



Expertise
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Franz Andersson

Drones in Humanitarian Logistics - Benefits in the Last Mile Context

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<p>This research addresses the question of where do drones provide the greatest benefits in the humanitarian logistics' 'last mile' context? The research evaluates different drone models and evaluates their suitability for different applications and contexts.</p> <p>The research was conducted mainly as a literature review. This data was complemented by empirical data that was derived from a questionnaire distributed among professionals working either with drones or on humanitarian operations. Two professionals filled out the questionnaire. However, their contribution is significant from the perspective of this research due to their expertise in the field.</p> <p>Drones have two main functions within humanitarian logistics – mapping of the terrain affected by crises and delivery of goods to those affected by the crisis. Of these, mapping is by far the most common, with 60% of drone usage being focused on this function. Delivery of goods is limited by the low carrying capacity of drones, and as such they are best used for small, specialty loads, such as medical supplies.</p> <p>This research finds that drones are most beneficial in earthquakes, floods, tsunamis, and large-scale accidents, where mapping the magnitude of the disaster helps in planning the most appropriate relief response.</p> <p>Fixed wing model drones are the most suitable in most cases of disasters, but have limitations related to their requirements in relation to space for take-off and landing, as well as due to their high purchase price. The hybrid-model drone, on the other hand, is useful for delivering loads in challenging terrain, such as mountainous areas.</p> <p>More R&D and unified regulations are needed to further develop the field of drones in HL. Practitioners would also welcome further collaboration in this area in terms of information sharing. Use of drone fleets instead of individual drones should be explored further to increase the overall capacity of drone-assisted deliveries.</p> <p>The topic is relevant as humanitarian crises are affected by more and more people worldwide. The technology behind drones is also under constant development and therefore drones can offer considerable potential to support humanitarian relief missions in the future.</p>	
Keywords	Humanitarian logistics; last mile; drones; natural disasters floods; earthquakes; man-made disasters, wars, large-scale accidents

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1 Introduction

This research is very timely, as an increasing number of people are affected by various types of humanitarian crises, caused for example by global warming, uncontrolled population growth, and rising inequality. A generally agreed definition of humanitarian crises is *a sudden event which disrupts the functioning of society or community, causing destruction in human, material, economic or environment which exceeds the society's own capability to handle the crises situation* (World Vision International 2020).

Furthermore, our world is currently facing a massive pandemic, COVID-19, which only exacerbates these challenges. Humanitarian aid has been addressing these types of persistent issues for decades, by delivering different types of essential supplies to the affected populations throughout the globe. The various activities that comprise the chain of mapping the affected area, as well as the storage and transportation of the needed items to the affected areas is referred to as Humanitarian Logistics (HL).

Broadly speaking, humanitarian logistics follows much of the same patterns as traditional business logistics do: various types of goods move and are stored. Both logistics systems cover the delivery of products from the manufacturer to the final user through a network of short- and long-term warehousing, using a different combination of land, air and sea- transportation. Depending on the situation, the urgency, the availability and the price, among other things, determine the choices that are made in terms of where the desired products are ordered.

However, the current resources do not meet the future demands of new humanitarian challenges. Currently, the need to find solutions within HL has become more pressing. For example, the effect of climate change and the current COVID-19 crisis alone, has doubled the risk of starvation (Paul Anthem 2020), further signalling a need for new large-scale solutions. Also challenges related to global warming have become more common. This phenomenon affects particularly people who live in areas that are already suffering from drought. Together with overpopulation global warming creates massive challenges to societies in Global South, where large parts of the population often already live-in

extreme poverty. As a result, inequality continues to increase, which in turn causes tensions between people, which often exacerbates humanitarian crises.

Drones are unmanned aerial vehicles (UAV's), capable of delivering certain types of (typically small) loads in certain types of contexts. Drones were originally developed for commercial use, and their potential in relief work has only started to set off. The use of drones in humanitarian crises is a relatively new, but a very promising approach to aid delivery. There are some early examples of using drones in the context of humanitarian crisis in the past, for example, in a 1996 NATO surveillance mission in the Bosnian war (Lohne 2013), but it is only of late that there has been more interest in scaling up these activities.

This research addresses the question of ***where do drones provide the greatest benefits in the humanitarian logistics 'last mile' context?*** In addition, the purpose of the paper is to introduce humanitarian logistics, and particularly the use of drones within humanitarian logistics, for broader audiences. Research questions that further guide this research are:

Q1: In what type of a crisis is the use of drones most useful?

Q2: What types of benefits do the different drone types offer?

Q3: What type of developments would promote the use of drones going forward?

This research starts by exploring the relevant literature on the key concepts related to HL, drones, as well as the intersection of the two. The literature is supplemented by empirical data derived from experts from the field, who filled out a questionnaire on their experience of the benefits of the use of drones in humanitarian crises. The experts' contribution offers valuable perspectives for this research from the practitioner's viewpoint. In the analysis, these two strands of data – literature and expert insights - will be analysed. The analysis will be guided by the research questions.

2 Research Methodology

This research is based on a literature review that comprises some basic tenets of HL, drones and the intersection of the two. The literature also includes comparing the use of drones and traditional means of distribution in the last mile context.

There are many studies conducted on the topic of the use of drones in HL. With ample information available on the topic, this research adopts a qualitative approach. The qualitative approach ensures a way to incorporate the previously published information in the most comprehensive way possible. Furthermore, most research done in the field of HL is qualitative, as it often describes particular scenarios and cases. In that sense, this research follows the research tradition emblematic to HL. This secondary data will be analysed together with the data gained from the questionnaire filled out by experts of HL.

The literature is supplemented by empirical data. A questionnaire has been distributed to 17 professionals representing some key informants in relation to the research focus. The professionals represent one of three distinct groups: academia, aid organizations, and the private sector. The purpose of sending out a questionnaire was to gain up-to-date information from the field, as well as to provide further support to the robustness of this research.

3 Literature review

This literature review addresses the existing knowledge on the use of drones in the context of humanitarian logistics. The literature review presents relevant literature related to the definition of humanitarian logistics in general, and then moves on to discuss the challenges related to the 'last mile' delivery of goods in crisis-inflicted areas. The main focus of the literature review is on last mile context and the drones' possibilities to respond to the challenges in that context.

3.1 Humanitarian logistics defined

HL is a sub-sector of logistics, that has been gaining more and more attention in recent decades. It explores the mapping of crisis-inflicted areas and the delivery and storage of goods that aim to alleviate different aspects of humanitarian suffering. The reasons for the increased interest in HL are embedded in the growing number of humanitarian challenges that have risen up in recent times (Dubey and Gunasekaran 2016: 2-5). According to the UN, the challenges that occurred in 2020 in the humanitarian field are the greatest since the Second World War.

The following figure illustrates the division of different types of humanitarian crises based on their nature (natural or man-made), and on the level of urgency (sudden-onset or slow-onset)(Van Wassenhove 2006: 475–489). Natural disaster refers to crises related to events such as earthquake, hurricane, tornado or a tsunami, which all occur with reasonably little prewarning and as such, fall into the 'sudden-onset' category; and famine, drought and poverty, which develop more slowly and as such fall in the slow-onset category. Man-made disasters, on the other hand, refer to events such as terrorist attacks, coup d'état or chemical leak (sudden-onset), and political crises and refugee crises (slow-onset). This definition has been widely used in the field of HL and it is referred to in several relevant articles (eg. Chandran 2015; Kedar 2019: 149-151). Grouping disasters in different categories helps organizations to adjust their response in terms of speed, scale, and allocated resources accordingly.

		Source	
		Natural	Man-made
Speed of Onset	Sudden	Earthquake Hurricane Tornado Tsunami	Terrorists attack Coup d'etat Chemical Leak
	Slow	Famine Drought Poverty	Political Crisis Refugee Crisis

Figure 1 Nature of crisis (Wassenhove, 2006)

According to literature, humanitarian crises can be seen to go through three to four phases, depending on the situation. The response-phase in humanitarian crises by HL commonly flows through three distinct stages: preparedness, immediate response and reconstruction (Merminod, Nollet and Pache 2014: 4-22). Some literature adds a fourth phase, mitigation, that precedes the previous three (Cozzolino 2012: 5-16). Each of these phases requires a different set of capabilities, resources and activities from the humanitarian organizations. Collaboration with local people and organizations enhances effectiveness of a humanitarian mission in all the different phases. In a sense, collaboration ensures that the preparedness phase of next potential crises in a given region is already in progress (Fabre 2017: 1-26).

HL involves number of different stakeholders including aid organizations, other NGO's, governments, local people, aid workers, as local and international donors and drone manufacturers (Wisetjindawat 2014: 413). These stakeholders together possess adequate resources and influence to protect against a full-blown crisis in situations where adequate notice is received. As collaboration between these actors requires notable resources in terms of coordination, it makes sense to attempt to fend off the occurrence of humanitarian crises, where possible. It is worth noting that 60-80 percent of the costs in humanitarian aid field consist of its supply chain activities (Hein, Behrens and Lasch, 2020).

All stakeholders involved in HL have a common goal of helping those who are most vulnerable. Getting help to those in need is at the core of humanitarian aid. HL is a complex field, and the operations take place in challenging circumstances with no time to spare. The different stakeholders need each other to work and to form a working supply chain to get the aid to its destination.

All the phases of a humanitarian crises are interconnected. As such, the HL operations can also be seen as a cycle, where the stages follow each other. While in humanitarian crises the most attention is often placed on the immediate response, that often also elicits broad public and media attention, the final stage in the cycle – that of recovery – includes valuable learning from the perspective of future catastrophes (Kovács and Spens 2010: 222-239).

Compared to traditional business logistics, HL has some distinct characteristics (Kovács and Spens 2009: 506-528). For example, the concept of profit has a different meaning in HL, as the timing and speed of delivery commonly have notable value in this field. The core purpose of HL is to save and relieve peoples' suffering in a crisis as swiftly as possible. Consequently, the aid needs to be delivered promptly. For this reason, the pursuit of financial profit is given less weight (Ibid).

In humanitarian logistics, goods and services are transported and stored in disaster areas, where the infrastructure is often fully or partially destroyed. As a rule of thumb, in traditional business logistics there is a stronger level of knowledge regarding which specific products are needed, at what time, and in which quantity. Also, the available vendors and delivery pathways are generally known, and the flow of information between them is routinized. As a result, operations within traditional business logistics are more proactive. In contrast, HL is reactive in nature (Kovács and Spens 2010: 222-239). Although it is nowadays possible to predict natural disasters, such as floods and earthquakes, in certain areas to some extent, many conflicts still occur unexpectedly and require the deployment of necessary resources without much advance notice.

The flow of goods in humanitarian logistics is demonstrated in figure 2 (Escribano Macias, Angeloudis and Ochieng 2020: 56). The process starts from the main hub, which are commonly large international warehouses operated by aid organizations. In these warehouses the humanitarian aid organizations focus their equipment storage, and this is also where they collect various types of donations.

Organizations also have regional warehouses around the globe, often placed in strategic locations. They are smaller deposits in the field, equipped with basic inventories of the most needed resources. From the regional warehouses further last-mile distribution can

be more easily organized. The last-mile distribution refers to the final leg of the delivery chain, where the goods are delivered to the recipients (Escribano Macias, Angeloudis and Ochieng 2020: 56). Last mile deliveries are discussed in greater detail in section 3.2.

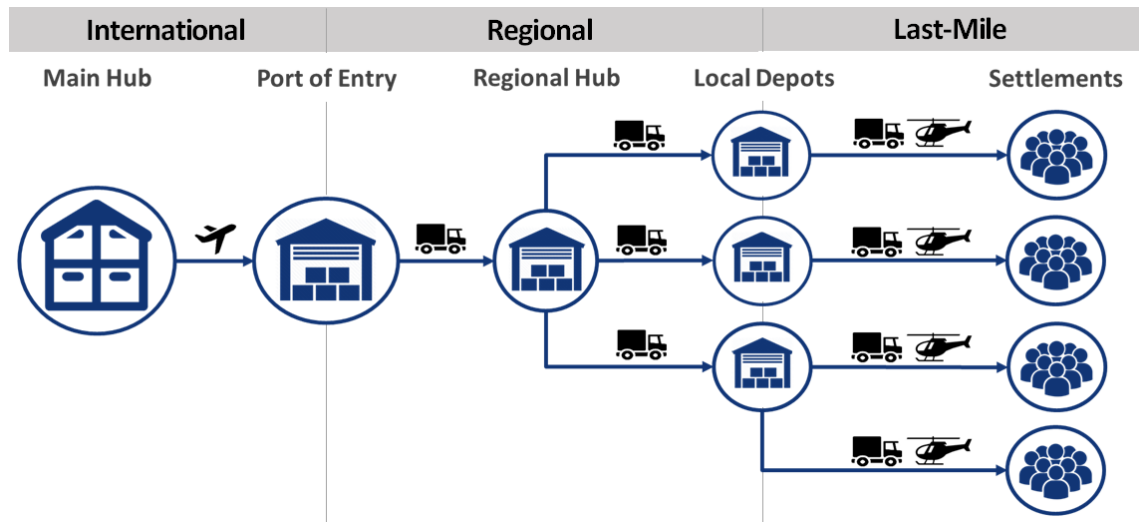


Figure 2 The flow of humanitarian logistics (Escribano Macias, Angeloudis and Ochieng 2020)

3.1.1 Preparedness

Preparedness is a crucial phase in every humanitarian crisis, regardless of the type of disaster and whether a crisis is presently happening. Past events have taught us that when a disaster strikes, it is too late to start planning for solutions that are not presently in existence. Furthermore, uncertainty in terms of the location and the scale of a disaster is one of the biggest challenges within HL, greatly affecting the level of preparedness. Naturally, it is prohibitively costly to be prepared for every type of eventuality, at any time. This is in part also due to the complex network of suppliers that needs to be mobilized at the occurrence of a crisis (Tomasini and Van Wassenhove 2009: 549).

Proper preparedness consists of different types of operative planning as well as listing all the needed equipment and resources for different crises situations (Rodríguez-Espíndola, Albores and Brewster, 2018). This includes the readiness of trained people. Procurement and donations have a big role in preparedness as they provide the equipment and foundations for upcoming challenging situations.

Organizations often focus on supply chain structures as this is the key for a successful outcome in an emergency. If the supply chains are kept active, also uncertainty related to demand of resources is more under the responding organizations' control. Demand uncertainty in a field like HL is constantly ongoing. However, it can be significantly lowered with proper preplanning processes and by establishing enough regional warehouses for adequate inventory (van der Laan 2016).

Demand forecasting is an effective and regularly used tool in procurement, as it helps predict demand for instance in situations where the price of goods fluctuates. In HL the principle for forecasting is the same - there are just more variables at play, which makes forecasting more difficult (van der Laan 2016). Variables like challenges in infrastructure can develop from bad to worse within minutes, if, for example, electricity disappears in a field hospital environment.

Local warehouses help in the prevention of bottlenecks. As mentioned earlier, time is a key factor in HL. Inventories closer to the crisis-affected area equalize unexpected surges in demand. Supply chains are time consuming processes and most of this time does not add value to the process itself.

3.1.2 Response

While proper level of preparedness creates a solid foundation for crisis-response, HL remains a challenging field to navigate, due to previously-mentioned uncertainties. Immediate response is one key tool to control some of the uncertainty brought forth by a crisis.

Immediate response process starts from humanitarian organization's regional hubs (see Figure 2, Escribano Macias, Angeloudis and Ochieng 2020). The eventuality of a disaster situation marks the activation of the supply chain for needed aid items such as tents, clothes, food, water, etc, to flow to smaller local depots. This maximizes the chances for the aid items to end up in the needed destination in a timely manner. In addition to a well-timed supply chain, enough trained and well-coordinated workers are needed to ensure all aspects of the delivery of the goods are handled properly, as this saves invaluable time.

3.1.3 Reconstruction

Reconstruction is the last phase in humanitarian logistics, it is usually the longest, and also an expensive phase in HL (Kwon and Kim 2018: 114-122). In many disasters the geographical area might be completely destroyed. This requires rebuilding the infrastructure from the very beginning. This is commonly also a phase where international attention and donations dry up, which can severely prolong the process (Ibid.). Here particularly vulnerable parts of the affected society are at risk. In many cases the poor have lived in illegal but permanent settlements and have no ownership or official claims to the land. As such they often fall outside the more coordinated reconstruction efforts and funding schemes.

Recognition of the mistakes previously made after the final phase of reconstruction is a valuable learning experience, the lessons of which can be drawn upon for a better performance during the next time a similar disaster occurs (Christopher and Tatham 2011: 9).

3.2 Last mile defined

Last mile in logistics refers to the delivery of goods or services from the service provider to the end user. This process marks the final step in the distribution chain. Despite the name "last mile" the distance for this concept can vary from few blocks to hundreds of miles (A. Robinson 2020). Last mile logistics took a great leap when e-commerce became a more popular way to do business. The first peak of mail order firms' success took place in the 80's and 90's which introduced customers to doing business by mail. This created a foundation for e-commerce companies such as Amazon, to enter the market and eventually even take the lead and to become trendsetters (Macharis and Melo 2011).

This phase of logistics is usually the most expensive part of delivering the goods or services. This is mainly due to the lack of efficiency in the last mile distribution (Macharis and Melo 2011). To address this inefficiency, this part of logistics needs further attention. The last mile is also one of the key focus areas in my work. Typical challenges in the last mile context are minimizing cost, ensuring transparency, increasing efficiency, and improving infrastructure (Allen 2011), as will be discussed further in the next section.

3.2.1 Typical last mile challenges

Typical challenges that arise in last mile delivery are mostly related to the inefficiency of the delivery. Regardless of how the goods are combined for the last mile delivery the efficiency suffers inevitably when there are more than one stop for the items to be delivered. In general, this means that short delivery routes with multiple delivery stops are not cost efficient. This poses a challenge both in urban areas with traffic jamming the deliveries, and in countryside where the distances of few delivered items can be several miles (Dolan 2021). Due to these issues, the improvements to distribution, as well as new technological implementations, are usually directed to the last mile phase.

3.2.2 Last mile in humanitarian logistics

Last mile distribution in HL is the final phase of the aid delivered to those in need of relief aid. This phase starts from local distribution centres, where the last mile delivery is prepared and set in motion (Balcik, Beamon and Smilowitz 2008: 51-63). Situations like tsunami, earthquake, flood, forest fire, pandemic, famine, etc. each pose features that have different challenges and constraints.

Delivery methods can vary depending on the terrain that needs to be crossed. Also, weather circumstances can affect the most suitable methods for the last mile delivery. Due to the variation in circumstances the types of deployed vehicles used also vary - aid can be delivered through a wide range of means. For instance, depending on the circumstance and available resources, the delivery can take place using ground vehicles, helicopters, planes or drones, even on foot or using a beast of burden.

3.3 Drones

Drones can be described as unmanned aircraft that can fly autonomously (Villasenor 2012). There are various aspects that distinguish drones from passenger planes, for instance, which can also be flown by automation. The most notable feature that separates drones from other autonomously flown vehicles comes from the name unmanned aerial vehicle (UAV), which means that there is no pilot on-board (Ibid.). Yet there still is a pilot on-ground that controls these devices.

There are various types of drones, ranging both in size and the purpose of use. They can be used by professionals in demanding operations and they are also becoming more popular in civilian use (Zurli, Bravo and Leiras 2015).

Transportation with drones has two distinct business models. Manufactures can either guide their customers to use a maintenance platform to provide support for their activities, or companies can keep the whole service platform in their control and instead charge for their delivery services. Both scenarios have notable uncertainties from the perspective of further development of this form of delivery service. Furthermore, many drone models are still prototypes, with no field experience. They also have relatively high total operating price. In addition to the uncertainties related to this relatively new technology, and costs therein, the regulations considering air traffic with drones still varies from region to region (Emery 2016: 153-165).

3.3.1 Drones - first appearance

The history of UAV's goes back to World War One, when the first experiments took the form of torpedoes and flying bombs (Newcome 2004). In later times drones have been widely used in military operations in tasks related to surveillance, combat actions and training purpose. The professional use of drones is perhaps best known to the greater public from military operations.

However, in recent years drones have started to appear increasingly also in non-military activity. Non-military activities consist of people and civil organizations like hobbyists, activists, humanitarian organizations, film makers, etc. (Choi-Fitzpatrick *et al.* 2009: 9). Non-military use of drones has in recent times surpassed military use (Ibid.).

3.3.2 Types of humanitarian cargo suitable for drone delivery

This section lists most common cargo for drone assisted delivers within HL. Section concentrates on drone deliveries in HL and will not focus on drone's transportation in different context.

- Small load delivery-last mile

- Medical goods
- Food/water delivery
- Communication gadget/GPS receiver delivery

3.3.3 Needed resources for drone deployment and maintenance

There are various specific resources that are needed when deploying drones. For example, drones require a proper landing zone (Emery 2016: 153-165). The needed characteristics depend on the particular drone model, which will be presented and discussed further in section 3.4.3. The landing zone needs to be sufficiently long and flat, so that drones can land safely without risk of damaging the expensive technology. Preferably there should be a storage building next to the landing zone where the drone can be serviced if necessary. The building can also serve as a storage place for the delivered items and give protection against theft and weather conditions. Furthermore, the infrastructure has to provide access to electricity grid, as drones use battery technology, which requires recharging. Dependence on electricity can also be considered a major risk factor in relation to use of drones, in circumstances where basic infrastructure is otherwise fragile (Ibid.).

Pilot training also requires resources from the operator, depending on whether they use their own drones or if they use a drone service providers' facilities.

Drones used in mapping need special software programs so that the data can be analysed, which also requires trained workers. Communication channels have to be available and in readiness, for basic communications between relevant actors in case of any sudden surprises or an emergency. Drones also have to be equipped with GPS receivers or equivalent gadgets to allow the following of their flight paths. They can also help in the coordination of drones where they are used as a fleet (Cawthorne and Robbins-van Wynsberghe 2020).

3.4 Use of drones in humanitarian logistics

Drones first entered the humanitarian field as a surveillance technology. In the beginning, drones were only used by a handful of trained people. In 2006, the Democratic Republic of Congo was one of the first places where drones were deployed (Van Wynsberghe and Comes 2020: 43-53). Going even further back in history, drones were used already in 1994 in Bosnia, when they were used for surveillance to ensure the safety of NATO troops (Lohne 2013). Since those times, technological development has been rapid, and drones have become more accessible also in everyday use. Appendix 1 will show more details on the models commonly used within HL. The information provided includes the name of the drone, the estimated purchase price, the model type, the manufacturer and the most used purpose.

While, drones are widely used in HL operations, it is hard to estimate the actual number of drones being used in the field. This might be due to the fact that there is no current requirement to register the use of drones (Van Wynsberghe and Comes 2020: 43-53).

The use of drones in humanitarian field could be roughly divided into two areas. The first relates to (further) disaster prevention and the second to the aid response (Fabbroni 2016: 35). Both uses follow the different phases of HL (preparedness, response and reconstruction), as previously covered in chapter 3.1. For example, drones can be used in preparation for certain types of catastrophes. For example, in areas that experience floods, drones can be used to conduct risk assessment as part of their mapping activities. They can provide information on the infrastructure that is in place as well as on the number of people that live in the risk area. Mapping activities are further highlighted in section 3.4.1.

The conventional drone models use battery technology and therefore require recharging stations in their operating environment. Recharging stations can be installed in existing infrastructure, or they can be incorporated even for a truck or SUV platform. An example of this is the Austrian Red Cross' collaboration with Land Rover, in a project called "HERO". For this project, Land Rover Discovery was transformed to function as a commando vehicle for drones. This means take-off, landing and recharging possibilities during an existing operation (Greenwood and Joseph 2020).

3.4.1 Mapping

Drone mapping is one of the most common use of drones (Fabbroni *et al.* 2016: 23). Drones are able to provide highly beneficial help in mapping large areas, where infrastructure has been destroyed. One of the objectives in HL is to minimize the total travelling distance (time/cost), and drones are much more efficient at this, compared to traditional methods of observation (OCHA 2014).

Mapping refers to a process of gathering data by using drones' sensitive sensors (Ball 2021). The applicability varies depending on the type of drone (fixed wing, rotor model or hybrid model), (Andrew 2019) and the specific features and applications the drone offers. During mapping, drones collect data to form accurate two-dimensional maps or 3D models of the observed terrain. This information is used by the humanitarian organizations to find the right response in terms of disaster relief. (Fabbroni *et al.* 2016: 24).

Using drones, instead of traditional mapping methods such as manned planes, is less costly. Another significant advantage is that drones can operate in much lower altitudes compared to other aerial vehicles, which makes the quality of the data better (Fabbroni *et al.* 2016: 24; Ball 2021). The quality of the images can make a significant difference to the adequate response in operations where time is a crucial factor.

An example of the usefulness of high-quality data was the relief operation in Haiti in 2012 when Hurricane Sandy struck the island. In that kind of large scale crises the mapping of the destruction, and a fast estimate of the aid needed is of utmost importance (Luege 2016).

Drones are able to work also on cloudy days. They can quickly map the size of a flooded area, for example, which helps rescuers and relief organizations to concentrate on the right parts of the affected area. Drones' advantage compared to satellite imagery is that UAV's can give more detailed data and do it faster (Luege 2016).

However, according to literature, for the drones to function to their full potential, there needs to be a preparedness procedure in place in the deploying organization. This means the right equipment/software needs to be ready for use, as well as skilled human

resources to fly the drones. Currently, only the biggest NGO's have financial resources to invest in measures that allow for the deployment of drones that have adequate mapping features needed for immediate response in a crisis (Besada *et al.*, 2019). The rest of the organizations have to use external service providers, which will unfortunately reduce the crucial responding time beyond the important 72-hour window, which is considered the most critical timeframe when trying to 1) get an understanding of the scale of the disaster and 2) to get emergency help to the affected areas to prevent further casualties (Fabbroni *et al.*, 2016: 32).

It takes much more time, when using an outsourced drone service provider. In the case of humanitarian crises, the benefits of fast response will be lost, and using drones will not provide added advantage compared to more established ways, such as using planes or satellites. The only benefits in such a situation are the lower cost of using drones and the higher quality images taken by drones of the affected terrain (Fabbroni *et al.* 2016: 24).

Until the technology becomes more available for a greater number of service providers, partnering with local drone providers makes the process more efficient compared to a situation where all resources are brought from abroad.

3.4.2 Cargo delivery

The biggest potential in drone logistics lies in cargo delivery (Azmat and Kummer, 2020). However, the currently available drones still have various limitations in terms of their range and the suitable cargo's weight. In terms of mapping, the drawbacks are limited to slow deployment time.

Drones are not specifically designed for the humanitarian sector, and the technological applications are more geared towards private sector operations (Joshi, 2019). Still, they can be reasonably easily modified for the needs within the field of humanitarian aid.

Traditional cargo distribution by manned aircraft is relatively costly compared to drone delivery. This is true especially when the needed delivery frequency is continuous, as is the case in many humanitarian crises situations such as floods, famine, war conflict, etc.

One of the most sensitive items to be delivered in HL last mile context are vaccines and other types of medical products that are sensitive to external conditions. Unlike other non-perishable aid items, these medical items require special conditions in the supply chain. After the last mile delivery, they need to be used within a short time frame. As will be elaborated further in the next section, hybrid and rotor model drones can be used in difficult environments. They do not require extensive landing/take-off space and for that reason they are perfect for last mile distributors who need to get high-importance items, such as sensitive medical supplies, swiftly to the recipients (Emery 2016: 153-165).

The drones can also drop their cargo with parachutes, to get it safely on the ground. Parachuting is not as safe as landing, but it is considered more efficient. However, many countries have strict regulations about dropping cargo. As a consequence, safety measures and applications are widely tested to find suitable technology for dropping packages (Emery 2016: 153-165).

The technological advances drones have experienced focus mostly on civilian drones' and on cargo capacity. Currently, there are prototypes of different types of drone models that have not yet been approved for field use. The development of cargo drones involves NGO's, and universities in addition to manufacturers. These partnerships are commonly focused on finding ways to improve drones' cargo-carrying capacity (Joshi, 2019).

The current state-of-art drones can have a few kilograms of cargo onboard, with a range of up to 150 kilometres (Fabbroni *et al.*, 2016: 38). In practise this means that they are best suited for high-value, low-volume cargo. This means items such as medicine, water tablets, vaccines and first aid kits.

3.5 Drones' vs traditional air delivery

Traditional air cargo has been delivered using airplanes and helicopters. Air cargo has distinct benefits compared to ground transportation in situations where the infrastructure has been damaged or does not exist to begin with.

Challenges in relation to air delivery are commonly related to the availability of transport fleet (Xavier *et al.*, 2021). Helicopters and planes need continuous maintenance, as well as spare parts, which are not always readily available. In poor countries, aircrafts are commonly out of date, which raises different types of safety concerns. Humanitarian aid is dependent on well-functioning supply chains and any delays in the chain jeopardizes the success of the entire operation.

Cargo deliveries with manned aircraft can also pose a threat to the pilots. For example, in the Democratic Republic of Congo pilots refused to fly over certain areas because of the safety issues on the ground (Fabbroni *et al.* 2016).

The more traditional manned aircrafts have an advantage in certain types of situations. For example, in famine the required loads are often large. Current drone models are unable to compete in terms of load capacity. Drones might, however, be able to offer additional support by for example distributing medicine. Still, their ability to respond to food shortages is currently severely limited.

In the case of forest fires, the hot air mass can damage the drones, whereas traditional aircrafts fly at much higher altitudes and are therefore better protected from the detrimental effects of the heat (Pöysti 2019).

Unlike manned aircraft, drones cannot transport any human passengers (Dirks 2017). Sometimes this means that the use of drones needs to be discarded altogether. For instance, if doctors need to be moved along with the medical items, drones are not able to provide a solution.

3.5.1 Fixed-wing drones

Fixed-wing drones are designed to work like a regular airplane. It has a two-wing design which provides lift under the wings. This saves energy when the plane is in the air because it requires energy only for moving forward not for staying up (Fabbroni *et al.* 2016: 17; Andrew Chapman 2020).

This model is specifically designed for longer distance and heavier cargo. The broad range combined with fast flight speed makes this model effective also for mapping larger areas. They can move up to 50 km/h with a capacity to stay in the air for up to seven hours at a time for the models that use battery technology. Even longer airtime can be reached with the use of gas-powered engine, which can keep the drones in the air for up to 16 hours (Ibid.).

The main drawback of fixed-wing drones relates to the large space the drones need for launch and landing. As a result, bigger fixed-wing models are unable to land in mountainous areas, for example. Furthermore, the landing process requires a skilled pilot to navigate the demanding stages of the flight. There are some smaller models of fixed wing drones which can land on an open field (Ibid.).

The actual flight can be preplanned using flight paths and autopilot. Fixed-wing drones are harder to land and launch and also more expensive to buy. For these reasons, the customer segment for fixed-wing models is more professional than for the basic rotor model drones (Ibid.).

The fixed-wing models gather data on a wide scale, which further suggests a more professional approach related to this type (Ibid.).

Table 1 Fixed-wing drone features (Fabbroni et al. 2016; Andrew Chapman 2020)

Strengths	Weaknesses
<ul style="list-style-type: none"> • Long range • Cargo capacity • Developments in technology • Awareness working with drones increasing 	<ul style="list-style-type: none"> • High purchase cost • Difficult to fly • Need space to take off/landing

3.5.2 Rotor-model drones

Rotor-model drones are the best-known type of drones, as they are relatively cheap and easily available. These are known as the 'enthusiast model'. The most common types of

rotor-model drones have four propellers, some models have as many as eight rotors, whereas others have just one. The latter are also called copters (Fabbroni *et al.* 2016: 17; Andrew Chapman 2020).

Unlike fixed-wing drones, the rotor-model drones are used mostly for short flight trips. They also have a small capacity for cargo. The short airtime and small load capacity mean that in the professional field this type of drone is often an inefficient choice. They cannot be used for similar tasks as fixed-wing models, which have the ability for more advanced tasks (Ibid.).

However, the advantage for rotor drones is that they don't need a large area for landing and they can be used in a constricted environments.

Table 2 Rotor drone features (Fabbroni *et al.* 2016; Andrew Chapman 2020)

Strengths	Weaknesses
<ul style="list-style-type: none"> • Easy to fly • Take off/Landing no space requires • Cheap • Developments in technology • Awareness working with drones increasing 	<ul style="list-style-type: none"> • Range • Cargo capacity

3.5.3 Hybrid-model drones

The combination of fixed-wing and rotor-model drones is referred to as a hybrid-model drone. They are relatively new to the market. The hybrid term means that the drone combines both fixed-wing and rotor design (Fabbroni *et al.* 2016: 17; Andrew Chapman 2020).

The hybrid-model drones have the benefits of both models, as they have the ability for vertical take-off, and also the ability to fly long distances horizontally. Their cargo-carrying capacity also exceeds that of rotor-model drones (Ibid.).

Table 3 Hybrid drone features (Fabbroni et al. 2016; Andrew Chapman 2020)

Strengths	Weaknesses
<ul style="list-style-type: none"> • Easy to fly • Take off/Landing no space requires • Cheap • Developments in technology • Awareness working with drones increasing 	<ul style="list-style-type: none"> • Range • Cargo capacity

3.6 Last mile challenges in various humanitarian crises

Humanitarian assistance operations commonly take place in areas of damaged infrastructure, destroyed roads, floods and armed conflicts. The challenging circumstances restrict aid workers from working safely. In addition to difficult circumstances, the most affected areas are usually also the poorest, and located in remote places, far away from (functioning) airports and roads. Situations in disaster areas can also change rapidly due to issues such as weather phenomena (Merminod, Nollet and Pache 2013: 4-22).

One of the common challenges in HL operations is damaged infrastructure which means that distribution has to be completed without routes for vehicles. This amplifies the value of air deliveries. Currently most drones available can deliver products with a maximum load of between 0.5 kg and 2.5 kg” (Rabta, Wankmüller and Reiner 2018: 107-112). This sets limitations for the cargo drones can deliver, as it cuts off many heavier relief items such as tents, clothes, food, water, etc.

More detailed challenges are identified by the expert informants in the field and discussed further in chapter 4.

3.7 Use of drones in different types of humanitarian crises

Unmanned aerial vehicles (UAVs) and drones as a tool for last mile delivery in HL has gained increased attention for their capacity to reach remote and destroyed areas (Rabta, Wankmüller and Reiner 2018: 107-112). In this section I elaborate on some specific contexts where drones can provide benefits in the quest for humanitarian relief.

3.7.1 Flood, earthquake and tsunami

Drones can be considered in situations where destruction has been caused by a flood/tsunami or an earthquake. Their main benefit is in mapping, which helps in assessing the extent of the destruction. The process is relatively cost- and time-efficient, particularly when there is equipment already available in the vicinity. Drones can also be used to deliver small loads of needed equipment or medicine in flood- or earthquake-affected areas (Restas 2018).

3.7.2 Pandemic

Drones' applications in pandemic crises mainly focus on delivering medicine, vaccines, laboratory samples and small medical equipment. The delivery is most suitable application due to relatively light medical cargo. Mapping does not provide much benefit in a crisis like pandemic, however it can be used to estimate the number of people in certain areas (Tatsidou *et al.* 2019).

3.7.3 Forest fire

Drones are not widely used in forest fires, as they can be easily affected by the hot air masses. In this context, more traditional aircraft are better apt to conduct mapping. They

can also be used for extinguishing work due to their load bearing ability. However, there have been some small scale experiments using drones in forest fires mapping (Sudhakar *et al.* 2020), but the data available is limited on subject.

3.7.4 Armed conflict

According to the literature, drones are commonly used in situations where there is a threat of conflict, as this can reduce the threat on human lives. Unmanned deliveries can be conducted also in highly volatile environments. Their applications relate mainly to delivering necessary equipment (Del and Rico 2018).

3.8 Regulations on the use of drones

Drones are a relatively new occurrence in airspace, commonly inhabited only by more traditional aircraft. As such, laws and regulations have not been developed to account for this change. Rules, regulations and practices can therefore differ greatly in different parts of the world and are sometimes not congruent even in different parts of the same country. Both the commercial drones those delivering humanitarian aid need to be accounted for. As in many new developments, only time and mistakes can provide lessons to create workable practices as well as new regulations (Fabbroni *et al.*, 2016: 44).

The development of drones has been much faster than innovations in traditional aviation. Therefore, the regulations and laws have followed conventional aviation leaving plenty of uncertainty in relation to the use of drones. The strictest limitations targeting drones relate to their flying. For instance, airports and important governmental or safety related buildings prohibit flying drones in the immediate vicinity of their airspace (Ibid.).

Some countries have banned the use of drones entirely, others have rules that only certain trained pilots can fly them. However, there are also those countries that do not have any rules at all regarding drones. Incomplete legislation regarding the use of drones provides humanitarian organizations a good chance to show the positive impact of

drones in crises. This has the potential to influence the passage of drone positive regulations (Greenwood and Joseph 2020).

Regulations influence the ethical considerations related to drones as well. For example, areas affected by military crises have safety issues associated with drones. Especially middle east has been suffering by military attacks conducted with drones. This can cause notable concern among civilians, and the last thing humanitarian organizations want to contribute more suffering (Marin, 2016).

Unified operation model in humanitarian aid operations can increase awareness in relation to the use of drones and hopefully eliminate some distrust people might have towards them. This is also one of the aims of legislation related to drones (Greenwood and Joseph 2020).

3.9 Ethical aspect of drone use

Drones' public image is somewhat controversial. Nowadays drones are used more widely in delivery and in civilian activities, as before they were more connected to wars and conflicts, or even used as weapons (Marin, 2016). People on the ground have limited to non-existent possibilities to identify from the ground which drone is used to deliver goods or which has a military purpose. Even more challenges are created when the same drone type (fixed-wing, rotor or hybrid) is used in the same area by multiple operators. In such a case, it can be confusing for even the experts to be able to differentiate between them (Fabbroni *et al.*, 2016: 42).

Another issue relates to the information they collect. Depending on the model, drones can be equipped with accurate cameras that can take images of any objects that may pose security threats. Non-neutral actors can also be assumed to have access to the technology utilized by humanitarian organizations discussed in this paper (Ibid.).

Drones are a new technology, and not always familiar to the public. This may lead to situations where a drone's pilot's intentions may come into question. As a result of the suspicions of the new technology and bad communication between aid organizations

and volunteer helpers, an incident happened in Nepal in 2015 during a relief mission related to a recent earthquake (Cawthorne 2020).

Many aid organizations and volunteers came to help in the aftermath of the disaster, and drones were used by organizations and private actors for mapping the area. However, the different drone operators did not have adequate communication between each other, in addition to which sufficient coordination in terms of the use of drones was missing. This led to a situation where the government had to ban all unauthorized drone use, as some of the drone users' intentions seemed to have uncertain purposes. Reputation from this case caused some harm in future operations (Cawthorne 2020).

4 Research results

The empirical data for this research project is collected through a questionnaire which was sent both to professionals in the field of humanitarian logistics and to experts who are involved with drone operations in general. In this chapter we discuss the insights derived from the experts. The questionnaire was distributed to gain supporting information from the field. As has been mentioned, the use of drones in the context of the last mile in humanitarian logistics is constantly evolving and as such fresh insights from practitioners provides fresh and important insights.

The questionnaire was originally sent to 17 experts in Europe. They were based on their scholarly knowledge of the HL (academia) or due to their experience from the field of HL or drone operations (organizations). In the end we derived responses only from two of the selected experts in time for this analysis, despite reaching out to the remaining questionnaire recipients on several occasions both over email and via telephone to prompt further responses. We did receive a third response, as someone from our selected group had delegated the responsibility of responding to someone further in the organization but said expert did not have any experience with humanitarian logistics nor drones, so their answers were omitted from the analysis.

Despite the low response rate, the two respondents' background in terms of relevant work experience and the significance of the organization they represent allows us to use their responses to supplement our analysis. The respondents represent different categories of respondents, yet their responses indicate a solid understanding of the research topic, which can be seen in the considerable similarities between their responses. However, as will be noted in our discussion of research limitations, it cannot be overruled that a more nuanced picture might emerge if more respondents from differing backgrounds would have provided their answers.

4.1 Analysing the data gained from expert questionnaire

In this section we first present the respondent's background. We then move on to discuss their experience of different types of drones as well as the types of cargo the respondents estimated most suitable for drone deliveries in different contexts. Next, we discuss the

respondents' views on the most notable challenges/drawbacks related to the use of drones. We then move on to discuss the needed resources for drone deployment and maintenance, as well as issues related to the cost of drone usage in relation to other last-mile delivery methods.

One of the more interesting findings are the respondents' views on the contexts in which drone use offers particular benefits. While there were notable similarities in the experts' views, there were some interesting differences as well, which would benefit from further discussion. Another interesting theme relates to the collaboration that the respondents engage in with other actors in their respective positions.

The questionnaire is constructed in such a way that the topics covered form a cohesive whole, each question illuminating a new aspect of our research area. We end the analysis section with respondents' contemplations on possible future directions with regards to the use of drones.

One of the respondents represents an organization that provides drone-distribution services to the medical field – an area that needs to be covered also in humanitarian crises. They thus have good knowledge of distribution of time-sensitive cargo but have not worked directly in the last-mile context. We refer to this respondent as Expert 1 throughout our analysis and discussion.

The other respondent represents one of the largest international humanitarian aid organizations and has a relevant range of experience and expertise in the last-mile context. However, also the second respondent has not identified the use of drones in the last-mile setting. The second respondent's experience in the humanitarian last-mile context extends over ten years, and as such provides an appropriate background for commenting on the potential as well as possible drawbacks of drone use. They will be referred to as Expert 2 in the analysis and discussion.

4.1.1 Selection of different drone models

This particular question, combined with the knowledge gained from literature, gives us important information on which drone models are suitable for what types of operations.

The most common drone models (fixed wing, rotor and hybrid) and applications (mapping and delivery) used in HL are already discussed in the chapter 3.3.5, specifying the advantages and drawbacks for each drone model used in the context.

Expert 1 has experience in the distribution of medical goods. The drone models they have deployed are fixed wing and hybrid model drones. Features in fixed wing model (maximum range and cargo capacity) are also most beneficial for the field of HL according to our literature review.

Hybrid and rotor model drones have their specific advantages, such as deliveries to extremely difficult terrains such as mountainous regions. Expert 1 does not have experience of utilizing rotor model drones. This may be indicative of the generally bigger need for greater range due to the time-sensitive nature of medical/perishable goods. Drones can be used individually or be combined into a fleet of several drones.

Respondent from organization field has not specified any of drone models they have used, which leaves a lot of valuable information unanalysed, also related to future questions.

For the most part, cargo deliveries are made with fixed wing model, because of their significant advantages in the transportation compared to rotor/hybrid ones. Except in demanding landing conditions whereas hybrid model drones are best suited to the required situations. Purchase price could be also one determining factor when choosing the model.

4.1.2 The most suitable cargo

It is useful to understand the types of cargo that is currently being delivered using drones. It helps us identify items that can potentially be delivered in the last mile of HL. It also provides some understanding of the future developments in the use of drones. At the moment drones' capacity for cargo is limited to relatively small weight items up to 10kg as discussed further in chapter 3.3.8.

Expert 1 specified human organs, blood, vaccines and other small medical items to be the most suitable cargo for drones. This information confirms the data received from the previous question on. In previous question Expert 2 did not specify on the types of drones their organization had utilized, but they classified the most sensible cargo to be “small loads”. This leaves the answer to this question a bit hollow and therefore adds little additional value in analysing the best drone models in specified crises because all cargo delivered with drones could be named as small loads.

According to our empirical data, medical goods are the most important group of items drones currently can deliver, and they have also versatile applications in various context of crises. Vaccines and medicine deliveries needs special circumstances during the transportation, vaccines needing temperatures ranging between 2-8 degrees Celsius, which makes them together with laboratory samples the most challenging to be distributed with drones. However, medical goods have the biggest potential to serve the people who most need humanitarian aid (Dirks 2017). Naturally, it is important to note that our empirical findings are biased towards medical goods due to the specific role of Expert 1 in this field, and without input from other practitioners experienced in other types of cargo, we can only treat this particular type of cargo as exemplary.

4.1.3 The most notable challenges related to the use of drones

In this section we explore the expert views from the perspective of challenges related to drone-assisted deliveries.

Both experts had similar responses to this question. Expert 1 named challenges related to medical cargo itself to be one of the most notable challenges due its vulnerability and high cost. According to our literature review, the challenges related to cargo are mostly related to the weight and sensitivity of the transported items. Expert 1 mentioned that also weather conditions may pose challenges, especially fog, as when visibility is poor, it is hard to find suitable landing zones. It is worth noting, that weather does not pose a challenge to drones alone but is a noteworthy risk for any aircraft.

Expert 2 importantly identifies the purchase cost of drones to be one the biggest challenges at this moment. They also mentioned that the field of drones is under constant

change and development. This may indicate a price correction in the future as the technology becomes more available. However, Expert 2 only brings up the cost of purchase and there is no discussion and evaluation of the total cost of using drones which includes maintenance, warehousing and training of the operators.

4.1.4 Needed resources for drone deployment and maintenance

Drones have certain requirements that need to be fulfilled before they can be deployed. Here we present the respondents' understanding of the needed resources.

The experts responded to the question related to the needed sources in a way that reflects their respective positions in the field. Expert 1 identified special conditions such as right temperature, sterile circumstances, prompt deliveries and trained staff both in take-off and landing phase to receive special cargo as some of the key requirements. Also, an interesting requirement that was highlighted in the response, is that medical equipment often needs special certificate in order to be delivered.

Along with trained staff members, the facilities/warehouses have to be available also when operating drones. On an organizational level these are usually local depots (see Figure 1, the flow of humanitarian logistics, page 7).

Expert 2 emphasized the activities related to drones themselves as a needed resource. They specified the need for pilots, maintenance, infrastructure and coordination platform for ongoing missions. In practise this means previously mentioned facilities/local depots with proper take off zones. Costs of drone usage, cost effectiveness in relation to other last-mile delivery methods

Considering alternatives for suitable transportation, price is one of the key factors. This section will do some comparison between traditional distribution including manned aircraft and ground vehicles compared to drones.

Expert 1 considers drones more cost-effective than helicopters in last-mile delivery. However, they also stated that particularly in the last-mile phase, traditional ground vehicles still have the advantage in relation to cost-effectiveness compared to drones.

They also emphasized that drones are a relatively new technology, and that it takes time to develop working platforms and operating models for drones to operate smoothly.

Expert 2 has a similar view that drones are the most cost-effective air delivery method in the last-mile context. They see potential opportunities especially in training multiple drone pilots at the same time which would not be the case in traditional aircraft training.

Our respondents share a perspective that drones have advantages in the air delivery compared to manned aircrafts, even though the state-of-the-art drones have a relatively high purchase price (see appendix 2 about drone models and prices). Drone use in different contexts

The respondents were asked to weigh the suitability of the use of drones in various contexts using a scale from 1 to 9, 9 being most useful and 1 least useful. Both experts have several years' experience in the relevant field and can consequently provide us with valuable information about drones' applications in different crises situations. These responses help us identify situations where drones have most benefit. The responses are shown in Table 1.

Table 4 Expert responses on drone usage in different contexts

Context	Earthquake	Flood	Tsunami	Large Scale Accident	War/ Conflict	Forest Fire	Pandemic	Famine
Expert 1	8	8	8	8	2	7	9	9
Expert 2	9	9	9	9	3	2	3	5

As we see, both experts' answers are quite consistent in the context of earthquake, flood, tsunami, large-scale accidents and wars/conflicts. Forest fires, pandemic and famine are dividing their opinions. We will discuss these responses in relation to the existing literature further in chapter 5.

4.1.5 Collaboration with different actors

Expert 1 has had some collaboration with drone manufactures on R&D related to drone transportation. Collaboration has encompassed development of drones' features. In particular, Expert 1 would like to witness more range and capacity for drones in the future. However, it was not specified which type of drone they have discussed. They have extended R&D also for war arial procedures which was also mentioned briefly without further elaboration. The drone operator has also collaborated with public administration in cases of forest fire and when trying to locate a missing person.

Expert 2 described their collaboration as "very close" with other humanitarian aid organizations as well as with private sector actors.

4.1.6 Future direction

Relating to the previous question both respondents expressed their desire to connect more with parties who have a shared interest in the field. Sharing their knowledge with each other was considered to hold benefits for all parties involved with drones.

Both experts expressed that the research done on drone technology is valuable as it can lead to reduced purchase prices in relation to of drones. As noted earlier, price was seen as one of the greatest challenges related to the use of drones.

5 Analysis of the research questions

In this chapter we discuss the interplay between literature and our empirical findings. As mentioned, the aim of this work is to find out in which situations the use of drones provides the most benefit in humanitarian logistics. The analysis is largely based on the literature review, complemented with the findings from expert perspectives.

5.1 In what type of crises is the use of drones most useful?

Drones represent a form of new technology that is under constant development. They provide comprehensive functions for responding to various types of humanitarian crises around the world. According to the literature, as further elaborated in chapter 3.1, humanitarian crises can be divided into natural or man-made, as well as based on their urgency criteria, to sudden-onset or slow-onset.

Drones can be used in a number of contexts, but both literature and experts highlight the potential of drones in sudden crises requiring urgent response. Compared to more traditional means, the advantages related to drones are quick response time and the ability to operate in areas where the infrastructure has been destroyed, as highlighted in sections 3.4.2 and 3.4.5.

The literature is consistent with the experts' responses, and they both consider drones most beneficial in earthquakes, floods, tsunamis, and large-scale accidents as shown on table 4 (below). Advantages are identified both in terms of drones' mapping and delivery capabilities. Mapping is needed particularly in large scale crises like floods, earthquakes, tsunamis, etc. to assess the destruction and to evaluate the scale of needed help. The assessment of destruction is not the only function drones can carry out. In these kind of crises situations, the infrastructure is commonly damaged, and the aid needs to be delivered by air. Both experts agree that drones are useful in the above type of situations, reflected by the high value they filled out in questionnaire for each respective scenario (see table 4). As both the reviewed literature and the empirical data are in agreement over this question, it can be concluded that drones are best suited for these crises situations.

The main differences between the literature and the experts' opinions relate to the use of drones in war/armed conflict. The literature considers drones' to be a valuable humanitarian tool in armed conflicts, that can be used in situations where it would be too dangerous to consider human delivery or surveillance methods, as discussed in section 3.7.3.

However, literature also mentions that there are risks related to the use of drones in areas where there is or has been military activity. This is caused by the risk of humanitarian drones being confused with military drones which also conduct surveillance missions. In conflict zones, people already live in extreme stress and fear, caused by the destruction and uncertainty. Therefore, causing further strain to civilians should be avoided where possible. In these instances, literature emphasises the delivery value of drones more than surveillances features.

Both of the respondents state that war/conflict are situations where drones do not provide notable benefits (see table 2). They have not identified the reasons why they do not suggest drones in conflict situations. The topic is contradictory, and the literature is mostly on the view that drones are more useful than harmful in humanitarian conflict situations, even though it recognizes the risks related to the ethical aspects.

The differences between literature and respondents' may be explained by their own experiences in conflict situations or they may have received third-hand information about the unsuitability of drones in conflict situations. Individual negative experiences of users may also skew a wider range of people using drones, as information and collaboration are nowadays spreading rapidly and widely.

The current situation, where there is really no clear legislation on the use of drones, is also likely to bring to the scene actors, who are not sufficiently qualified to use drones in conflict zones and who are likely to increase negative perceptions towards them.

Having said that, it can be concluded that due to the contradictory information between literature and empirical data using drones in conflict situations, the usefulness, or perhaps more accurately, the potential harmfulness related to drones requires further investigation.

Respondents have somewhat contradicting views on the questions related to drones' suitability in the following situations: forest fire, pandemic and famine. Here, also the literature deviates to some degree, and as such, there is no academic consensus as of yet.

First, we analyse the differences between experts' opinions and then add relevant thoughts from the literature to add more weight to the discussion. The literature's general direction is more in line with the views of Expert 1 on forest fire and pandemic, however, when it comes to famine the views of the literature deviate from those expressed by Expert 1.

Expert 1 is a medical supplier and they have had years of experience distributing medical goods. As a result, they tend to lean more firmly towards a positive view on utilising drones in a pandemic. It follows then rather naturally, that their practical experience in this particular scenario adds credibility to their responses.

Literature supports Expert 1's views in terms of drones being a suitable response in a pandemic, as drones' strengths include light cargo delivery, which for instance medicine and laboratory samples represent. However, Expert 2's opinion on this issue is the stark opposite of Expert 1, but unfortunately their standpoint is not elaborated further.

These differing opinions can only be contemplated, and possible reasons can be perhaps unravelled by evidence found in the literature. Considering the relatively low carrying capacity of drones, it can be assumed that also within pandemics, the only sensible way to carry out the distribution of needed items is handled out by a larger scale humanitarian relief operation.

The other main function attributed to drones, namely mapping, does not generally need to be conducted in a pandemic situation, as a pandemic does not generally have any impact on existing infrastructure. As such, the delivery function would be the only type of drone application suitable in that type of crises.

We can conclude that due to the views of Expert 1, supported by current literature, drones can offer an added benefit in a pandemic, but the scale of the benefit may be limited.

In terms of forest fires and famine, the views of Expert 2 are in line with the literature. They stress in their response, that the currently available drone models do not respond well to the actual need within the demanding conditions caused by forest fires and famine. The experience of Expert 2 lies on small goods deliveries, which, according to the respondent, do not meet the needs placed on deliveries within forest fire or famine. Both of those types of crises require considerably more capacity from the cargo deliveries.

Expert 2 also does not place much emphasis on mapping in a forest-fire situation either, based on their response to the questionnaire. However, literature cites some positive examples of mapping activities in a forest fire situation. Still, it needs to be noted that, there are no indicators that suggest drones can be used in any way to combat fires. The burning hot air masses generated from large fires as well as smoke, which has visual effects on navigation prevent effective utilization of drones.

Conditions can vary greatly, which determines whether drones are useful for mapping or not. Partially for the same reasons, the traditional manned aircraft are also at risk in forest fire situations. As Expert 1 still responded positively towards the possibility of using drones in forest fires, and literature also suggested some successes in this type of situation, the potential of drones in this type of a crisis cannot be fully discarded without more thorough research of the subject.

According to the literature, when it comes to famine, mapping does not work very well from the aerial perspective. The literature suggests that drones can only be used to estimate the number of people in large masses. There is little information on such operations, other than a short mention in the literature. As in the case of forest fires, deliveries are not very useful in famine, as food and water weigh a lot. Consequently, drone-assisted delivery would not be cost-effective compared to more traditional methods of transportation with manned aircraft or ground vehicle.

Despite this, Expert 1 considered drones to be a great help in famine. However, due to lack of further elaboration, we do not know if they meant delivery or mapping when providing their answers. Without this additional information, this opinion cannot be given much support as the other experienced respondent, as well as the literature do not see drones in famine as the most effective solution.

Table 5 Experts' questionnaire responses on drone usage in different contexts

Context	Earthquake	Flood	Tsunami	Large Scale Accident	War/ Conflict	Forest Fire	Pandemic	Famine
Expert 1	8	8	8	8	2	7	9	9
Expert 2	9	9	9	9	3	2	3	5

Table 5 summarises the findings from section 5.1 based on the analysis on literature and expert viewpoints.

Table 6 Summary of drones' usefulness in different contexts

Context	Earthquake	Flood	Tsunami	Large Scale Accident	War/ Conflict	Forest Fire	Pandemic	Famine
Experts	Fully proved	Fully proved	Fully proved	Fully proved	Not proved	Semi proved, needs more research	Semi proved, needs more research	Semi proved, needs more research
Literature	Fully proved	Fully proved	Fully proved	Fully proved	Semi proved, needs more research	Semi proved, needs more research	Fully proved	Semi proved, needs more research

5.2 What types of benefits do the different drone types offer?

In this section the most suitable applications for each drone type used in humanitarian context are identified and elaborated further. HL typically uses drones from three categories (fixed wing, rotor or hybrid) depending on the contexts, (see more on section

3.4.3). The particular situation determines which type of drone model is best able to offer the needed solution.

The diagram shows us the current activities where National Society has used drones (Greenwood and Joseph 2020), the data is collected from appendix 2 which shows the list of countries and activities drones are involved in within National Society's operations. A total of 30 countries uses drones in the National Society.

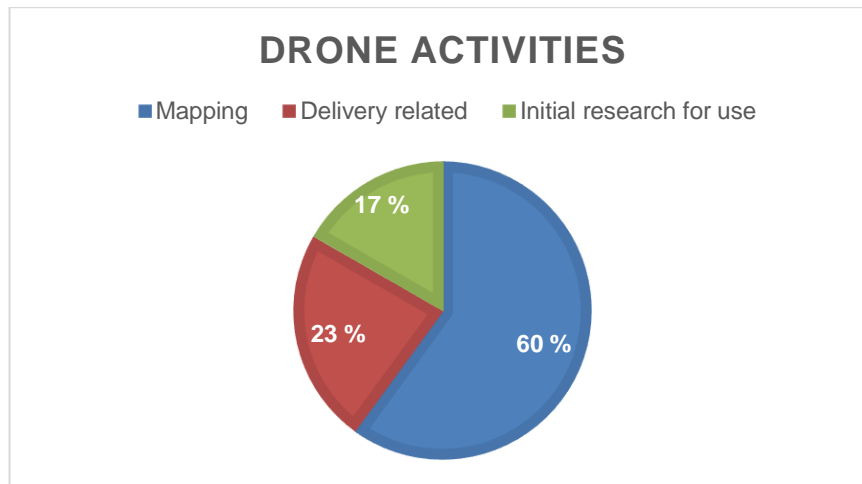


Figure 3 Drone activities in National Society (Greenwood and Joseph 2020)

As we can see in the diagram mapping is currently the most widely used application of drones, covering 60% of the activities. This can be explained by the large number of functions mapping contributes to in different crises situations.

As discussed in the analysis of the previous research question (section 5.1), mapping is very useful in disasters related to earthquake, flood, tsunami, large scale accidents and it has also been proven useful in war/conflict situations, despite the risks involved. Because mapping is such a popular application, it can be deduced, that in the humanitarian field the focus of R&D and procurement of drones should lie on the models that have strong mapping features.

According to the experts as well as the literature, most used drone type in mapping is the fixed-wing model. This is mainly because of their long-range abilities. Therefore, these models are able to map large areas. They are particularly useful in assessing

damages in the above-listed crises situations, as well as making pre-disaster risk assessments. For example, in case of a flood or an earthquake, the areas that have experienced destruction are often vast, and therefore also the range of the drones must be adequate.

Hybrid- and rotor-model drones are mentioned in literature as a solution for challenging terrain, where there is no proper landing zone and therefore the fixed wing model cannot operate in the given circumstances. Another limitation related to fixed-wing models is the high purchase as mentioned by Expert 1. However, both experts and the literature envision that in the future, prices are likely to come down as technology advances in this area.

Other concerns related to drone deliveries relate to challenges caused by weather conditions, such as fog and rain. For example, monsoon rain puts a tremendous force on a relatively small flying object. As such, careful planning plays an important role in HL. Planning of drone operations can prevent flying in murky situations, which would increase the risk of accidents. Flying routes also need to be pre-planned, which prevents entering situations where there are no suitable landing zones.

There is not one correct solution for a drone model that fits in all situations. Each crisis and operation has their own circumstances and the best tools have to be chosen for on a case-by-case basis.

As we view drone's delivery capabilities, we can see from the diagram (Figure 3: 37), that transportation of goods is the second largest application of drones. However, this function is currently still less than half of the use than that related to mapping. The delivery process largely requires the same capabilities from the drones than mapping. Expert 1 has had experience of both hybrid- and fixed-wing models in the delivery of medical goods. This suggests that it can be beneficial for the operator to be prepared to use different drone models for different situations, as also mentioned in the previous section.

While fixed-wing drones have better capacity for cargo than rotor-models, they still cannot be compared to manned aircraft, which can have loads measured in tons. As

Expert 1 states, they can only have small loads in deliveries. However, the literature brought forth an interesting possibility of using drones as a fleet instead of using just one or two drones at a time. Using drones as a fleet could be at least a partial answer to cargo capacity issues, as cargo could be split between several drones (Rabta, Wankmüller and Reiner 2018: 107-112). This would naturally increase the costs related to each delivery due to the high purchase and operation cost involved. Furthermore, the coordination of a fleet of drones will create challenges not present in case of a single drone. However, this is an issue that would benefit from further inquiry. We came to the conclusion that it is not possible to unequivocally choose a particular drone type that would be suitable for all situations, and that different models each have their own advantages.

The last 17 percent of the chart in Figure 3 describes the research and development work in the National Society regarding drones and their uses. In this section they have not yet gone to the practical level of using drones. It can be considered very useful for the drone industry that there are ongoing R&D activities, and that awareness on their use and possibilities are increasing. The challenge mentioned by the experts related to the high cost of drones can also become less of an issue when the technology is developed further, and becomes available for broader public.

5.3 What type of developments would promote the use of drones going forward?

The lack of unified regulations was strongly brought forth in the literature. This poses limitations on the drones to compete with more traditional modes of aid transportation. Currently, the limitations on the field prevent humanitarian relief actors from gaining first-hand experience of drone-assisted operations, which is typical at the beginning of the arrival of new methods and technology (Greenwood and Joseph 2020). It is a widely recognized challenge, that requires only time to be solved. Once the legislation is unified it could be that drones will also become more common in HL.

The respondents both emphasized their desire to share their knowledge of the field for the sector to develop further. Currently, drone users share no or very little information with each other, according to the experts. They suggest an international drone organization to be founded in humanitarian logistics where information could reach

broader audience of (humanitarian) professionals. According to the literature such an organization already exists (Meier 2016). The purpose of the organization is to promote common regulations in the field, develop drone technology in humanitarian logistics by sharing information and conducting its own research work. They also have a training program for drone pilots. More than 600 drone pilots from more than 70 countries work with them, according to their own web pages, so the organization seems to have gained a foothold in the industry (Ibid.). The question remains why the activities of the organization have not reached the knowledge of our respondents.

6 Research Limitations

This research has been conducted as a final thesis at the study programme on International Business Logistics at Metropolia University of Applied Sciences. As such, the scope of the project is more limited than at a more advanced level of studies or academic setting, and the aim is to look at the issues at a more practical level.

While this research includes empirical data from a highly relevant group of informants, the number of respondents is limited and may not encompass all nuances witnessed on the field. The total number of respondents were only two, as a conclusion, the results and conclusions based on them are not very reliable even though the respondents were professionals in their field. In order to counter some of this challenge, three distinct groups have been identified and included in this research. Furthermore, as much literature as possible has been reviewed to provide for an adequate level of triangulation. This helps ensure that the presented data and conclusions represent reality to a sufficient degree.

7 Conclusion

The literature confirms that the research question is topical; humanitarian crises are becoming more common due to issues such as global warming and COVID-19 (Paul Anthem 2020). Humanitarian logistics is the key to solving crises. HL has similar structured supply chains as to those found in traditional business logistics. However, in the last mile phase of these two branches there are various key differences. These differences need to be taken into consideration when evaluating the supply chains within HL — the unpredictability being one of the most distinct differences between these two fields.

HL, like traditional logistics, is constantly looking for ways to increase its efficiency in responding to the forever changing uncertainties of the field. In HL, there is particular focus on improving time efficiency. Time is the determining factor in whether humanitarian aid relief succeeds or not, and the overarching aim lies in relieving suffering within crisis-affected sites.

Research shows that the most time- and money-consuming phase of HL is the last mile context (Allen 2011). It is the last stage from the local depots directly to those in need of aid. Challenges in the last mile distribution to remote disasters locations can be responded to also with the relatively new technology of drone-assisted deliveries. In developing countries, the infrastructure is usually already incomplete and in poor condition, and only made worse by any crisis situation. Drones can offer solutions in case of inaccessibility to remote areas which can not be reached by traditional means of land-based transportation.

Despite the good accessibility to cut-off regions, drone technology has limitations related to limited load capacity and operating range due to their energy constraints. Because of these limitations, it is especially important to choose the right drone model for each situation based on the requirements and conditions.

In HL applications, the greatest potential is currently related to mapping, due to the restrictions drones face in the delivery function. The information gathered from National

Society's drone activities (Greenwood and Joseph 2020); 60 percent of their activities are related to mapping.

As a result, fixed-wing drones are most beneficial in crises such as earthquake, flood, tsunami, and large-scale accident due to the model's ability to conduct mapping over a vast area. Drone-assisted mapping has some key advantages compared to traditional manned aircraft or satellite mapping, which both have lost some market share for drone operations; drones can offer more cost-effective solutions with a quick response time, which is highly valued in HL.

Deliveries cover 23 percent of National Society's activities (Greenwood and Joseph 2020). In this smaller application, distribution is currently largely based on the distribution of medical supplies. However, drone technology is constantly being developed. Challenging circumstances such as mountainous areas require drones that do not need a big landing zone for take-offs and landings, these hybrid- or rotor-type drones are mainly used for delivery purposes.

It is possible to recommend solutions for individual situations and certain circumstances. However, it is not possible to give blanket suggestions as to which type of drone-based solution might be overall best. Especially for aid organizations, the aims and circumstances influence the instruments chosen.

In this study we looked at drones within simplified models and that is why it is not possible to draw too many broad conclusions. For example, in the literature as well as in the experts' questionnaire, we emphasized the use of individual drones, and the study did not take into further consideration fleets of drones as a practical application beyond mentioning them as a possibility. The big stumbling block at the moment is the lack of legislation in the field of drones that would bring clarity and courage to drone operators to buy and invest in their business'.

Drones have proven field experience and are useful in many situations where traditional instruments would be too dangerous to perform an operation or where they might be economically unprofitable. For these reasons, it is recommended that drones should be studied more, and their applications be extended to more diverse tasks. More research

is needed on their safety, and awareness of their applications and potential needs to be raised, especially in areas where the ethics are being tested.

Important perspectives on the importance of co-operation in the relatively new area of the use of drones as a solution within HL was also raised by literature and experts. Ready-made collaborative platforms can be found in the industry, but it turned out that they are not always easy enough for those involved in humanitarian or drone operations to find.

7.1 Recommendations for future research

In this paper we have noted the usefulness of drones in the last mile context within humanitarian logistics. However, there are still limitations, as is the case with any new technology. The ongoing R&D activities carried out by a number of stakeholders will hopefully help solve some of the challenges going forward.

Table 5 on page 36 summarizes the contexts where the use of drones makes the most sense, and also identifies areas where future research is needed to form a more solid understanding.

In particular, the use of drones in a pandemic situation is something that needs further research, as there is no consensus on this topic. Both literature and one of the contributing experts to this research see value in using drones during pandemics. Yet, the other expert saw little value of their use. Based on my research I see great potential in drone deliveries during pandemics, as finding cost-effective solutions for the last mile deliveries is an ongoing quest and drones can offer features other means can not.

One of the essential items during a pandemic, medical supplies, are generally light weight, and their ongoing distribution is needed also after the most urgent phase of the crisis has passed. Drones are an interesting option in this type of a situation, as their use also limits further contagion/contamination, commonly associated with human interaction. Here, using drone fleets would likely further increase the efficacy of the operations, as the use of fleets can theoretically overcome at least some of the limitations

related to drones' overall load capacity. Further research on drones in a pandemic situation could provide important insights in terms of future response options.

In terms of crises such as famine or forest fires, more research is needed to establish efficacy. In particular, using fleets of drones also in these situations can open up interesting possibilities, at least if some of the other obstacles can be eliminated. Exploring the potential for drones in these contexts would likely further benefit the field.

The last important research area that requires immediate attention relates to the laws and regulations that govern the use of drones on a broader scale. This research could offer important insights and help develop a more unified regulatory approach to the use of this technology. This would also benefit the technological development of drones, as it would result in a more thorough understanding of the opportunities and challenges related to their use.

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Drone models used in humanitarian logistics



*Estimated commercial retail price

Figure 4 Drone models used in Humanitarian Logistics (Fabbroni *et al.* 2016)

Countries where the National Society has undertaken activities with drones

Table 7 Countries where the National Society has undertaken activities with drones
(Greenwood and Joseph 2020)

American Red Cross	Initial research into drone use, post-disaster situational awareness, mapping.
Australian Red Cross	Initial policy research into drone use.
Austrian Red Cross	Initial policy research into drone use.
Belize Red Cross Society	Community mapping efforts, disaster resilience work.
Brazilian Red Cross	Post-disaster mapping, public relations photographs.
The Canadian Red Cross Society	Video and photographs for public relations and communications, situational awareness, post-disaster mapping.
Colombian Red Cross Society	Post-disaster mapping, search and rescue.

Ecuadorian Red Cross	Post-disaster mapping, community mapping.
Fiji Red Cross Society	Damage-assessment mapping, post-disaster photography and video.
German Red Cross	Search and rescue, situational awareness.
Indonesian Red Cross Society	Disaster resilience mapping, IDP camp planning, vulnerability and capacity assessment support.
International Committee of the Red Cross	Mapping, infrastructure planning.
Italian Red Cross	Search and rescue.
Kenya Red Cross Society	Mapping, agricultural monitoring, risk mapping, disaster response.
Korean Red Cross	Health.

Lesotho Red Cross Society	Mapping, pre-disaster mapping.
Malawi Red Cross Society	Pre-disaster mapping.
Mexican Red Cross	Damage assessment and search and rescue, with particular emphasis on supporting staff safety and facilitating better decision-making.
The Netherlands Red Cross	Post-disaster mapping and damage assessment, flood risk assessment for disaster resilience.
New Zealand Red Cross	The NZRC hopes to use drones for sea-based search and rescue and disaster assessment.
Philippine Red Cross	Community mapping, disaster preparedness mapping.
Salvadorean Red Cross Society	Communications and PR, training.
Senegalese Red Cross Society	Training.

Spanish Red Cross	Search and rescue, situational awareness, mapping.
The Sri Lanka Red Cross Society	Flood mapping, pre-disaster mapping, disaster planning, climate change planning.
Tanzania Red Cross-National Society	Pre-disaster mapping, disaster planning, flood mapping.
The Uganda Red Cross Society	Post-disaster mapping and situational awareness, as well as limited use for monitoring population movement.

QUESTIONNAIRE, USE OF DRONES IN HUMANITARIAN LOGISTICS

The following questionnaire is used to gain information for my bachelor's thesis in Metropolia University of Applied Sciences. The aim of this research is to find answer to the following question: In which situations does the use of drones provide the greatest benefit in the context of humanitarian logistics.

1. What is your role in the field of Humanitarian Logistics (HL)?

2. How long have you worked with HL?

3. What is your experience in Last Mile context?

4. Have you been exposed to the use of drones in Last Mile context? What were the circumstances?

5. Have you utilized:
Fixed wing drones? YES/NO

a. If yes, specify type of cargo _____

Rotor model drones? YES/NO

b. If yes, specify type of cargo _____

Hybrid model drones? YES/NO

c. If yes, specify type of cargo _____

I have used drones, but not aware of the type? YES/NO

d. If yes, specify type of cargo _____ -

6. What do you consider the most sensible cargo for drone assisted deliveries?

7. In which situations is the use of drones most beneficial compared to other ways of aid delivery (ground vehicle, plane, helicopter, by foot, etc.). Please rate (1=most beneficial, 8=least beneficial)

Earthquake	Flood	Tsunami	Large Scale Accident	War/Conflict	Forest Fire	Pandemic	Famine

Please comment on your choice:

8. What are some of the most notable challenges/drawbacks when using drones in the context of HL?

9. How much collaboration is there with your organization and others in Last Mile context? Is this typical?

10. Have you collaborated in using drones specifically? YES/NO

If yes, please elaborate:
