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# Ambulance Drones in Norway

A Stakeholder Analysis


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I would like to thank my supervisor Bjørn Andersen, and my mother, who probably did more work on this than I did.

T.R.

# Summary and Conclusions

Cardiac arrests claim millions of lives each year. The condition can often be treated with a defibrillator, but time is a very critical factor. As a consequence, survival rates are low.

Recent developments in drone technology have made civilian drones cheap, easy to operate, and reliable. This paper looks into opportunities to use drones to deliver defibrillators to out-of-hospital cardiac arrest victims faster than an ambulance. The main focus is on unifying the needs of emergency response with the rules and regulations required to operate the drones safely.

The study is performed as a literature study combined with interviews. The primary stakeholders were identified as emergency response and the Civilian Aviation Authority.

The results showed that there was both a perceived use for ambulance drones and a way to legally use them. The suggested approach involves using ambulance drones at sporting events such as "Birkebeinerrennet" as a proof of concept, before more advanced or permanent programs are considered.

# Sammendrag

Hjertestans krever milioner av liv hvert år. Tilstanden kan ofte behandles med hjertestarter, men er også meget tidskritisk. Som en konsekvens er overlevelsesraten lav.

Nyvinninger innen droneteknologi har gjort sivile droner billige, enkle å bruke, og robuste. Denne rapporten ser på muligheter for å bruke droner til å levere hjertestartere til pasienter som får hjertestans utenfor sykehus raskere enn en ambulanse. Hovedfokuset er på å forene behovene for nødhjelp med lover og regler som kreves for å kunne fly dronene på en trygg måte.

Studien er en litteraturstudie kombinert med intervjuer. Hovedaktører er nødhjelpen og Luftfartstilsynet.

Resultatene viser at det er både et estimert behov for ambulansedroner, og måter de kan brukes på i henhold til loven. Den anbefalte tilnærmingen er å bruke ambulansedroner ved idrettsarrangementer som "Birkebeinerrennet" som pilotprosjekt, før eventuelt mer avanserte programmer blir vurdert.

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# Chapter 1

# Introduction

Sudden cardiac arrest is a condition that claims many lives each year, as much as 700,000 in Europe alone (1). A common rhythm for a heart to be in if a sudden cardiac arrest occurs outside a hospital is ventricular fibrillation (VF). This means that the electrical signals in the heart are stuck in a chaotic state and the heart is unable to contract as a consequence. In a hospital, doctors would attempt to “reset” the heart using a defibrillator, but these are not available everywhere. CPR alone is very rarely enough to restart a heart, and is done to keep the victim alive until a defibrillator and medication can be administered.

Time is probably the most important factor in survival. According to the American Heart Association(2), risk of death rises by 7-10% for each minute that passes between collapse and defibrillation. This is reduced to 3-4% per minute if CPR is applied until a defibrillator arrives. Both CPR and defibrillation are vital for survival (3).

Due to the need for defibrillators to be used quickly, automated systems have been placed in some heavily occupied areas, such as airports, shopping centers, train stations, and so forth. These are known as Automated External Defibrillators (AEDs) (4), and are designed to be simple enough to be used by untrained bystanders, using visual and audio commands to direct the user. As the name implies, these devices can automatically diagnose and restart hearts that have stopped due to ventricular fibrillation or ventricular tachycardia.

Another technology that has appeared in recent years is the civilian drone. Remote controlled aircraft such as planes and helicopters have existed for a long time, but in recent years, autonomous aircraft able to carry cameras and goods have become more commonplace, and

Figure 1.1: AED (picture from Wikipedia commons)


available to most people. Most importantly however, these drones are able to automatically navigate to a GPS coordinate, and move at considerable speed. They are also able to bring a few kilos of payload with them.

Smartphones have also seen a rise in popularity recently, to the point where most people have one(5). What is important to this paper is that they have internal GPS modules and applications exist that can automatically share your position will emergency services when you need help (although not yet in Norway).

These technologies create opportunities to save victims of cardiac arrest by using drones to carry AEDs to the victims. In theory, this could save lives by shortening the time from collapse to defibrillation. In practice, however, this concept faces several challenges. Firstly, while all the components of the technology exist, complete systems have not matured or even been created at all. This means that systems would need to be developed and cannot be bought complete-off-the-shelf at time of writing. Secondly, the laws and regulations in Norway put serious restrictions on what drones are allowed to do. This means a system would either have to follow these rules or wait for the rules to be changed. Lastly, there is little data on whether such as system would actually provide a benefit, how big the benefit would be, or how much it would cost to acquire and use.

## 1.1 Problem Formulation

The purpose of this paper is to perform a stakeholder analysis on the possibility of implementing such a system in Norway. The main stakeholders in such a system is the Norwegian Civil Aviation Authority (Luftfartstilsynet), and the medical personnel who would use the system and benefit from it. The stakeholder analysis will be performed as a series of interviews with the CAA and medical personnel, with the goal of creating a series of recommendations and requirements.

The main problem lies in finding a solution that compromises the potential need for drones in emergency services with the potential dangers for air traffic and bystanders.

## 1.2 Objectives

The main objectives of this Master's project are:

1. Find out if ambulance drones could provide a benefit
2. Find out about the risks that could be involved with ambulance drones
3. Create a list of requirements or suggestions for ambulance drones

## 1.3 Limitations

This is a stakeholder analysis, and the field of civilian drones is rapidly changing and evolving. It is likely that the technologies involved will have changed within just a short time after writing, and opinions of interviewed parties are likely to change along with them.

## 1.4 Approach

This is a stakeholder analysis based on interviews and literature study. Each interview is performed either by phone, skype, or mail, and the questions vary. The basic idea of interview is to present the opportunities that drones could provide in cardiac emergencies, and ask what they think are important success factors.

The interviews will also be used to find more sources of information or more people to interview.

## 1.5 Structure of the Report

The rest of the report is structured as follows. Chapter 2 details theory and earlier work. Chapter 3 describes the methods used. Chapter 4 discusses the results and presents a suggested approach, and chapter 5 is a conclusion.

# Chapter 2

# Theory and Earlier Work

The three main categories in this chapter are drones, hearth attacks and emergency response, and laws and regulations. Each will be covered in a separate section, with a small summary at the end.

## 2.1 Drones

In this paper, I use the term "drone" to describe Unmanned Aerial Vehicles (UAV). The term could also be applied to ground vehicles, or even autonomous boats or submarines, but I will focus on flying drones. I also use the term drone and UAV interchangeably.

To understand drones, it is important to understand their military use and history. Historically, UAVs have been used when a job has been too "dangerous, dirty, or dull" to be done by people. As early as 1849, unmanned balloons carrying bombs where used to attack Venice(6), and a kite was used for aerial photography during the Spanish-American War in 1898. In World War 1 drones were used for target practice and remote controlled bombs. World War 2 saw more advanced guided aircraft, including tv-guided, gliding bombs. In the Vietnam War drones were used for reconnaissance, and the modern day drone fills many roles, most notably the hunter-killer, able to detect and take out targets, while operating nearly autonomously for several hours and from half the world away.

Military drone systems have mostly been involved in surveillance/reconnaissance and direct engagement, but has more recently been used to deliver supplies in combat zones. An example

Figure 2.1: Predator Drone (picture from wikipedia commons)

of this is the Kaman K-Max helicopter(7), delivering towed loads to friendly and hard to reach outposts. This unmanned helicopter has also been used in firefighting (8), where it automatically identifies hotspots and dumps water on them. It does this by cooperating with a quad-rotor drone, Lockheed's Indago, that acts as a sensor platform, providing information about the fire to fire-fighters on the ground. The system can also operate at night and in heavy smoke, something manned systems cannot do. This results in 2-3 times as many sorties as a manned system. The helicopter has also been tested for autonomous casualty evacuation (9; 10). This was done in tandem with a UGV (unmanned ground vehicle), that navigated to and found the wounded person (in the test case it was a mannequin).

This paper(11) titled "The Rise of the Humanitarian Drone" tackles the concept of the “humanitarian” drone, as opposed to the military drones that serve as their technological source. Drones first used in as a humanitarian tool in 1994 in Bosnia, when Gnat 750 drones (a precursor to the Predator drone) were deployed by the US to monitor NATO convoys.

The “drone war” has created several technological advancements in drone technology. This opens up opportunities for technology transfer to more humanitarian uses, and can be thought of as a sort of “war dividend”. One of the main stakeholders in establishing the concept of peaceful drones is the drone industry, who are looking to expand to new markets and make up for cuts in the American defence budget. Some of the techniques used is a focus on saving lives and brightly coloured drones (as to be noticeable and non-threatening).

Some of the first uses of drones for non-military uses has been for surveillance, such as monitoring of disaster areas and Search and Rescue (SAR). This task has often been accomplished by military drone systems, such as the Global Hawk.

Jack C. Chow writes about using drones to deliver aid to hard-to-reach areas in countries prone to corruption(12). The less people involved in handling supplies, the less chance of it getting stolen or delayed. It would also make transportation to remote areas where security is not as good as in population centres safer. The use of drones for “first-strike” against disasters, supply-trains using drones, and constant delivery of, for example, AIDS medication are discussed as possible use cases. Due to their ability to circumvent traditional channels for aid (where officials and others in power could control the channel and skim of the top), regimes might be reluctant to employ drones, as this weakens their control and potential profit.

Drones were used to gather information in for example the Philippines(13), and have been considered for use in SAR in Norway by the Norwegian Red Cross(14).

### 2.1.1 Civilian drone technology

For this paper we are interested in civilian drone systems that can navigate and move relatively autonomously, and that are capable of carrying an AED as a payload. This subsection list a few such systems.

Several companies have unveiled plans to use drones for civilian commercial use. Amazon.com is an online store, originally dealing in books, and are planning to launch a drone delivery service called Amazon Prime Air(15). The system is designed to autonomously deliver packages under 5 pounds to customers in a 10-mile radius. The system is still in testing, and much of the work involved is in making the drones cooperate with existing air traffic. Amazon has proposed a couple of ideas on how to do this. The first proposal(16) involves classifying drones according to capabilities. Drones with better capabilities would then get access to more restricted airspace, with urban, BLOS flight reserved for the best drones. Capabilities measured include how the drone communicate (from radio control to full internet access), collision avoidance (collaborative and non-collaborative), and autopilot navigation (from simple hover to full automation). The second proposal(16) is about how to divide airspace, creating different zones based on altitude, urban/rural, and restricted zones.

A similar concept is Googles Project Wing(17). Again, much of the work is developing an aircraft control system for the drones. Google plans to use internet and cellular networks to control the drones, and plans to use a “crane” to lower packages to the ground, as they feel landing is too dangerous for bystanders.

DHL, a delivery company, are already using a drone to deliver medication and other important goods to a remote island(18).

The Linux foundation has launched the OpenRelief program to create a remotely operated plane to survey damages in hard to reach places(19).

An example of a drone system designed for first responders is Qube(20). This drone system can fit in a suitcase and is ready to fly in 5 minutes. The system is designed to provide an eye in the sky at, for example, accident sites (train crashes etc).

An actual, working prototype of an ambulance drone has already been developed by Alec Momont (21) (22), and was the inspiration for this project. The six-rotor drone can travel at high speeds (100 km/h) and deliver an AED along with a camera and microphone very quickly to nearby victims.

### 2.1.2 Autonomy

In order to be effective, drones should have a certain degree of autonomy(23). A high degree of autonomy allows cheap drones to provide information to personnel on the ground about, for example, the location of victims and damage estimation, without having dedicated personnel to operate the drone, as would be the case with a helicopter.

Getting drones to avoid colliding with each other is an important issue. More drones in use means more congested skies, and while drones are currently quite good at avoiding stationary obstacles, they are not always good at sharing airspace. Ian Chipman talks about collision avoidance in a Stanford paper written by Mykel Kochenderfer and Hao Yi Ong(24; 25). The Stanford Intelligent System Laboratory has been working with NASA to develop an unmanned aircraft traffic control system. This would function much like an air traffic control system for manned aircraft, but would be much more automated and cloud based. One of the key aspects of such a system is a function that detects possible collisions between multiple drones and alerts them, along with calculating and delivering new flight paths. By using the number of manned flights as an indicator, the authors estimate that the US would need 30 000 additional air traffic controllers to deal with just Amazon Prime's drone delivery service, something they say is just not feasible. Automated systems are therefore required if the "drone delivery revolution" can take place. Likewise, we would need such a system for automated AED delivery.

### 2.1.3 Summary

It is clear that drones, and especially civilian drones, are somewhat immature technology, or at least rapidly evolving. Big changes and improvements are being made almost yearly, and an innovative, cutting-edge product now might be obsolete next year. Due to the large number of products "on the horizon", such as Amazon Prime Air and Google Project Wing, but no currently operational such systems, it seems that a fully autonomous network of drones is not yet practical. This looks to be solved in the future, however, so such a system might be implemented later.

This is also supported by looking at the concept of civilian drones being a "war dividend", in other words civilian drone technology follows military drone technology. As military drones have for a long time been about surveillance, and not delivery of goods (not counting the delivery of very fast moving, non-lifesaving missiles), we can see that reflected in what civilian drones are capable of. Few systems are designed with transportation in mind, and most are built for aerial photography. As military drones have recently begun being used for transportation, and because civilian drones have become an economic powerhouse of its own, it is likely that civilian drones for payload transportation will emerge in the same way camera drones did.

The systems that are currently operational are simpler ones, focusing on single drones and single deliveries, and are manually operated. It seems like such a system would be a logical starting place for an ambulance drone, as opposed to a more advanced automated or multi-drone system.

## 2.2 Laws and regulations

A new set of laws(26) regarding aircraft without a pilot went into effect in Norway at the start of 2016. The laws where developed to make it easier to operate smaller drones. There are just a few parts that are important for this paper, and they will be summarized here.

First, the drones we will be using will very likely be over 2.5 kg. This means that we operate in either the RO 2, or the RO 3 category. RO 2 covers drones up to 25 kg, so this will likely be sufficient. However, the drone will need to fly over or close to groups of people, and this requires an RO 3 licence.

We will also likely need our drones to operate beyond-line-of-sight (BLOS), and that requires special permission, and often either permission from air traffic control, or an issued NOTAM. In addition, we need permission to carry the AED, which counts as transported goods.

Although the laws regarding the use of drones in Norway are not too complicated, they are none the less quite restrictive. There are a few make-or-break qualities our drone most likely must have:

1. BLOS operation
2. Fly over, and land close to, people
3. Take-off on demand, without waiting for approval

The first point seems obvious, as a cardiac arrest happening within sight of the operator would likely be resolved without the use of a drone, and not operating BLOS would severely limit range. The second point is also obvious, as landing a drone near a victim would by definition require flying close to people. Both of these points require a special licence, and often a NOTAM. This might interfere with point 3, as the approval to take off with the drone needs to be granted quickly.

It seems like our system needs to be manually operated, at least for the time being, and it would also need to be used in areas and durations pre-approved by the CAA. The drone we use will also need to be approved before we can start operating it.

## 2.3 Hearth attacks and emergency response

The purpose of the conceptual ambulance drone is to increase the survival rate of out-of-hospital cardiac arrest (OHCA). There are several factors affecting the overall survival rate(27). 23.8% of patients survive to be admitted to hospital, but only 7.6% are ever discharged alive. This survival rate has not changed in almost 3 decades, although it has improved in some areas. Important factors for survival are; if the events are witnessed by bystanders or EMTs, and if CPR is performed.

This study(28) shows that when adjusting for factors like time-to-CPR and time-to-defibrillation, survival rates in different areas appears to be the same, further suggesting that these are the most important factors in survival.

An important concept during out-of-hospital cardiac arrest is the chain of survival(29). The chain is designed to save life and works by having a series of events happening rapidly:

1. Recognition of early warning signs
2. Activation of the emergency medical system
3. Basic cardiopulmonary resuscitation
4. Defibrillation
5. Intubation
6. Intravenous administration of medications

It is important that each link in the chain is strong (in other words happens quickly), in order to achieve high survival rates.

A study on patients with a high chance of survival showed that defibrillation is not as time critical as CPR or ACLS, but is still vital for survival(30). This study also shows how quick the chance of survival deteriorates, as mentioned in the introduction.

This study(31), detail the outcomes of early defibrillation by security guards in casinos using AEDs. The data clearly shows an increased survival to discharge from hospital, and shows that time is a very important factor. For patients with a shockable rhythm that were shocked within

3 minutes, the survival rate was 74%. The mean arrival time of paramedics, however, was 9.8 minutes, showing the importance of bystander defibrillation.

Even laypersons can be trained to use an AED(32). This study also showed an increase of survival to release from hospital when an AED is used prior to arrival of paramadics, again showing the benefit of earlier shocking.

Another factor that can influence survival is hypothermia (33). Inducing moderate hypothermia is associated with better outcomes for out-of-hospital cardiac arrests.

Even though CPR has been proven to be vital to the survival of out-of-hospital cardiac arrest victims, it is not always given. This study(34), shows that compression are only given 48% of the time at the scene by paramedics (38% when subtracting time used for defibrillation and electrocardiographic analysis). Compressions where also shown to be too shallow in most cases. However, EMTs instructing bystanders over the phone can significantly improve the quality of the CPR given by laypeople(35).

### 2.3.1 Hearth attacks and emergency response in Norway

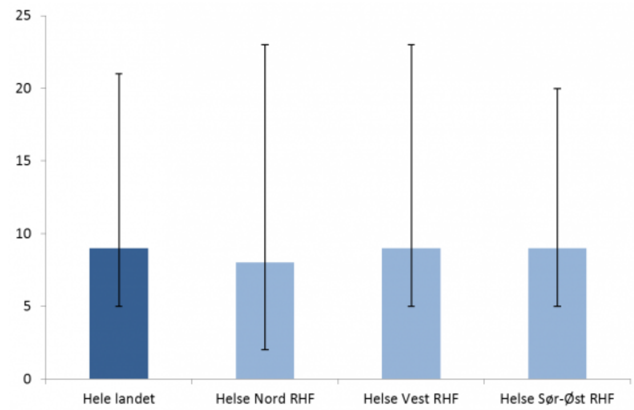
NAKOS maintains a registry of sudden cardiac arrests outside of hospital in Norway. The report from 2015(36) covers about 55% of the population and had an incidence of 44 out-of-hospital cardiac arrests per 100 000 per year.

The response time is measured as the time from the first call to the medical emergency hotline, until the first ambulance is on site. These numbers are measuered electronically by computer and are considered to be quite reliable. It is important to note the time does not include time from collapse to the phone call is made, or the time required for EMTs to get from the ambulance to the patient. The median response time was 12 minutes, with 23 minutes being the 90-percentile. The numbers are not normal distributed.

About one third of out-of-hospital cardiac arrests are not witnessed by anyone, and about 10% are witnessed by EMTs (already at the scene when the cardiac arrest occurs). CPR is started before EMTs arrive in about 78% of cases.

This study(37) details the response time for ambulances in Oslo to out-of-hospital cardiac arrest in the period 1996-1998. It shows a median response time of 7.2 minutes, but importantly also shows that the response time in central parts of the city (where more cardiac arrests hap-

Figure 2.2: Response times in Norway



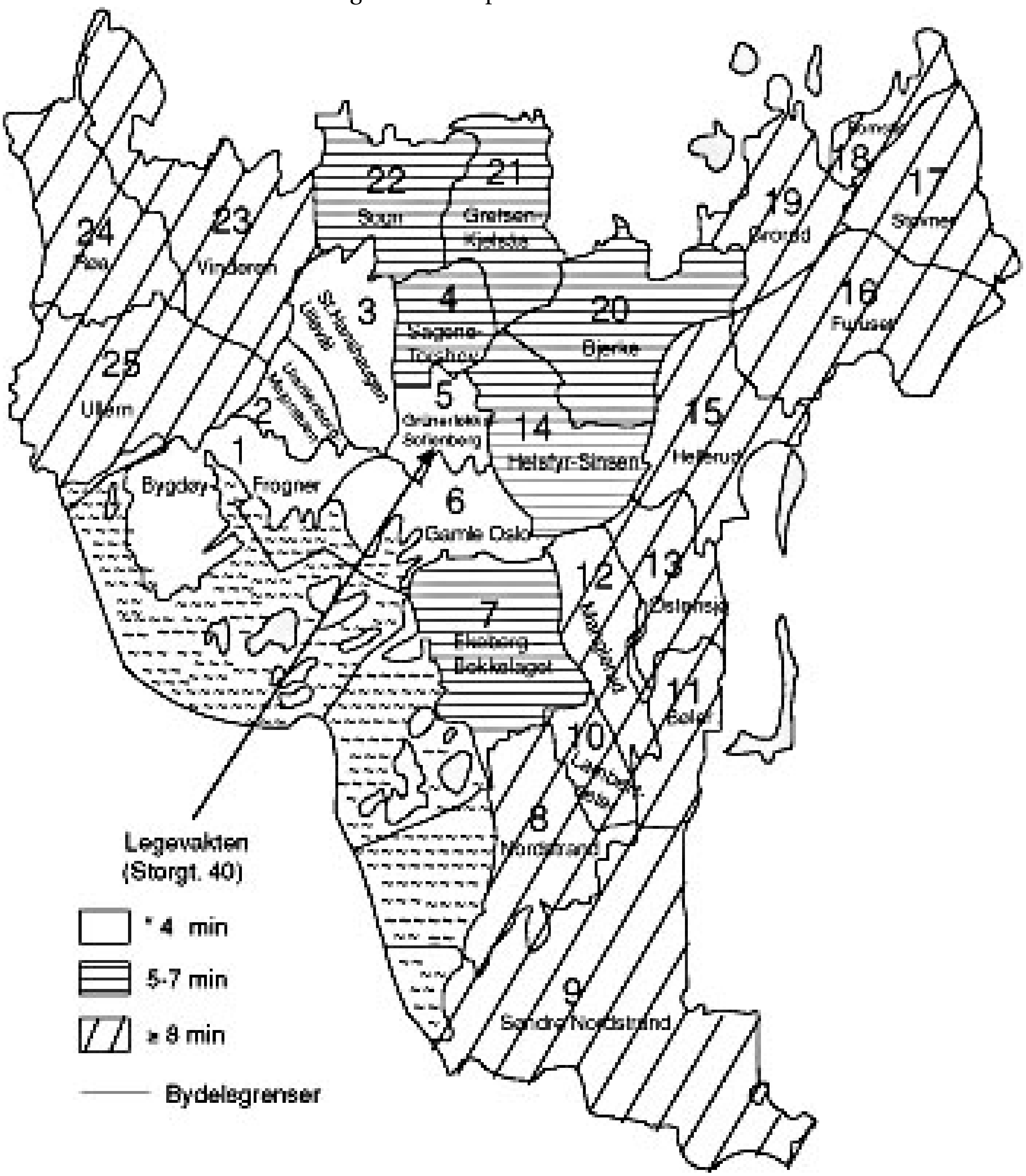

pen, both relatively and absolutely) was only 3-4 minutes. The response time median in more suburban parts was as much as 14 minutes.

### 2.3.2 Summary

There are two very important takeaways for our purposes. Firstly, lives can be saved by using a defibrillator earlier. Secondly, there is room for improvement in collapse-to-shock times in Norway.

Ambulance drones fit into the chain of survival by providing earlier defibrillation, and could assist bystanders in proper CPR with the use of cameras, microphones and speakers.

Figure 2.3: Response times in Oslo



# Chapter 3

# Method

This chapter describes the methods used throughout writing the paper, gathering data, and performing analysis. The choice of methods will be backed by research theory.

## 3.1 Subject and scope

I wanted to do a study where I could use both my skills from computer science, and my contacts in the health sector, while at the same time being relevant for project management. The inspiration for the subject came from the prototype developed by Alec Momont(22). Although the concept was valid, there were still many questions to be answered, such as what the costs and benefits would be, and how the drones would work with existing air traffic. This would eventually require something like a pilot project, but I wanted to do a feasibility study to find out more about how to perform this pilot project.

Another reason that I wanted to research ambulance drones was because of the emergence of delivery drones. Although the technology to deliver small items using drones is quickly emerging, rules and regulation have not been as quick to catch up. I am working under the hypothesis that life-saving technology will make legislators more eager to change the rules. This would in turn pave the way for more mundane task, such as rapid pizza delivery.

Although several promising drone systems for automatic and manual delivery have been created and proposed, the technology still seems somewhat immature. In addition, most information is provided by the companies themselves, rather than a third-party, making it hard to verify. This is another reason to do a feasibility study rather than a pilot project.

The study is limited to the main 2-3 stakeholder groups, but will try to get a sampling within each. It will also describe functionality rather than concrete technical details.

## 3.2 Choice of method

The goal of this paper is to look into the possibility of using ambulance drones in Norway. This means we should do a feasibility study of some kind. According to Tim Bryce (38), there are six parts to any good feasibility study.

1. **Project Scope**

   The project scope needs to be well defined. Our scope is not well defined, so part of the analysis will be to get a better idea of what the scope should be.

2. **Current Analysis**

   What is the situation now? This means an analysis of first response services, which is what we are trying to improve.

3. **Requirements**

   This could be a list of important features, such as time-to-patient, costs, operating safety etc.

4. **Approach**

   How to create a viable solution. For example, we might need a pilot project to demonstrate usefulness and viability.

5. **Evaluation** Here we evaluate the cost effectiveness of the project. This is going to be difficult due to the inaccuracy of the information we have available.

6. **Review** The review should substantiate the thoroughness and accuracy of the study, and either approve or reject the project based on it. This is beyond the scope of this paper.

There are several different ways to gather data for a feasibility study. We could gather data from several similar projects or programs, and do a quantitative analysis. We could pick one or two and do an in depth case study. However, since there are very few such programs or projects, we need a different approach. I chose to do an approach based on gathering information from literature and interviews with potential stakeholders. The interviews would be of an exploratory nature.

Due to the qualitative nature of the study, certain questions will be hard to answer in this way, such as estimated cost of a viable solution.

The interviews was performed in two sessions. First, initial interviews was performed to get an overview of make-or-break features and stakeholders. Then, a second round of more focused interviews were performed with emergency response and CAA.

## 3.3 Qualitative Research Interviews

This is partially an interview project, and the interviews are of an exploratory, qualitative nature. According to(39), a good interview project has seven stages.

1. **Thematizing**

   Formulate the purpose of the investigation. The why and what of the study.

2. **Designing**

   Planning the study. Before performing interviews, plan who to interview and how.

3. **Interviewing**

   Perform the actual interviews.

4. **Transcribing**

   Transcribe the interviews to get a written account of oral interviews.

5. **Analysing**

   Decide on a method of analysis and analyse the transcribed interviews.

6. **Verifying**

   Verify the validity, reliability, and generality of the study.

7. **Reporting**

   Present the results of the study.

The purpose of the study is detailed in chapter 1, and the design of the interview process is written below in the next two sections. The transcription was performed real time as the oral interviews were not recorded.

### 3.3.1 Analysis Method

The interviews were conducted in a "self-correcting" manner, meaning that they were continued until a consensus was achieved. The second set of interviews were also performed to verify the conclusions of the first interviews.

The main analysis technique used was "meaning condensation", in order to extract the relevant information from the interviews in a shorter form.

As the goal of the interviews was to get feedback on ambulance drones, the technical details were provided by the interviewer. In the first round of interviews, the details were kept general, but the conversations naturally revolved around about 3 different variations of ambulance drones. These variations were then refined and used as a basis for the second round of interviews.

## 3.4 Initial interviews

The initial set of interviews were performed to get an understanding of what various medical personnel thought of ambulance drones as a concept, and also what the CAA thought of it. I used my primary contacts in the medical sector to get the initial list of people to interview. In addition I reached out to the CAA.

### 3.4.1 Structure

The structure of the first interviews were kept very simple:

1. Explain the basic concept of an ambulance drone
2. What do you think about this as a concept?
3. What is important to focus on?
4. Who else should I talk to?

The concept was simply described as "a way to get an AED to a scene faster than an ambulance using a drone". The technical aspects were intentionally left out. When interviewing people regarding innovation in the health sector, some additional questions about how this is done were asked, such as how to get money, who can provide assistance and so forth.

### 3.4.2 People interviewed

1. Innovation in the health sector - two people in the ministry of health
2. Emergency medicine - Three doctors
3. CAA - One person

## 3.5 Second interviews

The purpose of the second set of interviews was to get a more detailed response on some more specific concepts based on feedback from the first round of interviews. Only one person in emergency services was interviewed, and one in the CAA.

Three different systems where described to the interviewee, and they were asked what they thought of the systems, especially how useful/feasible they thought it was, along what they considered make-or-break conditions.

## 3.6 Summary

This is a feasibility study performed both by analysing literature and by performing qualitative research interviews with the main stakeholders. The goal was to find out what benefits ambulance drones might provide, along with the risks and challenges involved. The interviews were performed in two rounds, one discussing the basic concept, and a follow-up round discussing more specific implementations.

### 3.6.1 Discussion

The literature study found plenty of relevant studies to use on both cardiac arrest and laws and regulation. However, there was less information to be found on drones. This can be explained by the relative immaturity of the field. Much of the information available on complete systems was provided by the creators of the system, as they had not yet been completed or been tested by third parties. This makes it hard to verify the accuracy of the information.

Although the main stakeholders responded to requests for interviews, it would have been preferable to get a wider sampling of interview subjects. Specifically, I reached out to law enforcement and 3 different companies that produce drone systems similar to ambulance drones, without getting a response. The drone companies could have given valuable insight about technical challenges and costs, and law enforcement could have provided insight into their side of emergency response.

The transcription was performed by writing down key words and sentences while interviewing over the phone. This was done as I did not have the proper equipment for recording, nor knew about the legality of recording when the interview process started.

# Chapter 4

# Results and Discussion

The purpose of this paper is to create recommendations and suggestions for ambulance drones, based on literature and interviews. This chapter will present the results form the interviews and discuss the findings, and present a recommended approach.

The literature study revealed a few very important things. First, cardiac arrest deaths can be reduced by faster application of defibrillators, and there is room for improved response time in Norway. Second, drones have been shown to be able to accomplish this task, although mostly though prototypes and other early tests. Third, the laws in Norway do allow for the use of drones for these purposes, but they are very restrictive.

It is also revealed that both laws and regulations and available technology favour simpler, manually operated systems, where flight can be pre-approved by the CAA, in areas outside of restricted airspace. This is also where some of the areas with high response time are.

## 4.1 Initial Interviews

### 4.1.1 CAA

Luftfartstilsynet was positive to the idea of using drones to deliver AEDs, but had concerns when it came to safety, legality, and interaction with other aircraft, both manned and unmanned.

At time of writing, drones cannot normally be flown out of sight of the operator. Having to follow this demand severely limits the usefulness of ambulance drones, the range would be to short.

However, there is an exception to the rule if the drone stays below 120 meters AGL and the flight is registered some time prior (usually the day before) as a NOTAM. This could be useful at events such as Birken or Oslo Maraton, where the drone flight could be registered before the event.

The CAA were also positive to changing the rules to accommodate emergency drones and other fully autonomous drones, but stressed that before the rules could be changed, these systems would need to be shown to be safe. There are a few issues that need to be solved:

1. **Drones aware of other drones**

   Today, drones are good at navigating and avoiding stationary obstacles, but not at cooperating with and avoiding other drones. This would need to be handled if drones should operate in shared airspace.

2. **Drones aware of manned aircraft, vice versa**

   Drones should never pose a threat to manned aircraft. In this scenario we would very likely see conflicts between ambulance drones and ambulance helicopters. A helicopter should be able to land without worrying about a drone being in the way. This could be done by having the drone move away, or by filing a NOTAM, or by using a transponder on the drone.

3. **Fly reliably and safely**

   The drones need to demonstrate that they can fly safely with an AED without being a danger to bystanders on the ground.

### 4.1.2 Innovation

In Norway, hospitals are required by law to conduct research. However, this does not apply to "innovation", which is what developing and using ambulance drones is. Rules for innovation in hospitals are currently being developed, along with indicators to measure it.

There are groups at for example Ullevål that work with new ideas, and it is possible to seek funding for such endeavours.

The most important thing to establish when presenting a concept or an idea is a thorough cost/benefit analysis.

### 4.1.3 Emergency response

Emergency response and medical personnel where positive to the concept, but said that it would likely be a while before it is put into use. Several important factors where identified:

1. The drones must beat the response time of ambulances by some margin. The response time in Oslo is 7-8 minutes, maybe 10 on average. About 80% are inside peoples homes, AED/drone needs to be able to enter, meaning the drone must be small, or the AED detachable.

2. The drones must not distract from CPR. This means that if only one person is assisting the victim, stopping CPR to retrieve the AED and apply it would in most cases be counterproductive.

3. A speaker, camera, and microphone would be helpful to direct bystanders.

4. If medication is included, it needs to be locked electronically so it is not administered untimely. This means that an operator decides whether or not to make medication accessible for bystanders to administer. Medication could include heroin overdose nose spray and epinephrine.

Interviewees also agreed that large, outdoor sporting events would be a good place to test the concept. For example, Oslo Marathon often has at least one heart attack. But the crowds are often to big to allow first responders to reach the victim. Drones might be able to get there faster.

Norway is currently implementing an "AED registry" to be used by emergency operators. The registry will contain information about where to find AEDs so that bystanders can be directed to retrieve them. Experiences from other countries, however, show that operators are often unwilling to trust this information. They cannot trust that the AEDs have not been moved, that they are not broken, or that the batteries are still charged. In addition, time might be wasted trying to find it. The AED registry program in Norway is concerned with creating trust in the system, and ambulance drones might help create that trust. This would in turn require the ambulance drones to be reliable.

Using drones to get an overview of the site of an accident was also highly sought after. It would be beneficial to cooperate with police to achieve this, and having a drone arrive before personnel would be preferable.

Other suggestions were drones carrying geiger-counters, drones used to search buildings and tunnels that are on fire, and seach-and-rescue (SAR) drones. Some hospitals are already planning to use drones to transport blood samples for analysis, a task that today requires an expensive taxi-service.

### 4.1.4 Discussion

The interviews seem to back up what we found in the literature study. For example, they agreed that faster access to AEDs could increase the chance of survival, and that response time could always be improved, especially in certain areas. This was further expanded upon by emphasising that the system must not distract bystanders from performing CPR, and the AED needs to be able to enter buildings, along with several other suggestions.

The CAA also expanded upon what I found in the literature study. While stating that the laws must be followed, they also said that laws are constantly changing, and that if you can prove sufficient safety, very little is impossible to get permission for eventually.

Almost everyone interviewed, in emergency response, CAA, and innovation, stated that proving the concept works is important. Emergency response wants to be shown a benefit, the CAA wants safety to be demonstrated, while innovation is concerned with the combined Cost/Benefit.

## 4.2 Second Interviews and Suggested Approach

Based on the literature review and the first round of interviews, three concepts where developed. These where then discussed in the second round.

The suggested approach is based on these three concepts, starting off simple with the first concept before getting more advanced. The purpose of each is to gather data on effectiveness and cost, and of course to hopefully save lives

### 4.2.1 Concept 1: Manual drone system at large, outdoor sporting events

#### Description

The simplest and most realistic option was one proposed by several of the people interviewed in round one. The idea is to have a manually operated drone with an AED standing ready at large sporting events like "Birkebeineren" and "Oslo Maraton". During these events there is often at least one cardiac event, and due to the crowds and distances involved it can be difficult to get paramedics to the victim fast enough.

The system would be manually operated by a team under the control of the people managing the event, or a group hired to act as first responders for the event, such as the Red Cross. This means that the national emergency response services (AMK) are not involved with the drone, but that it is controlled locally specifically for this event. It would have to be able to carry an AED over several kilometres, fly beyond-line-of-sight (BLOS), and land close to and fly over large groups of people. It also needs to be quick enough to beat for example snowmobiles to the location of the victim. In urban environments, such as Oslo Maraton, it will need to be able to navigate buildings and wires etc.

#### Emergency Response Feedback

This concept is feasible and might provide a benefit. The sporting event needs to be widespread enough to make the drone useful, such as a marathon or other long distance event. In an arena, for instance, the drone would not be useful.

This is a sort of a "proof-of-concept"-phase, and thus there are a few things that must be achieved. The system must show that it is safe to operate close to crowds, and measure the difference in time between drone delivery of AED and alternative methods (likely what the event was doing prior to using drones). Due to the fact that there aren't many cardiac arrest per event, data from more than one would be needed, and having the drone operational at around 10 major events would likely yield useful data.

#### Civilian Aviation Authority Feedback

The drones will need to be in good technical condition, on par with micro-light aircraft. This is because the drone will likely need to fly above and close to crowds, and the risk of a drone falling on someone needs to be minimal. Due to the high quality the drone needs to maintain, it is likely only achievable by a professional company. It is also important to establish a clear protocol to ensure that drones do not collide with ambulance helicopters, either responding to the same scene or others in the area. A NOTAM must be issued, and the drone must fly beneath 120 meters AGL.

#### Discussion

This was the most requested idea during the first round of interviews. It is also possible to achieve with currently available drone systems, and legal by Norwegian law. It should therefore be a good place to start.

The first thing to consider is the drone. It needs to be able to fly fast, BLOS, and of course carry an AED. The drone would need to demonstrate the same safety as a microlight aircraft. This means that not only does the drone need to be well tested and of good quality, but we also need maintenance logs, qualified pilots, flight logs, operational procedures and so forth. In other words, we need a qualified team to manage the drone.

Once this is done, we need sporting events to attend. This could be done either by cooperating with the organizers of the event, or with someone providing first aid at such events, like the Red Cross. The team operating the drone is placed under the command of the first aid team, and should have an EMT with them. An EMT could guide bystanders to better CPR according to(35).

The chain of communication would involve bystanders and the first aid team, meaning authorities would not be involved with the operation. However, we do need to issue a NOTAM, since we need to fly BLOS. Another problem we need to address is conflicts with ambulance helicopters, responding to the same incident or another one nearby. This means we need to establish procedures and channels of communication with AMK, to avoid any chance of collision.

It is also very important to log everything, as this is first and foremost a proof-of-concept. Conclusions on costs and benefit could be made after data is gathered from a number of events (N around 10 has been suggested).

### 4.2.2 Concept 2: Manual drone system covering a popular ski-area during the ski-season

#### Description

This is a manually operated program running for a season (or more) in one specific area known to be a problem. This means areas where response times have been historically shown to be high, and where there tends to be a lot of people certain parts of the year. Nordmarka in Oslo in winter is used as an example.

A team would operate one or more drones from a central location, and would be under the jurisdiction of national emergency services (AMK). That means if someone calls for help, it would be up to emergency operators to decide if a drone should be dispatched.

The drones would have to fly BLOS and land close to people, and would of course have to be able to carry an AED and fly quickly.

#### Emergency Response Feedback

Also a feasible concept, as the program could be run during normal daytime ours when most people would be in the area. This would allow for a normal "8-5"-operation and would be cheaper and easier to accomplish than a full time program.

We need a system to locate the victims, who would most likely be close to prepared tracks and might have a phone with GPS. The calls would also go through 113, meaning a resource coordinator at emergency services would decide whether or not to dispatch a drone. This does not differ too much from current practices when, for examples, snow-mobiles are dispatched in similar situations.

It is important to find an area and season with a lot of people, such as a popular cross country ski area during Easter or winter vacations. Helicopters that often respond to these areas often use 20 minutes to reach victims, and locally placed drones could easily be quicker.

A make-or-break requirement would be to get Akuttmedisinsk kommunikasjonssentral (AMK) invested in the idea. They will be the ones who make the decision to use the system, and when to dispatch drones, so their support is vital.

**Civilian Aviation Authority Feedback**

This might be covered by a different set of laws, as it is a government run program. Otherwise, the same requirements apply as for concept 1, other than that you might have to create a restricted airspace, rather than filing a NOTAM if the program lasts for more than 3 months. This could therefore be more expensive and require more time in planning.

**Discussion**

This concept could follow-up project if data from the first trail justifies it. The requirements are mostly the same, with a few exceptions. Firstly, we need a extended NOTAM, or even establish a restricted airspace. Secondly, our chain of communication goes through AMK and emergency services.

We therefore need cooperation with, at least local, emergency services, who would be in charge of the program. A resource coordinator would decide whether or not to dispatch a drone, in the same way snowmobile patrols are sometimes dispatched.

Victims would be located in the woods or mountains, and might be hard to find unless bystanders can accurately describe their location. GPS coordinates would be very useful, and having a system where smart-phones can automatically share their location with emergency services would be great. This is a reworking of existing infrastructure, however, and is way beyond the scope of this project.

### 4.2.3 Concept 3: Automatic system covering a major city

#### Description

This is the most advanced version of the concept, and would consist of an automatic network of drones covering a city. The emergency operator can dispatch a drone by the push of a button, and the drone navigates (either automatically or manually, likely a combination) to the victim. Base station around the city would house drones ready to take off with charged AEDs, and technicians would recover them at the scene.

The system would require a high degree off automation beyond simple BLOS flight, and needs to be aware of other drones and helicopters. It would also operate in an urban environment, always flying above people and buildings.

#### Emergency Response Feedback

This is clearly a more advanced system, at requires a bit more to get it to work. Firstly, a number of backing systems need to be in place, including systems that automatically share GPS position with emergency services, and drone control systems. Secondly, the system is unlikely to be used if emergency operators have to manually dispatch it. The system should therefore require minimal-to-no action required by AMK personnel.

The system might be a way to complement the AED registry currently being developed, creating more trust and flexibility. It also absolutely requires support with AMK, to an even higher degree than concept 2.

Since the system is automatic, all data on arrival times, collapse-to-shock, bystander performance etc can be recorded, and provides a great source to perform a range of studies, even after just a year of collecting data.

#### Civilian Aviation Authority Feedback

This is not possible according to the current set of drone laws, which do not allow for complete automation. However, several sectors wish to use automated drones, for example for inspection of pipelines, and the CAA are open to changing the rules once these systems can demonstrate safety.

If the rules would allow for a partially automatic system, it would need to be of a very high quality to be allowed to operate in urban environments, and would need special attention to the landing, as both traffic and bystanders create an unpredictable environment. The drone would also need to be equipped with an ADS-B (a transponder), relaying its position to nearby aircraft and personnel on the ground.

### Discussion

Although this is the most versatile system, capable of saving the most lives, it is not yet legal to operate and no systems have been demonstrated that fulfil the requirements. We also need a set of supporting systems, mostly software infrastructure. For example, we need a system that automatically shares GPS coordinates with emergency operators, and therefore also with the drone control system.

In short, we need an upgraded or new emergency network, and implement a citywide drone control systems, along with rules governing it, such as the proposals by Amazon(16)(40). This would be very expensive if done solely for this project, but many of these systems have other uses and are already being considered, so this concept would not have to field the cost of creating them.

## 4.3 Feasibility Study

This approach answers the six parts of a feasibility study as follows.

1. **Project Scope**

   This approach starts with a very small scope, and extends it gradually.

   It is likely that the scope of each concept would decrease over time, as off-the-shelf drone systems become more advanced and reliable, requiring less work on our part.

   The simplest concept can be roughly sized up as follows: We need to modify, build, or buy a drone with an attached AED. We need to show sufficient safety to the CAA, meaning maintenance logs, pilot certification etc, and get the necessary licences. The easiest way to accomplish this might be to outsource the operation of the drone. We need to establish communication protocols with CAA to avoid conflicts with ambulance helicopters. We need to cooperate with first aid teams at sporting events, being incorporated into the chain of communication. We need to file a NOTAM for each period of operation. Lastly, we need a system to record data.

   The second concept is pretty much the same as the first, but with a more ongoing operation and a tighter cooperation with AMK.

   The most advanced concepts involves upgrading and creating several support systems, and the cost would be prohibitive if factoring in the cost of these systems. However, these systems would provide benefits on their own, and might be implemented on independently.

2. **Current Analysis**

   First response today consists mainly of ambulances and helicopters, with a few exceptions like snowmobiles. Response time vary from less than 5 minutes in central urban areas to 20-30 minutes when helicopters respond. There are AEDs placed in various locations and an AED registry currently in the works. Apps have also been developed to direct bystanders to these AEDs, although they are not yet in use.

The current situation also shows that the survival rate for cardiac arrests is quite low, but also shows room for improvement. For example, a study from casinos(31) shows that very quick defibrillation vastly increases survival rates.

Also, there is a wish from both the drone industry and emergency response to use drones in emergency situations.

3. **Requirements**

   We have discovered a number of requirements and suggestions.

   (a) Drone technical quality, maintenance etc. on par with microlights
   (b) Drone must be capable of BLOS flight
   (c) Drone must be suited to fly over and land close to groups of people
   (d) Drone must be able to carry an AED
   (e) Drone must be faster than EMTs by some margin
   (f) System should not distract from CPR
   (g) Include speaker, camera, microphone to direct and assist bystanders
   (h) Medication, if included, must be locked in such a way that it cannot be administered without a medical professional granting access to it
   (i) AMK must be involved and invested
   (j) Start with a simple, manual system before creating more advanced systems
   (k) Create a system to collect data about response times, survival rates etc.

4. **Approach**

   See suggested approach above.

5. **Evaluation**

   Whether or not the project would be cost effective is hard to evaluate. The costs of a working system changes rapidly, and operational costs should be measured against other solutions that save the same number of lives (or quality adjusted living years, or similar metric).

Benefits are easier to estimate accurately. We have accurate data on number of cardiac incidents(36), how survival rates change when collapse-to-shock times change(2), and we can estimate lives saved by factoring in the incidents the system should respond and the estimated improved response times.

However, more accurate estimates of both costs and benefits are needed before a useful evaluation can be performed.

6. **Review**

   This is beyond the scope of this paper.

# Chapter 5

# Conclusion

All the people interviewed for this paper were positive to ambulance drones in some form. The two biggest obstacles are legality and technology. Simpler versions of ambulance drones have already been created, and are already legal to operate, but more advanced versions will take more development. When they can demonstrate sufficient safety in their operation, laws can be changed to accommodate them as well.

In the next sections, the research questions will be answered.

## 5.1 Find out if ambulance drones could provide a benefit

Ambulance drones can provide a benefit by shortening the time from collapse to shock during cardiac arrest incidents. They are best used in areas and situations with high response times with no AED close by.

## 5.2 Find out about the risks that could be involved with ambulance drones

The main risks involved are concerned with flying quite heavy drones at high speed close to and above bystanders, as well as sharing airspace with ambulance helicopters and other air traffic, both manned and unmanned.

## 5.3 Create a list of requirements or suggestions for ambulance drones

Perhaps the most important thing do demonstrate in a pilot project is a good cost/benefit analysis.

The suggested approach is to have a manually operated ambulance drone at large, outdoor sporting events. Gathering data from several events should be enough to justify a more advanced concept, which could be a seasonal program covering a popular cross-country skiing area.

The most advanced concept, a fully (or mostly) automatic system covering a city, delivering AEDs automatically when a cardiac arrest is registered. This system is neither legal, nor has there been demonstrated a complete technical solution. It would also require upgrades to existing systems.

## 5.4 Further Work

This paper has described several different potential pilot projects. Further work would likely involve developing a drone and then performing one or more of these projects. It would also be useful to study other uses for drones in emergency situations, such as search and rescue and law enforcement, as there is likely some overlap in both technology and regulation.

# Appendix A

# Acronyms

**AED** Automatic External Defibrillator

**UAV** Unmanned Aerial Vehicle

**UGV** Unmanned Ground Vehicle

**CAA** Civilian Aviation Authority

**AGL** Above Ground Level

**NOTAM** Notice to Airmen

**SAR** Search and Rescue

**OHCA** Out-of-Hospital Cardiac Arrest

**CPR** Cardiopulmonary resuscitation

**ACLS** Advanced cardiac life support

**BLOS** Beyond-line-of-sight

**AMK** Akuttmedisinsk kommunikasjonssentral

# Bibliography


[1] S. Sans, H. Kesteloot, and D. o. Kromhout, “The burden of cardiovascular diseases mortality in europe,” *European heart journal*, vol. 18, no. 8, pp. 1231–1248, 1997.

[2] M. F. Hazinski and J. M. Field, “2010 american heart association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care science,” *Circulation*, vol. 122, no. Suppl, pp. S639–S946, 2010.

[3] L. A. Cobb, C. E. Fahrenbruch, T. R. Walsh, M. K. Copass, M. Olsufka, M. Breskin, and A. P. Hallstrom, “Influence of cardiopulmonary resuscitation prior to defibrillation in patients with out-of-hospital ventricular fibrillation,” *Jama*, vol. 281, no. 13, pp. 1182–1188, 1999.

[4] R. E. Kerber, L. B. Becker, J. D. Bourland, R. O. Cummins, A. P. Hallstrom, M. B. Michos, G. Nichol, J. P. Ornato, W. H. Thies, R. D. White *et al.*, “Automatic external defibrillators for public access defibrillation: Recommendations for specifying and reporting arrhythmia analysis algorithm performance, incorporating new waveforms, and enhancing safety a statement for health professionals from the american heart association task force on automatic external defibrillation, subcommittee on aed safety and efficacy,” *Circulation*, vol. 95, no. 6, pp. 1677–1682, 1997.

[5] Andel som har smarttelefon. [Online]. Available: http://medienorge.uib.no/statistikk/medium/ikt/379

[6] I. G. R. Shaw, “The rise of the predator empire: Tracing the history of u.s. drone.” [Online]. Available: https://understandingempire.wordpress.com/2-0-a-brief-history-of-u-s-drones/

[7] A. P. Betson, "The case against a cargo unmanned aircraft system," *Army Sustainment*, vol. 44, no. 5, p. 28, 2012.

[8] Unmanned k-max tested for firefighting. [Online]. Available: http://www.ainonline.com/aviation-news/business-aviation/2014-12-11/unmanned-k-max-tested-firefighting

[9] Neya systems awarded phase iii sbir to demonstrate vtol uav control. [Online]. Available: http://neyasystems.com/04042014-neya-systems-awarded-phase-iii-sbir-demonstrate-vtol-uav-control/

[10] Lockheed tests casualty evacuation mission with k-max drone (updated). [Online]. Available: http://www.nationaldefensemagazine.org/blog/lists/posts/post.aspx?ID=1823

[11] K. B. Sandvik and K. Lohne, "The rise of the humanitarian drone: giving content to an emerging concept," *Millennium-Journal of International Studies*, vol. 43, no. 1, pp. 145–164, 2014.

[12] J. C. Chow, "Predators for peace," *Foreign Policy*, vol. 27, 2012.

[13] L. A. Santos, "In the philippines, drones provide humanitarian relief," *Devex,[Online]. Available: https://www. devex. com/news/inthe-philippines-drones-provide-humanitarian-relief-82512*, 2013.

[14] Improving rescue operations: eyes on the ground or eye in the sky? [Online]. Available: http://securitydecisions.org/news/improving-rescue-operations-eyes-on-the-ground-or-eye-in-the-sky.html

[15] Amazon prime air. [Online]. Available: http://www.amazon.com/b?node=8037720011

[16] Determining safe access with a bestequipped, best-served model for small unmanned aircraft systems. [Online]. Available: https://images-na.ssl-images-amazon.com/images/G/01/112715/download/Amazon_Determining_Safe_Access_with_a_Best-Equipped_Best-Served_Model_for_sUAS.pdf

[17] Google set to launch air delivery service project wing in 2017. [Online]. Available: http://www.techtimes.com/articles/102411/20151103/google-set-to-launch-air-delivery-service-project-wing-in-2017.htm

[18] Dhl parcelcopter launches initial operations for research purposes. [Online]. Available: http://www.dhl.com/en/press/releases/releases_2014/group/dhl_parcelcopter_launches_initial_operations_for_research_purposes.html

[19] Openrelief launches open source disaster relief drone. [Online]. Available: https://www.linux.com/news/featured-blogs/200-libby-clark/586942-openrelief-launches-open-source-disaster-relief-drone

[20] Qube: Small uas missions. [Online]. Available: http://www.avinc.com/uas/small_uas/qube

[21] Tu delft's ambulance drone drastically increases chances of survival of cardiac arrest patients. [Online]. Available: http://www.tudelft.nl/en/current/latest-news/article/detail/ambulance-drone-tu-delft-vergroot-overlevingskans-bij-hartstilstand-drastisch/

[22] Drones for good. [Online]. Available: http://www.alecmomont.com/projects/dronesforgood/

[23] L. Apvrille, T. Tanzi, and J.-L. Dugelay, "Autonomous drones for assisting rescue services within the context of natural disasters," in *General Assembly and Scientific Symposium (URSI GASS), 2014 XXXIth URSI*. IEEE, 2014, pp. 1–4.

[24] Stanford team develops software to predict and prevent drone collisions. [Online]. Available: http://news.stanford.edu/pr/2015/pr-drones-avoid-collisions-121015.html

[25] H. Y. Ong and M. J. Kochenderfer, "Short-term conflict resolution for unmanned aircraft traffic management," in *Digital Avionics Systems Conference (DASC), 2015 IEEE/AIAA 34th*. IEEE, 2015, pp. 5A4–1.

[26] "Forskrift om luftfartøy som ikke har fører om bord."

[27] C. Sasson, M. A. Rogers, J. Dahl, and A. L. Kellermann, “Predictors of survival from out-of-hospital cardiac arrest a systematic review and meta-analysis,” *Circulation: Cardiovascular Quality and Outcomes*, vol. 3, no. 1, pp. 63–81, 2010.

[28] T. D. Valenzuela, D. J. Roe, S. Cretin, D. W. Spaite, and M. P. Larsen, “Estimating effectiveness of cardiac arrest interventions a logistic regression survival model,” *Circulation*, vol. 96, no. 10, pp. 3308–3313, 1997.

[29] R. O. Cummins, J. P. Ornato, W. H. Thies, P. E. Pepe *et al.*, “Improving survival from sudden cardiac arrest: the “chain of survival” concept,” *Circulation*, vol. 83, no. 5, pp. 1832–1847, 1991.

[30] M. P. Larsen, M. S. Eisenberg, R. O. Cummins, and A. P. Hallstrom, “Predicting survival from out-of-hospital cardiac arrest: a graphic model,” *Annals of emergency medicine*, vol. 22, no. 11, pp. 1652–1658, 1993.

[31] T. D. Valenzuela, D. J. Roe, G. Nichol, L. L. Clark, D. W. Spaite, and R. G. Hardman, “Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos,” *New England Journal of Medicine*, vol. 343, no. 17, pp. 1206–1209, 2000.

[32] A. Hallstrom and J. P. Ornato, “Public-access defibrillation and survival after out-of-hospital cardiac arrest,” *The New England journal of medicine*, vol. 351, no. 7, p. 637, 2004.

[33] S. A. Bernard, T. W. Gray, M. D. Buist, B. M. Jones, W. Silvester, G. Gutteridge, and K. Smith, “Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia,” *New England Journal of Medicine*, vol. 346, no. 8, pp. 557–563, 2002.

[34] L. Wik, J. Kramer-Johansen, H. Myklebust, H. Sørebø, L. Svensson, B. Fellows, and P. A. Steen, “Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest,” *Jama*, vol. 293, no. 3, pp. 299–304, 2005.

[35] T. Birkenes, H. Myklebust, A. Neset, T. Olasveengen, and J. Kramer-Johansen, “Video analysis of dispatcher-rescuer teamwork—effects on cpr technique and quality,” *Resuscitation*, vol. 81, no. 2, p. S9, 2010.

[36] Norsk hjertestansregister. [Online]. Available: https://www.kvalitetsregistre.no/registers/486/resultater

[37] K. Sunde, K. O. Fremstad, J. Furuheim, and P. A. Steen, "Utrykningstid for ambulansetjenesten i oslo ved hjertestans," *TIDSSKRIFT-NORSKE LAEGEFORENING*, vol. 121, no. 8, pp. 900–903, 2001.

[38] T. Bryce, "The elements of a good feasibility study." [Online]. Available: https://www.projectsmart.co.uk/elements-of-a-good-feasibility-study.php

[39] S. K. S. Brinkmann, *Interviews: Learning the Craft of Qualitative Research Interviewing*.

[40] Revising the airspace model for the safe integration of small unmanned aircraft systems. [Online]. Available: https://images-na.ssl-images-amazon.com/images/G/01/112715/download/Amazon_Revising_the_Airspace_Model_for_the_Safe_Integration_of_sUAS.pdf