drone: Giving Content to an Emerging Concept. *Millennium (03058298),* 43, 145.
SARIPALLE, S., MAKER, H., BUSH, A. & LUNDMAN, N. 2016. 3D printing for disaster preparedness: Making life-saving supplies on-site, on-demand, on-time. IEEE.
SAVONEN, B. L., MAHAN, T. J., CURTIS, M. W., SCHREIER, J. W., GERSHENSON, J. K. & PEARCE, J. M. 2018. Development of a Resilient 3-D Printer for Humanitarian Crisis Response. *Technologies (Basel), Vol 6, Iss 1, p 30 (2018)*, 30.
SEDLAR, U., STERLE, J., VOLK, M., KOS, A. & BESTER, J. 2014. Implementing mission critical services and applications on top of heterogeneous networks. IEEE.
SEE, Z. S., BLUNDELL, D. & THWAITES, H. 2017. Virtual reality 360 content preservation for disaster relief. Pacific Neighborhood Consortium (PNC).
SNIDERMAN, B., BAUM, P. & RAJAN, V. 2016. 3D opportunity for life - Additive manufacturing takes humanitarian action. Available: https://www2.deloitte.com/content/dam/insights/us/articles/3d-printing-for-humanitarian-action/DR19_3DOpportunityForLife.pdf.
STOLTZ, M.-H., GIANNIKAS, V., MCFARLANE, D., STRACHAN, J., UM, J. & SRINIVASAN, R. 2017. Augmented Reality in Warehouse Operations: Opportunities and Barriers. *IFAC-PapersOnLine,* 50, 12979-12984.
TATHAM, P. 2009. An investigation into the suitability of the use of unmanned aerial vehicle systems (UAVS) to support the initial needs assessment process in rapid onset humanitarian disasters. 13, 60-78.
TATHAM, P., BALL, C., WU, Y. & DIPLAS, P. 2017a. Long-endurance remotely piloted aircraft systems (LE-RPAS) support for humanitarian logistic operations: The current position and the proposed way ahead. *Journal of Humanitarian Logistics and Supply Chain Management,* 7, 2.
TATHAM, P., LOY, J. & PERETTI, U. 2015. Three dimensional printing – a key tool for the humanitarian logistician? *Journal of Humanitarian Logistics & Supply Chain Management,* 5, 188.

TATHAM, P., STADLER, F., MURRAY, A. & SHABAN, R. Z. 2017b. Flying maggots: a smart logistic solution to an enduring medical challenge. *Journal of Humanitarian Logistics and Supply Chain Management,* 7**,** 172.

THILMANY, J. 2010. part of the solution. *Mechanical Engineering,* 132**,** 46-49.

THOMAS, A. & MIZUSHIMA, M. 2005. Logistics training: necessity or luxury? *Forced Migration Review, Iss 22, p 60 (2005)***,** 60.

TOWLER, J., KRAWIEC, B. & KOCHERSBERGER, K. 2012. Radiation Mapping in Post-Disaster Environments Using an Autonomous Helicopter. *Remote Sensing,* 4**,** 1995-2015.

TUNA, G., NEFZI, B. & CONTE, G. 2014. Unmanned aerial vehicle-aided communications system for disaster recovery. *Journal of Network and Computer Applications***,** 27.

TZU-HUSAN, L. & DER-CHERNG, L. 2015. Development of an intelligent disaster information-integrated platform for radiation monitoring. *Natural Hazards,* 76**,** 1711-1725.

VAN WASSENHOVE, L. 2006. Humanitarian Aid Logistics: Supply Chain Management in High Gear. *The Journal of the Operational Research Society***,** 475.

VAN WEELE, A. J. 2014. *Purchasing & supply chain management : analysis, strategy, planning and practice*, Andover : Cengage Learning, 2014

6. ed.

VOSS, C., TSIKRIKTSIS, N. & FROHLICH, M. 2002. Case research in operations management. *International Journal of Operations & Production Management***,** 195.

WASFY, A. & GILL, W. Critical facilities virtual environment for emergency responders. 16th Conference on Behavior Representation in Modeling and Simulation 2007, BRIMS, 2012. 307-316.

XU, R., YANG, L. & YANG, S. H. Architecture design of internet of things in logistics management for emergency response. Proceedings - 2013 IEEE International Conference on Green Computing and Communications and IEEE Internet of Things and IEEE Cyber, Physical and Social Computing, GreenCom-iThings-CPSCom 2013, 2013. 395-402.

XU, Z., YANG, J., PENG, C., WU, Y., JIANG, X., LI, R., ZHENG, Y., GAO, Y., LIU, S. & TIAN, B. 2014. Development of an UAS for post-earthquake disaster surveying and its application in Ms7.0 Lushan Earthquake, Sichuan, China. *Computers and Geosciences,* 68**,** 22-30.

YANG, L., YANG, S. H. & PLOTNICK, L. 2013. How the internet of things technology enhances emergency response operations. *Technological Forecasting & Social Change,* 80**,** 1854-1867.

YIN, R. K. 2014. *Case study research : design and methods*, London : SAGE, cop. 2014

5. ed.

Appendix 1. Data extraction form

Bibliographic information		
	Title	
	Year	
	Publication	
	Publication type	
	Link	
	Keywords	
	Author(s) and affiliation(s)	
Aims and methods		
	Study aim	
	Research questions	
	Method used	
	Sample for data collection	
	Definition of technology	
	Definition of HSC	
Findings		
	Themes	
	Identified applications of technology, secondary sources	
	Identified applications of technology, primary sources	
	Identified benefits of technology, secondary sources	
	Identified benefits of technology, primary sources	
	Identified challenges of technology, secondary sources	
	Identified challenges of technology, primary sources	
	Connection to HSC framework	
	Suggested future research	

Appendix 2. Interview protocols

Interview protocol – 3D printing

A. The interviewee
1. What is your role within MSF, and within this project?
2. Do you have any previous experience with the technology in this project?

B. The project
3. What is the purpose of the project?
4. What is the duration and current status of the project?
5. In what context and environment will the project take place?

6. What type of technology will be used?

C. Applications and related benefits and challenges from literature

7. Manufacture of spare parts with 3D printing
   a) Do you believe that 3D printing would be suitable for manufacturing of spare parts/replacement parts? Why/why not?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) What type of spare parts (vehicle, medical equipment, WASH, etc.)?
   d) What part of the supply chain would the manufacture of spare parts with 3D printing improve? What supply chain activities? How?
   e) How would this this application of 3D printing affect strategic supply chain decisions? How would it affect operational decisions?
   f) In what type of mission and setting would this application be most useful? In what type of constellation?
   g) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   h) What challenges/barriers are related to this application?

8. Manufacture of customized items, designed for the specific situation
   a) Do you believe that 3D printing would be suitable for manufacturing of customized items? Why/why not?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) What type of customized items (medical, logistics, etc.)?
   d) What part of the supply chain would the manufacture of spare parts with 3D printing improve? What supply chain activities? How?
   e) How would this this application of 3D printing affect strategic supply chain decisions? How would it affect operational decisions?
   f) In what type of mission and setting would this application be most useful? In what type of constellation?
   g) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   h) What challenges/barriers are related to this application?

9. Manufacture of low demand items (not spare parts)
   a) Do you believe that 3D printing would suitable for manufacturing of low demand items? Why/why not?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) What type of items (medical, communication, WASH, etc.)?
   d) What part of the supply chain would the manufacture of spare parts with 3D printing improve? What supply chain activities? How?
   e) How would this this application of 3D printing affect strategic supply chain decisions? How would it affect operational decisions?
   f) In what type of mission would this application be most useful? In what type of constellation?
   g) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   h) What challenges/barriers are related to this application?

10. Manufacture of shelter or buildings
   a) Do you believe that 3D printing would suitable for manufacturing of shelter or buildings? Why/why not?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) What part of the supply chain would the manufacture of shelter with 3D printing improve? What supply chain activities? How?
   d) How would this this application of 3D printing affect strategic supply chain decisions? How would it affect operational decisions?
   e) In what type of mission would this application be most useful? In what type of constellation?
   f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   g) What challenges/barriers are related to this application?

D. Complementary applications or benefits

11. Are there any other applications or benefits of this technology?

E. General challenges and barriers from literature

12. Do you believe that the following is a barrier/challenge? Why/why not? Have you experienced this barrier? *(only ask for the factors that have not already been mentioned)*
   a) Competence to manage the printer
   b) Safety related to manage the printer
   c) Cost of printer
   d) Manufacturing time
   e) Routines for quality control of printed items
   f) Routines for handling of printer
   g) Transportability of printer
   h) Attitude towards using 3D printer
   i) Lack of robustness
   j) Available infrastructure (e.g. power source, telecommunication connections, possibilities to supply spare parts to printer)

F. Complementary challenges/barriers

13. Are there any other challenges or barriers related to the use of this technology?

G. Comparison

14. What do you consider to be the primary applications of this technology? Why?
15. What do you consider to be the primary challenge/barrier of this technology? Why?

H. More information

16. Who else would you recommend that I talk to regarding this project?

I. End of interview

Interview protocol – Immersive technologies

A. The interviewee

1. What is your role within MSF, and within this project?
2. Do you have any previous experience with the technology in this project?

B. The project
3. What is the purpose of the project?
4. What is the duration and current status of the project?
5. In what context and environment will/have the project take(n) place?
6. What type of technology will be/have been used (technical details)?

C. Applications and related benefits and challenges from literature
Comment: The supply chain includes the flow of materials, financial resources, information and competences across the organisation's network.

7. VR for training purposes
   a) Do you believe that VR would be suitable for training/education purposes? How, what type of training? In what context?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) How would the use of VR for training improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
   d) How would this application of VR affect strategic supply chain decisions? How would it affect operational decisions?
   e) In what type of mission and setting would this application be most useful?
   f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   g) What challenges/barriers are related to this application?

8. VR for recruitment purposes
   a) Do you believe that VR would be suitable to use for recruitment? How, what type of recruitment? In what context?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) How would the use of VR for recruitment improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
   d) How would this application of VR affect strategic supply chain decisions? How would it affect operational decisions?
   e) In what type of mission and setting would this application be most useful?
   f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   g) What challenges/barriers are related to this application?

9. VR/AR for reporting and content preservation
   a) Do you believe that VR/AR would be suitable for content preservation? How, what type of content? In what context?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) How would the use of VR/AR to preserve content improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
   d) How would this application of VR/AR affect strategic supply chain decisions? How would it affect operational decisions?

e) In what type of mission would this application be most useful?
f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
g) What challenges/barriers are related to this application?

10. AR to improve decision-making abilities
a) Do you believe that AR would be suitable as a way to improve decision-making? How, what type of decisions? In what context?
b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
c) How would the use of AR for decision making improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
d) How would this application of AR affect strategic supply chain decisions? How would it affect operational decisions?
e) In what type of mission would this application be most useful?
f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
g) What challenges/barriers are related to this application?

D. Complementary applications or benefits
11. Are there any other applications or benefits of this technology?

E. General challenges and barriers from literature
12. Do you believe that the following is a barrier/challenge? Why/why not? Have you experienced this barrier? *(only the factors that have not already been mentioned)*
a) User-friendliness of equipment
b) Fidelity of VR content (quality of images, to capture a correct representation of the reality, etc.)
c) Lack of familiarity, perceived as lacking credibility
d) Lacking hand-on and face-to-face of real life scenarios
e) Current state of technology is limiting

F. Complementary challenges/barriers
13. Are there any other challenges or barriers related to the use of this technology?

G. Comparison
14. What do you consider to be the primary applications of this technology? Why?
15. What do you consider to be the primary challenge/barrier of this technology? Why?

H. More information
16. Who else would you recommend that I talk to regarding this project?

I. End of interview

Interview protocol – UAVs

A. The interviewee
1. What is your role within MSF, and within this project?
2. Do you have any previous experience with the technology in this project?

B. The project

3. What is the purpose of the project?
4. What is the duration and current status of the project?
5. In what context and environment will the project take place?
6. What type of technology will be used (technical details)?

C. Applications and related benefits and challenges from literature

7. Use of UAVs for mapping purposes
    a) Do you believe that UAVs would be suitable for mapping purposes? How, what type of mapping (population count, damage assessment, radiation mapping, etc.)?
    b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
    c) How would mapping UAVs improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
    d) How would this this application of UAVs affect strategic supply chain decisions? How would it affect operational decisions?
    e) In what type of mission and setting would this application be most useful? In what type of constellation (one, several, etc.)?
    f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
    g) What challenges/barriers are related to this application?

8. Use of UAVs for deliveries
    a) Do you believe that UAVs would be suitable for deliveries? How, what type of deliveries?
    b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
    c) How would cargo UAVs improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
    d) How would this this application of UAVs affect strategic supply chain decisions? How would it affect operational decisions?
    e) In what type of mission and setting would this application be most useful? In what type of constellation (one, several, etc.)?
    f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
    g) What challenges/barriers are related to this application?

9. Use of UAVs for communication
    a) Do you believe that UAVs would suitable for deployment of communication networks? Why/why not?
    b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
    c) How would communication drones improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
    d) How would this this application of UAVs affect strategic supply chain decisions? How would it affect operational decisions?
    e) In what type of mission would this application be most useful? In what type of constellation?

f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
g) What challenges/barriers are related to this application?

D. Complementary applications or benefits
11. Are there any other applications or benefits of this technology?

E. General challenges and barriers from literature
12. Do you believe that the following is a barrier/challenge? Why/why not? Have you experienced this barrier? *(only ask for the factors that have not already been mentioned)*

a) Regulations, operating standards and permissions
b) Competence to manage the equipment
c) Safety related manage of the equipment
d) Cost of equipment
e) Flight endurance limitations
f) Payload limitations
g) Altitude limitations
h) Need to preposition markers/have a pre-disaster baseline
i) Image processing and large data volume
j) Attitudes towards UAVs
k) Effect on relationships/increase of "distance" between aid workers and beneficiaries
l) Concerns regarding privacy

F. Complementary challenges/barriers
13. Are there any other challenges or barriers related to the use of this technology?

G. Comparison
14. What do you consider to be the primary applications of this technology? Why?
15. What do you consider to be the primary challenge/barrier of this technology? Why?

H. More information
16. Who else would you recommend that I talk to regarding this project?

I. End of interview

Interview protocol – Internet of Things (IoT)

A. The interviewee
1. What is your role within MSF, and within this project?
2. Do you have any previous experience with the technology in this project?

B. The project
3. What is the purpose of the project?
4. What is the duration and current status of the project?
5. In what context and environment will/have the project take(n) place?
6. What type of technology will be/have been used (technical details)?

C. Applications and related benefits and challenges from literature

7. IoT for inter- and intra-organisational cooperation
   a) Do you believe that IoT would be suitable for cooperation purposes? How, what type of cooperation (number of actors, types of actors, etc.)?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) How would the use of IoT for cooperation improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
   d) How would this application of IoT affect strategic supply chain decisions? How would it affect operational decisions?
   e) In what type of mission and setting would this application be most useful?
   f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   g) What challenges/barriers are related to this application?

8. IoT for situational awareness
   a) Do you believe that IoT would be suitable for enhancing situational awareness? How, what type of awareness?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) How would the use of IoT for situational awareness improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
   d) How would this application of IoT affect strategic supply chain decisions? How would it affect operational decisions?
   e) In what type of mission and setting would this application be most useful?
   f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   g) What challenges/barriers are related to this application?

9. IoT to enable visibility of resources
   a) Do you believe that IoT would be suitable for visualisation of resources? How, what type of resources (material, infrastructure, personnel, etc.)?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) How would the use of IoT to visualize resources improve the supply chain? What supply chain activities, what parts of the supply chain, etc.
   d) How would this application of IoT affect strategic supply chain decisions? How would it affect operational decisions?
   e) In what type of mission would this application be most useful?
   f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
   g) What challenges/barriers are related to this application?

10. IoT for resource allocation
   a) Do you believe that IoT would be suitable for allocation of resources? How, what type of resources?
   b) Is this application tested in this project, or will it be? What are the lessons learned? What are the expected outcomes?
   c) How would the use of IoT to allocate resources improve the supply chain? What supply chain activities, what parts of the supply chain, etc.

d) How would this application of IoT affect strategic supply chain decisions? How would it affect operational decisions?
e) In what type of mission would this application be most useful?
f) When could this application be a reality (in the near future/in five years/in 10 or more years)?
g) What challenges/barriers are related to this application?

D. Complementary applications or benefits

11. Are there any other applications or benefits of this technology?

E. General challenges and barriers from literature

12. Do you believe that the following is a barrier/challenge? Why/why not? Have you experienced this barrier? *(only the factors that have not already been mentioned)*

a) Management of large data volumes
b) Maintenance, update and configuration of connected devices
c) The integration of objects in the IoT network
d) Update of current system to allow for IoT application
e) Internet connection required
f) Data security
g) Vulnerability of IoT to attacks
h) Trust between IoT and human, or attitudes towards IoT

F. Complementary challenges/barriers

13. Are there any other challenges or barriers related to the use of this technology?

G. Comparison

14. What do you consider to be the primary applications of this technology? Why?
15. What do you consider to be the primary challenge/barrier of this technology? Why?

H. More information

16. Who else would you recommend that I talk to regarding this project?

I. End of interview

Interview protocol – Round 2

A. The interviewee

1. What is your role within MSF?
2. Apart from your current position, what supply chain related positions have you had?
3. Which supply chain activities have you experience from working with? Example activities: assessment, procurement, warehousing, transport, operations support, reporting.

B. 3D printing

4. Please comment comparison of literature and interviews on the tab "3D printing" in the Excel fil “Results from interviews”.

C. UAVs

5. Please comment comparison of literature and interviews on the tab "UAVs" in the Excel fil “Results from interviews”.

D. VR
6. Please comment comparison of literature and interviews on the tab "VR" in the Excel fil “Results from interviews”.

E. IoT
7. Please comment comparison of literature and interviews on the tab "IoT" in the Excel fil “Results from interviews”.

F. Comparison
8. Which technology do you believe could bring the greatest benefits for MSF? Why?
9. Which technology do you see as furthest from implementation? Why?

G. More information
10. Who else would you recommend that I talk to regarding this project?

H. End of interview