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Incorporation of Drones into Fire and Rescue Service of Esbjerg Municipality for a Robust Emergency Response

MSc Thesis project

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Sydvestjysk Brandvæsen

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‘‘Incorporation of Drones into Fire and Rescue Service of Esbjerg Municipality for a Robust Emergency Response’’

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Emergency response services do the precious and very significant job of rescuing and securing human lives from the dangers of natural as well as non-natural emergencies and disasters. Some emergencies involving seriously injured persons need immediate medical treatment within first 10 minutes. But the average response time is 10 minutes making a room for improvement in current standard emergency procedures. This report initially investigates whether it could be dealt with either modifying the current system to make it respond faster or by induction of new technologies such as manned or unmanned aerial vehicles (UAV) and helicopters into emergency services. A research based on Multi Criteria Decisions Analysis (MCDA) reveals that UAV such as Ambulance Drone is the best alternative.

An example of a traffic crash at Kroskro roundabout in outskirts of Esbjerg is hypothetically considered for the application of UAV into fire and rescue service of Sydvestjysk Brandvæsen (SVJB) with the broader application of it in other emergencies as well. The findings of this report show that the socio economic benefits to the society of Unmanned Aerial Vehicles (UAV) can outweigh the costs of its induction by a huge margin. However rapidly evolving as new technology UAV incorporation comes along with the baggage of risk perception of dread and fear in the public and regulatory hurdles.

To tackle the risk perception based on the heuristic and psychometric factors a risk communication is needed in such a way that could make public accept the technology by paving the way of approval of UAV into emergency services. This report reckons not only the inevitable role that UAV can play but it also probes and analysis whether the advocacy and incorporation of it into emergency services can take safety to a higher level by incurring minimum costs.

Preface

This report, titled ‘‘Incorporation of Drones into Fire and Rescue Service of Esbjerg Municipality for a Robust Emergency Response’’. We are a group of two students of fourth semester of the MSc. in Risk and Safety Management programme. This programme is taught at the Faculty of Engineering and Science of Aalborg University campus Esbjerg. Writing period of this report has been spring semester of 2017. This report consists of seven chapters.

With the rapidly evolving technology of drones and their application for different purposes inspired us to search and seek how drones can be used for emergency responses of local fire and rescue service by improving safety to a next level and incurring less costs. For this purpose in this report we apply curriculum learnt during the course of this master programme by investigating and analysing a safer and cost effective way of emergency response to a traffic accident at Kroskro roundabout Esbjerg as an example with the broader implementation of drones to other emergencies as well.

We are very thankful to Anders Schmidt Kristensen (AAU Esbjerg) and Dewan Ashan (SDU Esbjerg) for their supervision, support and encouragement for this project.

We are also grateful to Søren Abildstup from Esbjerg municipality and Jens Mølgaard from Sydvestjysk Brandvæsen (SVJB) for their support and corporation.

Primary research is based on the interviews of Jens Mølgaard and Niels Strandvad Thomsen of Fire and Rescue Service of Esbjerg (SVJB).

Bibliography section containing sources used as mentioned are given at the end of the report. Harvard reference styles are used for referencing. Moreover the tables and figures are given numbers to the order in which they come in the text of report.

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8th June, 2017 Aalborg University Esbjerg

Acronyms

AAU	Aalborg University
AED	Automated external defibrillators (AED)
CPR	Cardiopulmonary Resuscitation
DEMA	Danish Emergency Management Agency
DMI	Danmarks Meterologiske Institute
EDMSIM	Emergency and Disaster Management Simulation
FARS	Fire and Rescue Service
FHWA	Federal Highway Administration
FEMA	Federal Emergency management agency ‘
GIS	Geographic information system
LBS	Lokal beredskabsstab
FRS	Fire and Rescue Services
MCA	Multi Criteria Analysis
MCDA	Multi Criteria Decision Analysis
MOD	Ministry of Defense
NATO	North Atlantic Treaty Organization
NGO’s	Non-governmental organization
RAS	Rescue and Search
SVJB	Sydvestjysk Brandvæsen
SAR	Search and Rescue
ICAF	Implied Cost of Averting Fatality

US	United States
CPA	Conventionally Piloted Airplanes
FOH	Fundamental Objectives Hierarchy
ID	Influence Diagram
UAV	Unmanned Aerial Vehicle
WHO	World Health Organization

1. Contents

Chapter 1

1. Introduction

The period from year 2002 to 2012 witnessed deaths of 1,117,527 people around the world due to global disaster according to data from the United Nations Office for Disaster Risk Reduction (UNISDR). The total economic and human impact are also huge with at least losses US$1,195 billions. There were over 302 disasters alone in the year of 2011 due to which 206 million people were affected resulting in 29,782 deaths and financial loss about US$366 billion. (UNISDR 2015) Therefore it can be said that the exposure to disaster risk is increasing.

Not only natural but also many other man made emergencies that lead to hundreds of thousands of casualties and loss of valuable resources. For instance, among them fires and traffic accidents are prominent to mention.

One of the main cause of human causalities and financial losses is fire. Fire costs lives of approximately 90 people every year alone in Sweden. (David Winberg 2016) Even though Sweden is not a very big country that ranks high in human development index and is considered relatively safe country. Similarly, in Denmark people are dying due to fire. Following figure depicts the number of deaths due to fires in Denmark from 2004-20016.

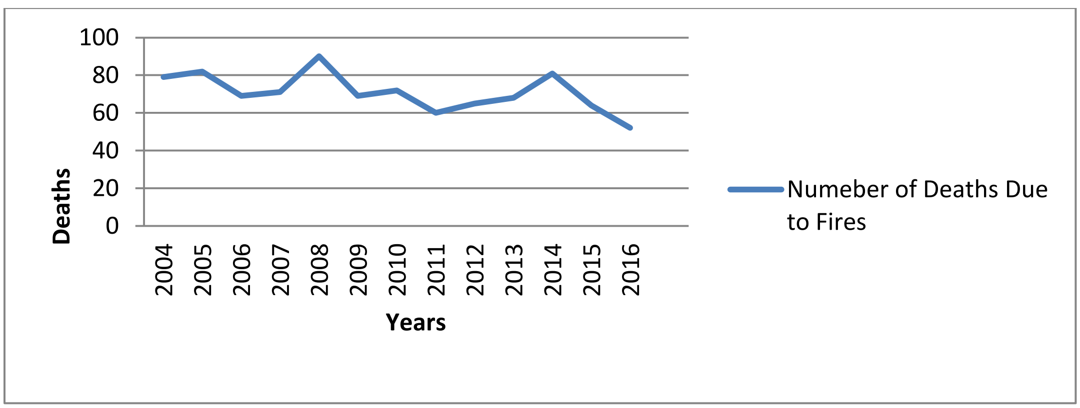

Figure 1 Number of Deaths Due to Fire

Source: DEMA 2017

In the above figure number of deaths are shown on vertical axis and number of years are shown horizontal axis. Statistics of deaths due to fires in Denmark are relatively low comparing to many other countries of the world. In the above figure it is shown that the last 4 years are showing improvement in safety and less deaths due to fires.

According to World Health Organization in recent years almost 1.25 million loss their lives worldwide due to traffic accidents. Around 20-50 million people suffer injures and a large number of them become disable for rest of life. These traffic injuries cost huge sums of money not only to individuals but also to society. These losses are incurred in terms of medical treatment as well as due to loss of productivity of those injured people and people caring them. It is estimated that road accidents costs in some countries is 3% of their gross domestic product ringing the bell to take measures to improve road safety. (WHO 2017). 90% traffic deaths are occurring in developing countries even though around 54% vehicles of the world are on their road (WHO 2017). This could be due to lack of proper road safety.

According to Statistics Denmark, Denmark has a declining trend of traffic accidents as shown in the statistics of the following table.

Table 1 Traffic Accidents

Years	Traffic Accidents	Years	Traffic Accidents
2006	5403	2011	3525
2007	5549	2012	3124
2008	5020	2013	2984
2009	4174	2014	2880
2010	3498	2015	2853

Source: Statistics Denmark 2017, Traffic Accidents

According to statistics Denmark there is also a declining trend in number of casualties due to road accidents. Which means Denmark has improved preventive and mitigating measures to minimize the number of casualties due to road accidents. The detail is shown in the following table.

Table 2 Casualties in Denmark Due to Traffic Accidents From 2005-2015

Year	Total Casualties	Killed	Seriously Injured	Slightly Injured
2005	6919	331	3072	3516
2006	6821	306	2911	3604
2007	7062	406	3138	3518
2008	6329	406	2831	3092
2009	5250	303	2498	2449
2010	4408	255	2063	2090
2011	4259	220	2172	1867
2012	3778	167	1952	1659
2013	3585	191	1891	1503
2014	3375	182	1797	1396

2015	3334	178	1780	1376

Source: Statistics Denmark 2017 Road Traffic Accidents

In the above table number of casualties are shown. From the above table, since 2005 the number of casualties are decreasing every year. But still in 2015 total number of causalities 3334, among them 178 persons died and 1780 people got serious injuries, whereas rest of the people were slightly injured. Per fatality cost to Danish economy is around 8,222,664 DKK while a serious injury costs about approximately 850,225 DKK. (Thomas C. Jensen and Ninette Pilegaard 2015)

Esbjerg has witnessed some traffic accidents tragedies in recent history causing casualties and losses. One polish man was dead as a result of traffic accident on Koldingvej north of Gabøl. (25 May, 2017)

A young woman aged 21-year-old from Holsted was dead due to a traffic accident on Esbjergvej in Estrup Skov between the road and Brørup on March 2017. In an another traffic accident a young man aged 18 years got killed while another 17 years old was seriously injured as result of accident on Roustvej in northeast of Esbjerg on February 21, 2017. A motorcyclist was also dead as result of a traffic accident between a car and a motorcycle on Frøkærvej north of Esbjerg on October 04, 2016.

Korskro round about in outskirts of Esbjerg is dangerous place for traffic accidents. According to Sydvestjysk (SVJB) about 5 accidents occur every year. For instance a motorist was seriously injured on July 29, 2015 when he drove straight in the roundabout instead of following the road's directions. This happened on Esbjerg highway, E20 on Korskro and road was blocked for sometime according to security officer for South and Sønderjylland Police, Erik Lindholdt to TV Syd.

1.1 Golden Hour Time to Save Lives

In case of an injury to a person medical help and first aid becomes very important to save his life and enable him to contribute to the welfare of society again. The first 60 minutes are really important in this regard. This one hour is termed as "golden hour" in trauma surgeries and emergency medical service (EMS). For the life injured person these 60 minutes become vital during which he has to get medical treatment from injury otherwise after this critical time the morbidity and mortality increase considerably. (Frederick B. Rogers 2014)

On average response time to emergencies in European Union is 10 minutes.(Alec Momont, Delft 2014) Some experts call the first 10 minutes 'Platinum Time' in response to accidents. (Len Watson 2001)

Though every injured persons severity of injury and initial medical treatment along with minimum time required to save his/her life may differ but achieving this minimum time to is crucial. Severely injured person who have brain or chest injury that could lead to death must be treated within first few minutes.

For instance, cardiac arrest must be given first aid in 3 to 5 minutes. If not treated within this time chances of survival are only 8 %. (SCA 2017)

Therefore there is a need to revisit as well as analyze the current emergency response system to any emergency management situation generally and specifically to traffic accident and cardiac arrest. This revisit and analysis can identify the scope for improvement in safety with less costs by inducting and integrating drones into the emergency management services.

1.2 Use of Drones for a Brisk Emergency Response

Unmanned aerial vehicles (UAVs) or drones have become an emerging technology in everyday life in recent years. Emergency management technologies have seen some remarkable breakthroughs in the past decade such as Drones that can overcome some of the hurdles that traditional methods of emergency management face. This report therefore analyses and investigates how can drones be used for better safety with less expenditure and improve emergency response to any emergency event. Human casualties and losses incurred due to different emergencies of fire, accidents, disasters natural are numerous therefore there is a need to consider using of drones to improve emergency management services. Drones can be integrated along with traditional rescuing technologies to serve this purpose. This is evident from some emergency managements services operations. For instance in November 2007, The West Midlands Fire Service in UK had used drones to tackle a fire emergency due to which four fire fighters lost their lives. (Pat Mika 2009) Drones were used in that event for Incident Support Imaging System (ISiS) since then UAVs are being used by the emergency management system to support incident management. Though militaries of some countries had been using UAVs since 1950s but the purposes that UAVs can serve are vast. For instance these can be used to aid research to predict the possible time period during which volcanoes can erupt. (Pat Mika 2009)

Unmanned Aerial Vehicles can serve many purposes such as inspection of bridges and building, surveillance, surveying for geological sites, emergency managements situations, search and rescue operations through thermo graphic cameras and assisting humans where they cannot reach due to higher risks of heating due to fires, heights, radiation and chemical risks. Drones can save humans from being exposed to these high risky situations and can considerably save time and money.

Emergency management services are important for any society to keep it safe and secure for an healthy life and economic activity. Emergency Management cycle consists of four stages of Preparedness, Response, Recovery and Mitigation.

The induction of new technology at preparedness level may increase its costs in the beginning but the UAVs can reduce response time and recovery costs associated with an emergency event. This report analysis and investigates the induction of high technology such as usage of drones for a brisk and robust Emergency Management service in Denmark. This study is primarily concentrated on well preparedness that is cost effective and discusses further the impact of preparedness on response, recovery and mitigation for the traffic accident at Kroskro, Esbjerg.

1.3 Problem Analysis

The previous sections highlights the need to have a quick response to in order to provide first aid to seriously injured persons. There is very limited time available to save precious lives and by using drones the response time can be decreased. For the purpose of analyzing all this an emergency of traffic crash at Kroskro roundabout is assumed. Following bow-tie is constructed that shows the causes and consequence of the incident along with barriers to prevent accident and mitigate the consequences of the accident.

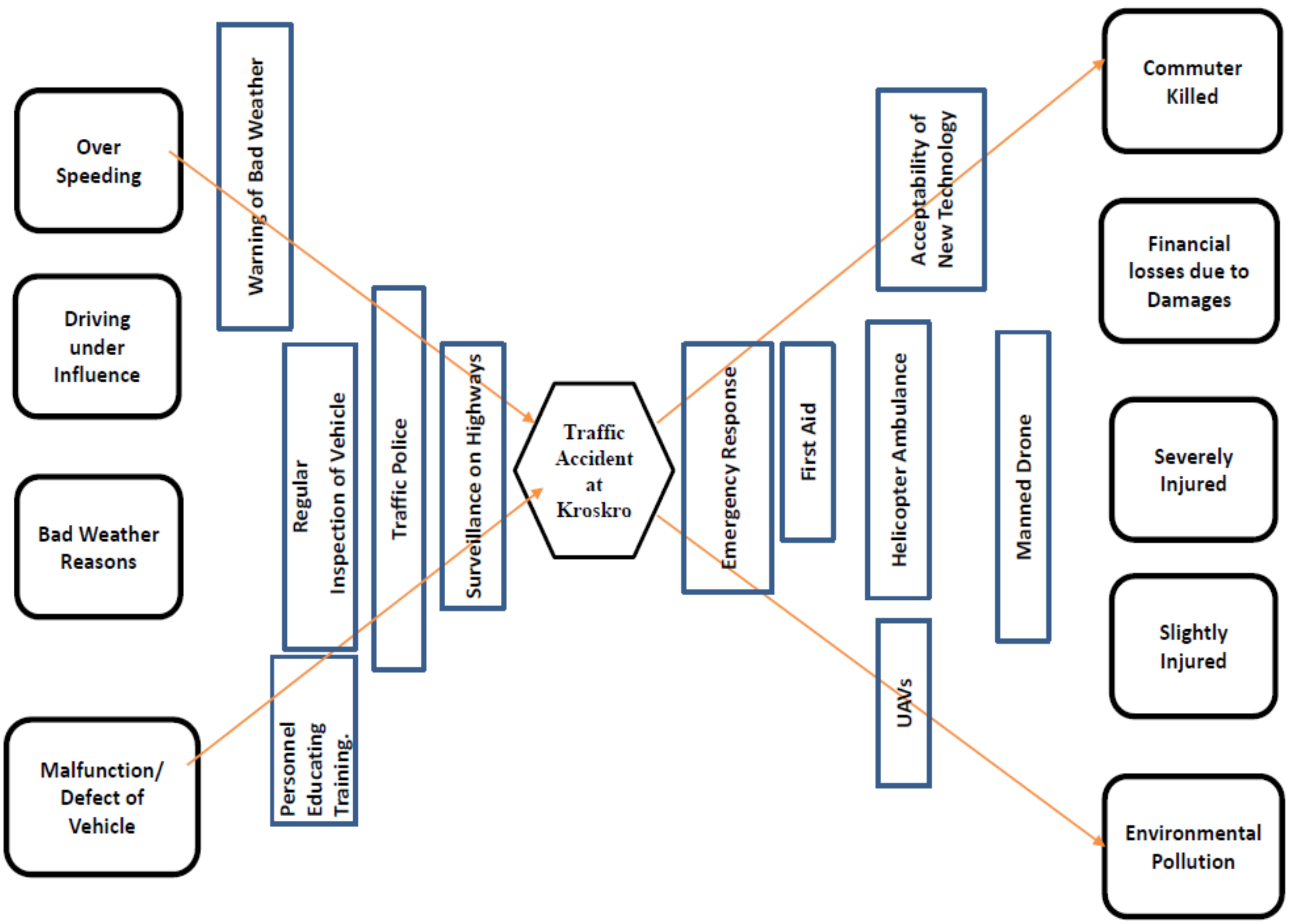

Figure 2 Bow-tie

The left side of the bow-tie identifies four causes of accidents at Kroskro roundabout that could be driving under influence of drugs or alcohol, over speeding, bad weather and malfunction of the vehicle. Moreover the left side also shows the traffic accident barriers to prevent traffic crash. Whereas the extreme right side of the bow-tie identifies the possible consequences of the traffic accident resulting in casualties of minor to sever injuries, deaths, damages. The inner right side of the bow-tie depicts the post traffic crash barriers to minimize the human, economic and environmental losses. The emergency services response will help to save lives and treat injured, and with approval of new technologies by regulators and acceptability by public can help induct drones into the emergency response to make reaching first aid to victims of the crash in shortest time possible. Medical helicopters can also be used to minimize the losses and improve safety by flying injured persons to hospitals quickly.

Bow-tie has illustrated the emergency of traffic crash at Kroskro with its causes and consequence in such a way that it paves the way of heading for analyzing and developing a robust emergency response system with maximum safety and that could be cost effective as well. Drones could be answer to the problems of delayed response time, hurdles, taking time to find victims or rescue them, limited imagining making rescue operation less affective in rescuing operations of emergency management services. However incorporating new technologies into any system and society has never been easy, same is the case with drones. Public perception of drones and the reaction of government and regulatory authorities play a vital role in the development and accepting them in emergency management services. In order to make legislation the Danish Government has adopted some regulations in May 2016 regarding safety, privacy and aviation of drones. (Regeringen, 2016) But it is not certain yet whether these laws will be able to improve performance of emergency services, protect people's privacy and safety of ordinary people will not be compromised.

There can also be other options to improve emergency management system such as use of helicopters either with or without existing emergency management system. However any change in current system or induction of new alternative has its own pros and cons. Reducing costs in rescuing operations may increase costs incurred in recovery phase of emergency management cycle due to the fatality of the seriously injured person that can be saved by quick response.

Therefore there is a need to have an emergency response with induction of new technology that its net benefit could outweigh the costs of it and maximize the safety by saving lives due to quick response.

1.4 Problem formulation

For the purpose of analyzing and exploring ways to improve overall performance of emergency management of Esbjerg municipality in terms of safety requiring less economic resources, this report conducts research based on the following problem statement and sub-questions.

Can drones be incorporated into Esbjerg's fire and rescue emergency service for brisk response either by reducing or incurring same costs as of now without compromising over safety?

As described and supported with examples and statistics in previous sections it is evident that drones can really be beneficial in rescue operations. However their use is still limited especially in emergency services. Nevertheless, their advantages of being less expensive comparing helicopters, fast speed and accessing places where human find themselves difficult to go are obvious.

But for investigation and analysis of this main question it is important to first find,

Can the current standard emergency response procedure be modified in such a way that it could become cost effective and safer?

To answer this question a hypothetical traffic crash at Kroskro roundabout in outskirts of Esbjerg is assumed. It happens due to collision of vehicles involving five people. Two scenarios are assumed as follows,

I. Today: 112 is called and a full crew responds to the call. The hypothesis result is that the response is effective and adequate, resulting in less fatalities and less long term injuries.

II. Future: 112 is called an inspector vehicle is sent to inspect the emergency on scene of accident. Inspector assess and initiate rescue, however not fully equipped and without support, if the emergency is assessed to be serious an extra rescue team is called. Hypothesis results in prolonged recovery phase and increased risk of added injuries and economical loss

Emergency management services incurs economic costs to maintain and operate full crew of 3 vehicles for a standard response to a traffic accident involving usually up to five persons. If there are more persons and vehicles involved in crash then they can dispatch more vehicles accordingly. These vehicles include inspector's vehicle that takes 10 minutes to reach at Kroskro roundabout. While the other two heavy vehicles of rescue and fire trucks reach at the scene of accidents by taking approximately 15 minutes.

However some in case of a serious injury this response time should further be reduced for maximum possible safety. To reduce response time there should be induction of new technologies such as drones into the emergency response that can reach at the scene of accident faster and assist in rescuing operation. Therefore for this purpose a quicker response than inspector's vehicle by using drones and its impact on overall performance of emergency management service is crucial to find. To find this the following question is raised,

Should drones either be used to replace or assist inspector vehicle in emergency response?

There is limited time available to save a life of seriously injured person and sometimes a first aid becomes very urgent. Seriously injured person facing head, neck and chest injuries may need a quicker response within platinum ten i.e. initial 10 minutes. For instance cardiac arrest's victim has maximum 6 minutes within which he must be given first aid as discussed before. But in both scenarios the first aid cannot arrive before 10 minutes in case of a traffic crash at Kroskro. There could be three alternatives to inspector's vehicle in form of helicopter, unmanned and manned drone. Whereas fire and rescue trucks should be used routinely because drones or helicopters cannot substitute their tasks. These three alternatives have faster response time with the first two i.e. drones can be even cost effective. Therefore it is shout of high time to probe whether drones can replace inspector's vehicle or these can work along with inspector's vehicle in an integrated emergency management system with fast response.

Incorporating drones into emergency management response is not that simple the public perception and legal requirements of the drone has to be considered. To ascertain the public perception and legal requirement following question is raised,

What is the risk perception of drones and status of legislation in Denmark?

Drone is a relatively new technology and people either due to lack of knowledge or not used to of seeing drones flying may not support or accept them. Moreover, there are also laws and regulations in Denmark that needs to be adhered. These laws are made to protect the interest of the common people as well as the authorities. Therefore it is vital to know whether people and authorities can either welcome the usage of drone into emergency management systems or they reject it due to reasons of fear of getting hurt by drones or privacy concerns etc. The last part of the report analysis is based on survey of risk perception and summary of existing regulations. An answer of good perception followed by legal adherence can pave the way of incorporation of drones into emergency management service.

1.3 Delimitation

This report is not considering the technical aspects of unmanned and manned drones. Any technical limitations of drones that may influence their future progress for the induction of emergency management situation has not be taken into account in this report. Emergency management cycle has four stages and the drone's induction and integration into the system mainly focuses on preparedness, response and recovery stages. Mitigation and prevention stage is less considered due to the reasons of more relevance and applicability of drone in the rest of the three stages. The fire and rescue service of Esbjerg region comes under SVJB that also covers municipalities of Varde and Fanø but for the purpose of investigation and analysis of using drones in case of a traffic crash at Kroskro in outskirts of Esbjerg, the latter two municipalities and other fire stations are not covered in this report.

1.6 Outline

This report consists of seven chapters as follows,

Chapter I: The report starts with an introduction of losses and casualties suffered due to emergencies and highlights the need for a better response by rescue service with drones. A problem is formulated based on a hypothetical scenario of a traffic crash in Esbjerg by investigating how the emergency response can improve safety and reduce costs either by changing current response with only a fast driving vehicle rather than whole rescue crew or replacing/incorporating drones into the emergency management system.

Chapter II: Second chapter of the report introduces the emergency management system of Esbjerg followed by the two scenarios created for the analysis and investigating purpose of the report. The first scenarios considers a whole crew responding to a traffic accident, second replacing the whole crew team with only an inspector's vehicle.

Chapter III: This chapter discusses data of casualties due to traffic accidents of Esbjerg municipality. Linear regression is applied to forecast future casualties and probability of casualties due to accidents. Moreover multinomial Distribution is applied to choose the event with highest probability. The socio economic cost of casualties are also discussed in this chapter. Furthermore, this chapter compares scenario I and II and determines which one is cost effective and safer than other.

Chapter IV: The fourth chapter of the report describes manned and unmanned drones. An analysis of their characteristic such as price, speed and payloads is considered to assess which one is better than others and can be applicable for emergency response to Kroskro traffic crash. A comparison of manned and unmanned drones is performed on the basis of Technological Readiness Level and Life Product Cycle to see which of the drone is at advanced stage that could be considered further for incorporation of emergency management system to handle traffic tragedy of Kroskro roundabout.

Chapter V: This chapter considers the four options available to handle emergency situation namely vehicle, helicopter, manned and unmanned drones. The Multi Criteria Decision Analysis (MCDA) is applied in this part of the report to reckon which one of the four options turns out as a best possible solution with highest scoring. To check the robustness of best possible option sensitivity analysis is also made.

Chapter VI: This part of the report explores, investigate and describes the risk perception of drones in public, their laws and regulations as well as risk communication to persuade people and authorities to accept drones as new friendly technology for the application of it into emergency services.

Chapter VII: Finally report concludes the findings by summarizing the outcome of previous chapters.

Chapter 2

2. Emergency Management Services, Esbjerg Municipality and Accident Scenarios

Emergency Management is the discipline that deals with risk prevention and risk mitigation, it is integral to the security of daily lives according to lecturing notes of Emergency Management course. Emergency management cycle (EPC) is a best way not only to prevent any incident from happening but it also helps to better prepare and mitigate consequences of that emergency. This cycle has different stages that entail the emergency management at different levels (Ahsan, Dewan 2016).

The cycle of emergency management is shown in the following figure,

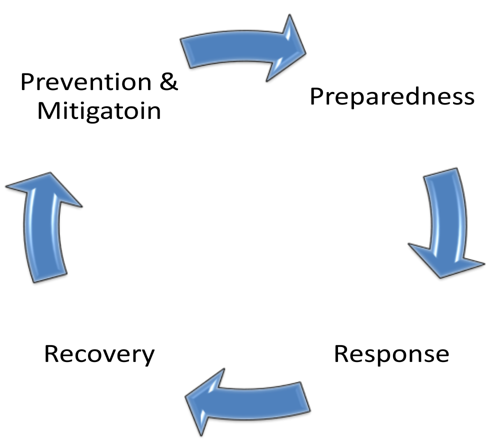

Figure 3 Emergency Management Cylce

Source: Haddow, D.H. Bullock, J.A, Coppola, D.P (2013) ‘‘Introduction to Emergency Management’’

Cycle of emergency management has four stages as follows,

- Preparedness
- Response

- Recovery
- Mitigation & Prevention

SVJB is well prepared to cope with any emergency. In case of traffic accident, preparedness means the readiness of three vehicles i.e. inspector vehicle, rescue truck and fire truck. Esbjerg emergency management responds briskly and reaches at the site of accident within 10 to 20 minutes depending on the location of the accident. Quick response mitigates the consequences of every accident. For preventing a traffic accident on roads Danish authorities keep constant check on drivers to stop them violating the traffic rules such as over speeding that may result in traffic accident. Recovery could be medical treatment of injured persons and other rebuilding of affected facilities.

2.1 Emergency Management Services in Denmark

In legislatively hierarchy Ministry of Defense tops the legislative body in emergency management services for the country. It's the defense ministry that makes guidelines and regulations to be followed. This set up is shown in the following figure.

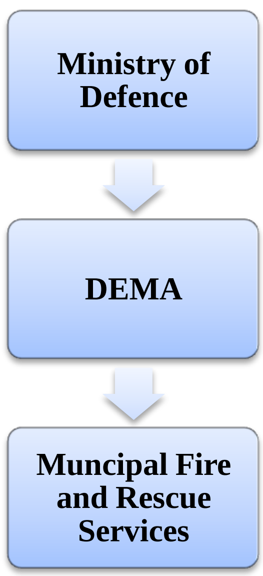

Figure 4 Hierarchy of Emergency Management in Denmark

Source: Figure based on information of Danish Emergency Management Agency 2017

The Danish Emergency Management Agency (DEMA) ranks second. DEMA is responsible for a better coordination and planning of emergency management of ministries on behalf of the Minister for Defense, DEMA co-ordinates the emergency management planning of the ministries. It has six centers across Denmark and it is also responsible for Danish National Fire Rescue Services through these centers. DEMA also administers the rules and regulations concerning emergency managements as well as conducting and implementing different training courses to stay prepared to cope with emergencies. The third level consists of Municipal Fire and Rescue Services. Municipalities and rescue services operate at the very local level, these municipalities and rescue centers have their own jurisdiction to operate for emergency events. (DEMA 2017)

The multi-level emergency management in Denmark consists of following three levels,

- Level 1: The Danish fire and rescue service, this level constitutes the municipal fire and rescue service.
- Level 2: It consist of the municipal and national support sites.
- Level 3: The national, regional fire and rescue service.

Under these levels in emergency events of fires and natural disaster deployment of the Danish fire and rescue service takes place. This multi-level emergency management system is designed to cope with emergencies efficiently. The first Level 1 of municipal fire and rescue service performs the tasks of daily emergency management. While at Level 2 the municipal and national support sites assists the other levels supplying equipment needed to execute most frequent tasks. Level 3 of the national fire and rescue centers supports in bigger and long-term accidents especially in emergency events of intensive accidents. (DEMA 2017 'Multi Level Emergency Management')

DEMA has six nationwide centers making it responsible for the Danish national fire and rescue service. These centers are North Jutland, Central Jutland, Southern Jutland, Zealand, Bornholm and Hedehusene Fire and Rescue Centers. These centers have employees and conscripts as well as volunteers to cope with emergency situations. These fire and rescue centers can support local police and fire and rescue services in case they need equipment and extra manpower to fight emergencies.
(DEMA 2017 'Assistance from the Danish Emergency Management Agency')

For emergency response in Denmark there are basically three parties ready and present in response area that consists of the working area of these authorities. These authorities are,

- The police,
- Fire and rescue service
- Emergency medical service (EMS)

These parties work in mutually coordinated environment to handle situation. In the case of an accident a remedial response will be started which is the working areas of the fire and rescue service as depicted in the following figure. Furthermore the response area for these services is the areas in which overall response is taken. A casualty ward for the initial treatment for the injured person is established which is the working area of the emergency medical service. Basically this area is situated between the inner and outer cordon.

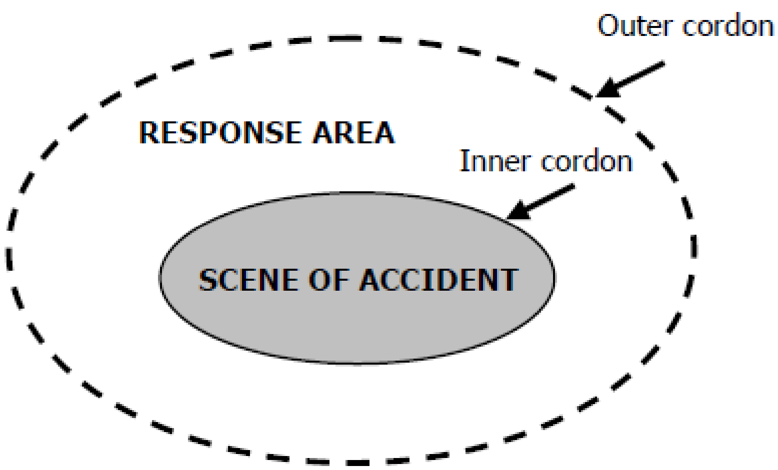

Figure 5: Illustration of the Response Area and the Scene of Accident

Source: DEMA 2017 ‘Emergency response management and co-operation’

The leaders of three emergency services i.e. police, medical and fire and rescue services form an Incident Management Teams in case of a major emergency situation. However leaders from other emergency authorities can also be present at the site of accident. In this case the police leader acts as a coordinator for management of the situation and it is his responsibility that the response is working efficiently as much as it is possible.

However the responsibility of the technical management for the response at the site of accident is in hands of the operational leader of the municipal fire and rescue service. He also handles the deployed units. Moreover according to the general sector responsibility principle, the leaders of medicals service and any other emergency management services are responsible for their relevant individual sectors for response. (DEMA 2017 ‘Emergency response management and co-operation’)

2.2 General Emergency Management Plan for Esbjerg, Varde and Fanø

The responsibility of updating and maintaining the general emergency management plan for the three municipalities of Esbjerg, Varde and Fanø is on SVJB under the creation of the article 60 company that SVJB (Sydvestjysk Brandvæsen) is part of to ensure there are extra resources are available whenever extraordinary emergency management situations demands.

The head of SVJB conducts emergency exercises whereas municipalities are responsible for testing and training the emergency plans. The emergency plan has to be updated within every election period for the city councils. The plan also be revised and has to get approval from councils of Esbjerg, Varde and Fanø. (SVJB, "Generel beredskabsplan 2016 - Esbjerg, Varde og Fanø kommuner'')

2.3 Sydvestjysk Brandvæsen (SVJB)

Sydvestjysk Brandvæsen (SVJB) is a fire and rescue services responsible for three municipalities of Esbjerg, Varde and Fanø. It has 11 fire stations in its area of jurisdiction with its administration being located in Esbjerg city. This service is responsible for a quick response in case of an emergency for the citizens of these three municipalities.

SVJB is responsible for different rescuing duties to limit and mitigate actions of the emergency situations. These rescuing operations include response to fire alarms from active preventions system, fires, explosions, traffic and train accidents, assisting in aircrafts accidents on land, building collapse accident as well as height and depth rescuing operations. SVJB also performs rescuing tasks in case of natural disasters such as distressed on harbors, creeks, lakes and marches and rescuing humans or animals in situations where there is imminent danger to them. It also carries out tasks of remedial and mitigation actions when it is asked for assistance by emergency call centers. SVJB is responsible for helping the victim of any emergency situation by providing them accommodation and food. It can legislatively agree to assist other authorities. Jens Mølgaard is the head of fire and rescue services of SVJB in Esbjerg responsible for daily management. Niels Strandvard Thomsen is the chief of operations. There are 15 full time workers in the organization set up who are tasked with maintenance, administration and preparedness planning among other daily routine works.

Moreover SVJB is further divided into 3 areas of operations, each region has its own incident commander who leads the operations in an event of emergency. There are around 140 volunteers available to SVJB to assist its emergency response and they are distributed to all fire stations in the municipalities. These volunteers can be called for various emergency assistance tasks such as flood preparedness, food and accommodation in distress, communication, storm protection, tackling with snow, providing light and oxygen at scene of accident to the injured, clearing paths after storm this could be removing trees, providing power supply and assisting authorities in major emergency events by providing manpower, equipment and blankets etc. (SVJB)

According to DEMA it is up to a municipality to have its own fire and rescue service or it can contract a private company like Falck or a fire brigade that works as a volunteer. However the rescue service must be quick to depart and react within five minutes of the alarm being triggered. The local council decides the number of vehicles and fire fighters it needs based on the risk assessment of its locality. (DEMA , 2017)

2.4 Scenarios for Traffic Crash at Kroskro roundabout Esbjerg

Fire and rescue center in Esbjerg which is SVJB is responsible to respond to the traffic crash such as at Kroskro. SVJB has a fire station at Vibevej 18, Esbjerg which will deal with it. According to the SVJB in a situation of traffic accident they will respond to the emergency call by seeing the scale of it.

If there are up to five people are involved in the accident they will respond with standard procedure of 3 vehicles. These vehicles are inspector car, rescue and fire fighting trucks. If there are many vehicles and more than 5 people are involved in accident then they may dispatch more than 3 vehicles at the site of incident for rescue operations. (SVJB) For the analysis of this report, it is assumed there would be an accident at Kroskro round about and in that accident 5 people are involved. For the application of objectives of this report in order to analyze and see how SVJB responds under current standard procedure of response and when there is change in standard procedure, two scenarios are developed.

First scenario belongs to the current situation, the way emergency management responds, in second scenario a change in response team is analyzed whereby only inspector vehicle goes to the scene of accident since it is less costly and there may not be a need of whole team of 3 vehicles.
The following table depicts the summary of scenarios and their response time. The calculation of time and other relevant information is elaborated under each scenario.

Table 3 Response Time Summary

Description	Scenario I	Scenario II
Resources Dispatched	Three Vehicles dispatched to the scene of accident. 1 Inspector vehicle 1 Fire Truck 1 Rescue truck	Initially 1 Vehicle of Inspector for inspection Calling the other 2 vehicles if needed
Response time	10-15 Minutes	10 min for Inspector Vehicle *OR* 26 Minutes for Rescue and Fir Trucks.

Scenario I

Traffic accident/vehicles collisions at Kroskro square located in outskirts of Esbjerg city, Denmark. The outline of the scenario is that,

112 is called and a full crew responds to the call. Result (hypothesis): effective and an adequate response, resulting in less fatalities, less long term injuries.

Fire station : Vibevej 18, 6705 Esbjerg Ø

Traffic accident location: Kroskro roundabout near motorway Esbjerg

Road distance or driving distance is 11 km which is shown in the following figure 6. In figure 6 the blue line shows the driving path between Vibevej 18, 6705 Esbjerg Ø to Kroskro roundabout near motorway Esbjerg.

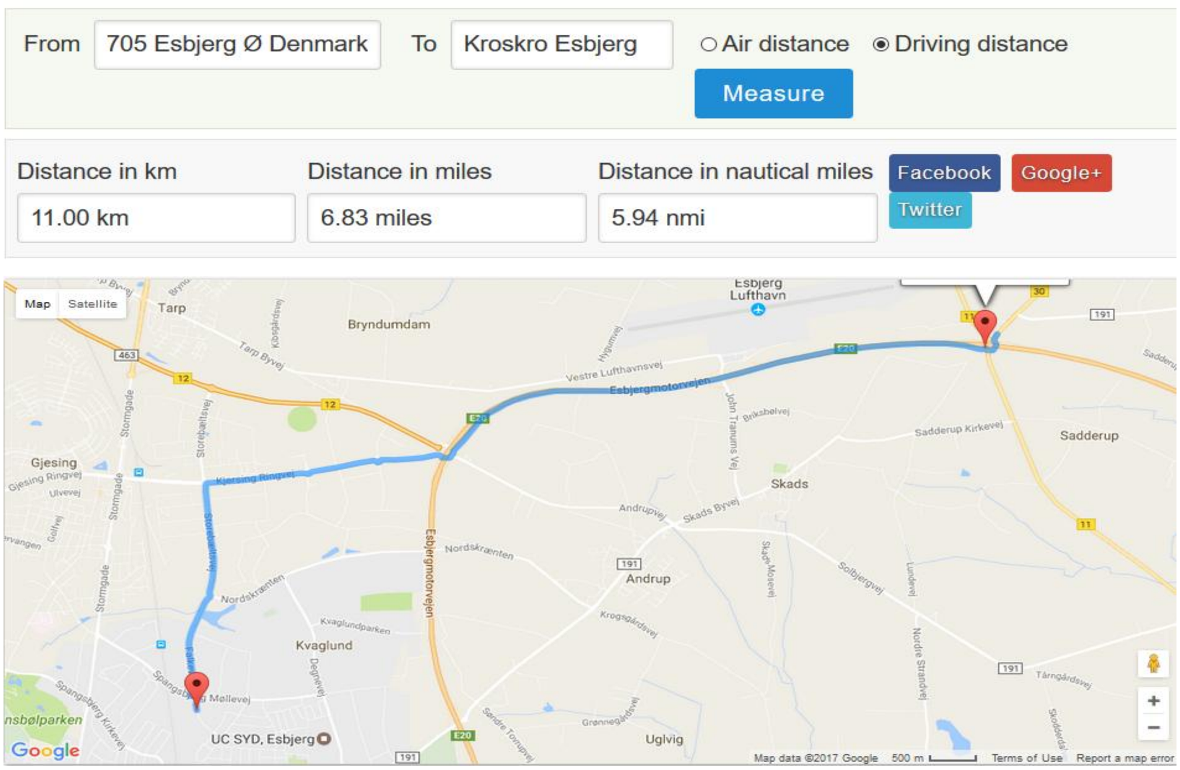

Figure 6 Road Distance between Vibevej 18, 6705 Esbjerg and Kroskro roundabout near Motorway Esbjerg

Source: www.distancefromto.net/ (2017)

Response time

10-15 minutes

Normal response time from Vibevej 18 Fire station to Kroskro roundabout is 10 minutes (with 80 % probability) but during rush hours it could be 12-15 minutes. The emergency team is comprising 7 rescues workers on 3 vehicles i.e. inspector car, fire and rescue trucks will be at the site. (Jens Mølgaard head of fire station Esbjerg and SVJB 2015 Report)

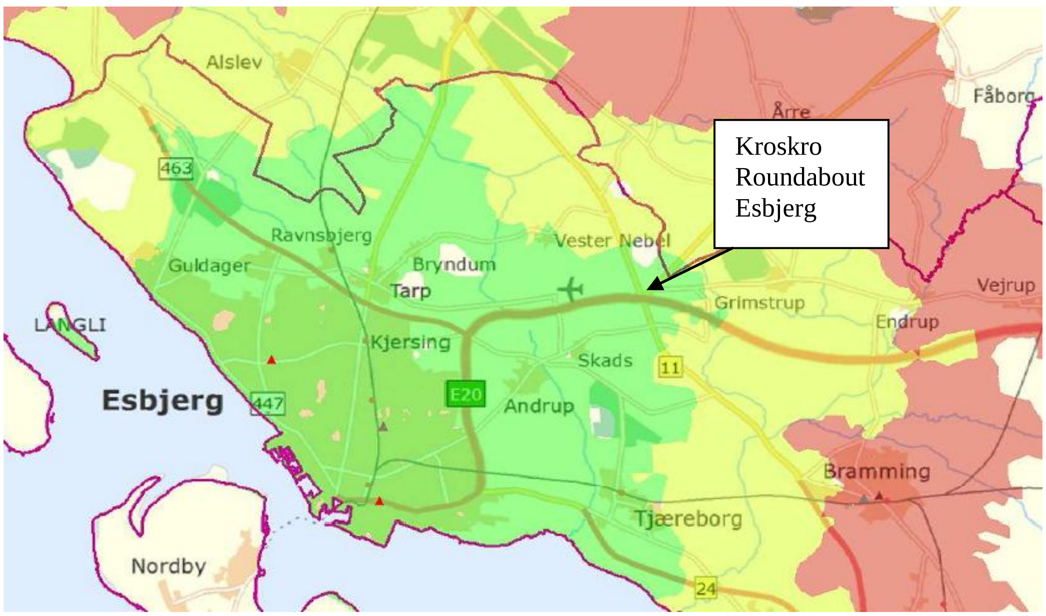

Figure 7 Esbjerg Fires Station Response Time to Emergency Call

Source: Sydvestjysk Brandvasen 2015

The green area of the map shows a response time of 10 minutes while yellow area's represents 15 minutes of response time. According to the above figure accident site of Kroskro roundabout is located in green area and it has a response time of 10 minutes.

Scenario II

The hypothesis outline of this second scenario is as following,

112 is called an inspection team is send to inspect the emergency. This team assess and initiate rescue, however not fully equipped and without support, if the emergency is assessed to be serious an extra rescue team is called. Result (hypothesis): prolonged recovery phase and increased risk of added injuries and economical loss.

This scenario primarily depends on the intensity of the incident. If the incident results in a major accident then this scenario may not work, whereas in case of small incident where services of rescue and fire trucks are not needed it could be cost effective.

Response time:

1. In case no need for further assistance from fire and rescue trucks

10 minutes for inspector vehicle

2. In case further rescue crew and resources are needed

26 minutes = (Inspector 10 minutes reaching time+ Approximately 1 minute of assessment of the situation + 15 Minutes Fire and Rescue trucks)

2.5 Conclusion

Emergency management cycle is well applied by the Danish authorities. SVJB is the prime response service in Esbjerg to respond to the emergency call at the Kroskro roundabout Esbjerg. In case of the accident the crew from fire station will take 10 minutes to respond it. The first person will be the inspector who will reach at the scene of accident followed by two vehicles i.e. fire and rescue trucks. The emergency medical service will dispatch ambulance from the hospital to treat injured and take them to the hospital. Police in this can coordinate the rescue operation. This is the standard response and emergency management at the first level of emergency management in Denmark. However if the scale of accident is big and there are further resources needed DEMA can assist by providing additional man power and relevant equipments to the local services.

This is the standard procedure however not every time there is a need of all 3 vehicles at the scene of emergency. Therefore two scenarios are considered either by responding as usual or dispatching inspector's vehicle first at the scene of crash to give first aid to injured if needed and deciding further after his initial assessment whether there is a need of more resources at the site or not. This could be cost effective but with a compromise on safety since this will delay the response of rescue and fire trucks from 15 minutes to at least 26 minutes. But for the purpose of application of the case of an accident at Kroskro this report first analyses and finds which scenario is better. The next chapter of this report deals with it.

Chapter 3

3. Analysis of Traffic Accidents and Casualties

In scenario I, emergency management responds with full capacity according to standard procedure whereas in scenario II only inspector vehicle goes to the accident site for assessment and decides for further action. In reality there is a big difference in scenario I and II. In this chapter comparison between scenario I and II is made to see which scenario is better, whereas rest of the report suggests alternatives either to replace inspector vehicle for fast response and quick provision of first aid because fire and rescue trucks cannot be replaced by other possible alternatives such as drones and helicopters they can only assist whole crew.

For the purpose of knowing which scenario is better between scenario I and scenario II. There are following two objectives to be considered.

- Health and safety of persons involved in an accident.
- Selecting a scenarios that is cost effective.

According to Jens Mølgaard SVJB there are around 5 accidents a year near Kroskro round about and the municipality's emergency response crew consisting of 7 persons on 3 vehicles is sent to the accident site if the number of persons involved in accident are up to 5. This situation is considered for this report, however if more than 5 persons are involved then the rescue crew and response is increased accordingly depending on the scalability of the accident . In order to have comparison between two scenarios following calculations and aspects are determined in this chapter.

- Traffic accidents. What does it mean?
- Statistics of traffic accidents in Denmark.
- Statistics of casualties due to accidents in Denmark.
- Esbjerg accidents and casualties.
- Estimated number of accidents in Esbjerg in 2017-18 based on historical data
- Probability of casualties
- Application of Multinomial distribution for determining casualty scenarios
- Most probable event is taken under consideration for Scenario I and II.
- The economic costs of this most probable casualty scenario to the society
- Selecting scenario based on quickness as well as cost effectiveness and most importantly safety parameters.

3.1 Traffic Accidents in Denmark

Traffic accidents are common around the world and thousands of people get killed in accidents on roads every year. Basically "traffic accidents" means accidents on roads involving at least one vehicle. According to Statistics Denmark glossary comprehensive definition of traffic accidents is follows,

''Accidents occurring on a public road. square. etc.. in connection with traffic where at least one of the parties involved in the accident was driving a vehicle''

There could be many causes of traffic accidents such as unintentional human actions or human mistakes as well as technical faults of vehicles or a mere combination of both that leads to an accident. Moreover several other indirect causes could also result in accidents due to bad weather or intentional actions like terrorism and vandalism etc.

Fortunately in Denmark traffic accidents seldom involve more than a few people killed or injured even though traffic accidents on the roads frequently happen. Traffic accidents causes financial as well as human losses such as deaths, physical injuries with psychological consequences for both survivors and their families.

Major transport accidents can also cause wide-ranging material damage. Repairs and cleanup after transport accidents can thus be a matter of great expense. If the damage necessitates prolonged traffic diversion or alternative transport arrangements, this typically also requires significant costs. Besides deaths, injuries and material damage, transport accidents can bring about environmental consequences in form of pollution. Transport accidents carrying dangerous substances can have serious consequences for life, property and the environment. Finally a discontinuation of road for a lengthy period of time can badly affect the population and business alike (DEMA 2013).

Denmark hasn't observed sever accidents for a long time which marks its better safety standards however a day in February 2001 recorded a major accident. Due to negligence of a double-decker bus driver resulted in two deaths and 10 seriously injured when the driver crashed the bus into Knippels Bridge at Copenhagen (DEMA 2013).

Denmark has not only observed less major accidents but the good point to be noticed is that both number of accidents and casualties are being reduced significantly in recent years. The reasons are better safety and check control such as speed-reducing devices, speed limits, spot checks and better signposting.

To meet the objectives of road safety as laid by EU, Danish authorities have set the goal of decreasing number of casualties suffered on road accidents of 2010 to halve by year 2020.

‘‘*We aim to halve the number or deaths. serious injuries and minor injuries on the roads in 2020 compared to 2010. In 2020 there should be no more than 1000 road users seriously injured on Danish roads. In 2020 there should be no more than 1000 road users suffering minor injuries on Danish roads’’ (*Danish Road Safety Commission 2013).

Its encourging to observe the decreasing trend of casualities on the Danish road as depicted in following table.

Table 4 Interim Targets Adopted for the Individual Years

Years	2012	2013	2014	2015	2016	2017	2018	2019	2020
Deaths	167	161	155	149	144	138	132	126	120
Serious Injuries	1952	1833	1714	1595	1476	1357	1238	1119	1000
Minor Injuries	1659	1577	1494	1412	1330	1247	1165	1082	1000

Source: Danish road safety commission 2013

Danish road safety commission is optimistic to achieve target of road safety based on the statistics of above table.

3.2 Casualties of Road Accidents in Denmark

The meaning of a serious or minor injury resulting due a traffic accident is subjective. However it is perceived that serious injury could be an injury that is life-threatening and it can also cause permanent impairment/damage. The definition of casualties is:

*‘People who die within 30 days as a result of a traffic accident count as people killed in traffic. Those included in the police report under bodily injury and any type of injury other than “minor injuries only” count as seriously injured’ (*Danish Road Safety Commission 2013)

3.3 Who gets hurt on Danish roads?

The statistic of year 2010–2011 of Danish road safety commission shows that 475 road users were killed in accidents. Moreover the Danish police figures tells that 8,192 persons either injured seriously or minor during the same period. These casulities had following modes of transport as depicted in the following figure.

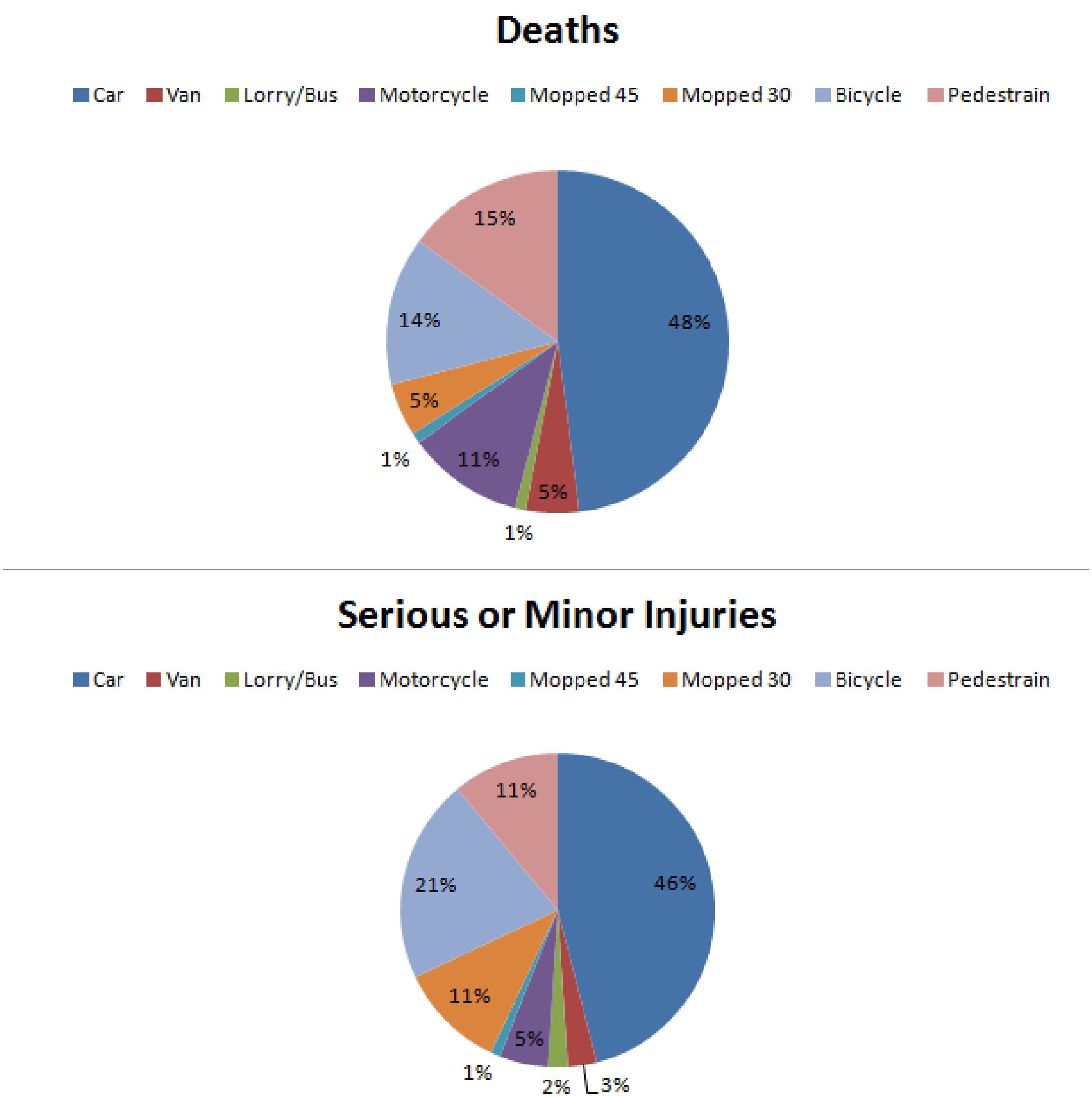

Figure 8 Casualties on Danish Roads According to Modes of Transports

Source: Pie Diagrams developed based on Statistics of Danish Road Safety Commission (2013)

These diagrams depicts the largest number of deaths and injuries occurred in passenger cars on Danish roads as it is the commonest mode of transport on the country's roads. Drivers of vehicles killed or injured had the percentages according to type of vehicles as 48% Car 5% Van 1% Lorry/Bus 11% Motorcycle.(Source: Danish Road Safety Commission 2013)

3.4 Road Traffic Accidents in Esbjerg and It's Outskirts

As mentioned in the above section Denmark is following the EU's road safety's objective, and its target is to halve the number of accidents and casualties by 2020. As a result of this objective, the number of traffic accidents are declining in the whole country including South West region of Esbjerg. The detail of road traffic accidents by Esbjerg is shown in the following table and graph.

Table 5 Road traffic accidents by region and time

Year	Road traffic accidents by region and time	Year	Road traffic accidents by region and time
1998	173	2007	131
1999	166	2008	86
2000	189	2009	117
2001	168	2010	88
2002	153	2011	96
2003	147	2012	87
2004	115	2013	54
2005	133	2014	74
2006	133	2015	75

Source: Statistics Denmark, Road traffic accidents by region and time 2016

It is depicted in table 2 that the number of accidents dropped from 173 in 1998 to only 75 in 2015. For better presentation of the road traffic accidents the following figure 9 is developed.

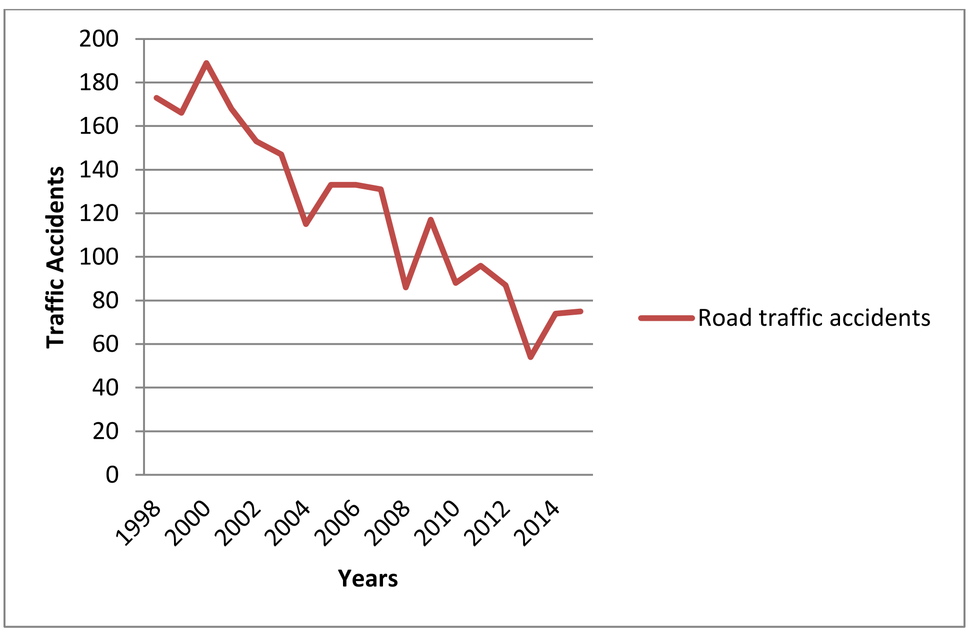

Figure 9 Yearly 1998-2015 Road Accidents in Esbjerg

Reference: Graph is based on data of Statistics Denmark

In the above graph on X-axis number of road traffic accidents while on Y-axis number of years are shown. In Esbjerg the number of road traffic accidents have also a declining trend. This shows negative relationship between road accidents and number of years.

3.5 Estimation of Road Traffic Accidents in Esbjerg for Year 2017

For the purpose of investigation and analysis of this report estimated number of accidents and probabilities of causalities for year 2016 and 2017 are needed. This is done in accordance with the statistical method of estimation and regression (R E. Walpole. Raymond H. Myers. Sharon L. Myers and Keying Ye 2012).

The time span for the data in the table 5 ranges from 1998 to 2015. For this project, first estimation of accidents of 2017 is required and then relevant probabilities are calculated in this part of the report. For this purpose, time series regression model is used. Road traffic accidents are regressed over time. The regression equation is as follows:

$$Road\ Traffic\ Accidents = \alpha + \beta * Years$$

Regression analysis is used to develop a functional relationship between the dependent variable being forecasted and one or more independent variables. In time-series regression models, the only independent variable is time (Hesham K. Al-Fares and Salih O. Duffuaa, Page 163). In the above equation, *Road Traffic Accidents* is explained variable whereas *Years* is the sole explanatory variable. The parameters α and β are respectively called the intercept and the slope of this line. Regression analysis is the process of estimating these parameters using the least-squares method. This method finds the best values α *and* β that minimizes the sum of the squared residuals. Regression result are shown in the following table.

Table 6 Regression Relationship between traffic accidents and time

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	*187.58*	*6.84*	*27.44*	*0.00*
Years	*-6.97*	*0.63*	*-11.03*	*0.00*

Regression equation with goodness of fit:

$$Road\ Traffic\ Accidents = 187.58 - 6.97\ Years$$

$$r^2 = 0.8838$$

In the above equation there is negative relationship between road traffic accidents and years. It means that with every passing year the number of road traffic accidents are decreasing. The decreasing number of road traffic accidents is also the objective of EU.

r^2 is the goodness of fit. It means that 88 percent of variation in the dependent variable is due to independent variable. Both intercept and slope are highly significant on 95% level of confidence, which is shown from *t Stat* and *P-value*. There are 18 number of observations.

In 2017 there will be 48 number of accidents calculated follow:

$$Road\ Traffic\ Accidents_{17} = 187.58 - 6.97\ Years$$

$$Road\ Traffic\ Accidents = 187.58 - 6.97 * (20)$$

In this equation number 20 is used for 2017.

$$Road\ Traffic\ Accidents = 48$$

Estimated number of accidents will be *48* in 2017.

3.6 Estimation of Casualties in Esbjerg For 2017

In the above section road traffic accidents are discussed, in this section casualties due to road traffic accidents are analyzed. Not only road traffic accidents have decreased significantly since 1998 there is also a declining trend of number of casualties. For the purpose of investigation and analysis of the report there is a need to know the number of casualties for year 2016 and 2017. Therefore the number of casualties for these two years are estimated by regression method in the following table.

Table 7 Yearly Causalities Due to Traffic Accidents in Esbjerg

Years	Total Casualties	Killed	Seriously injured	Slightly injured
1998	208	15	69	124
1999	228	13	114	101
2000	255	8	110	137
2001	216	10	94	112
2002	184	8	91	85
2003	188	8	88	92
2004	156	8	70	78
2005	165	4	90	71
2006	169	7	73	89
2007	162	7	88	67

2008	107	3	51	53
2009	139	6	64	69
2010	96	4	46	46
2011	110	6	53	51
2012	102	7	49	46
2013	61	1	32	28
2014	83	2	47	34
2015	86	7	42	37

Source: Statistics Denmark. Injured and killed in road traffic accidents 2016

It is clear from the above table, that number of casualties have dropped significantly. In 1998 there were total 208 casualties recorded, among them 15 people were killed, 69 were seriously injured and rest were slightly injured. In 2015 number of casualties dropped to 86, among them 7 persons were killed, 42 were seriously injured and 37 were injured slightly. For better presentation of casualties data the following graph is produced.

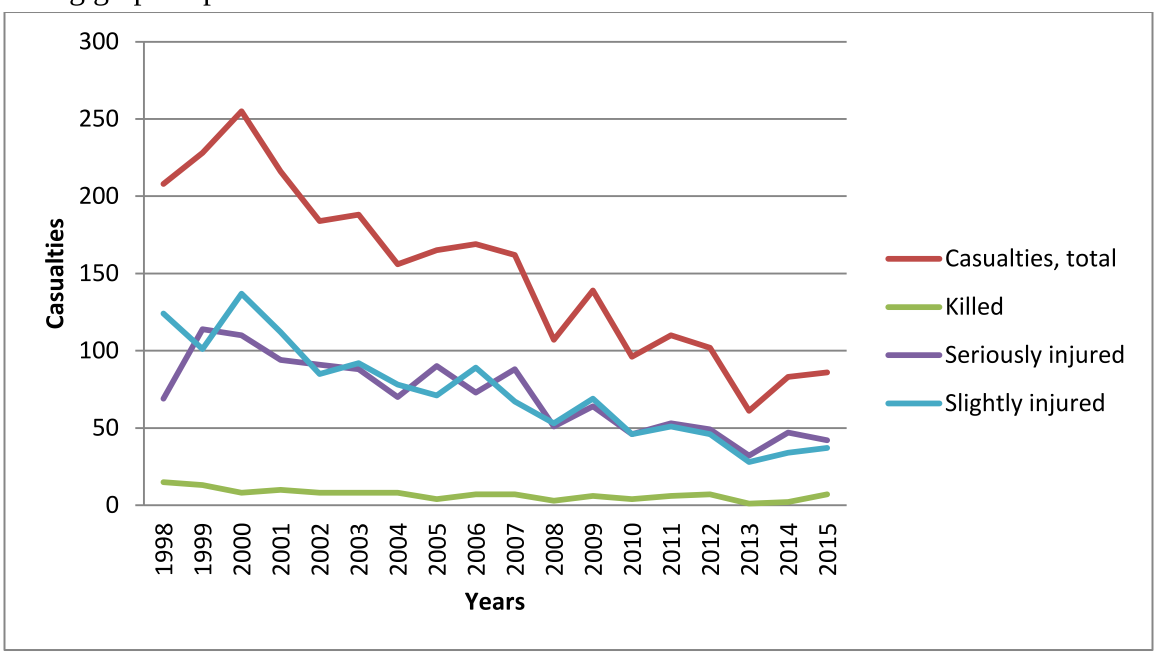

Figure 10 Total Casualties, Killed, Seriously and Slightly Injured Persons in Road Accidents in Esbjerg and Outskirts

Source: Graph is Based on Data of Statistics Denmark 2017

In the above graph, on X- axis number of casualties are shown and on Y-axis number of years are shown. Trend in casualties is also decreasing.

In the last section, estimated number of accidents for 2017 is calculated. In this section casualties for 2017 are projected. For casualties projection, once again regression model is used (R E. Walpole. Raymond H. Myers. Sharon L. Myers and Keying Ye 2012). Regression equation is as follows:

$$Casualties_{17} = \alpha + \beta * Road\ Traffic\ Accidents_{17}$$

It is shown from the above regression equation that *Casualties* are dependent on *Road Traffic Accidents*. Detail of the regression results are shown in the following table.

Table 8 Regression relationship between accidents and casualties

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	*-19.56*	*6.33*	*-3.09*	*0.01*
Road traffic accidents	*1.40*	*0.05*	*28.23*	*0.00*

$$Casualties_{17} = -19.56 + 6.33 * Road\ Traffic\ Accidents_{17}$$

$$Casualties_{17} = -19.56 + 1.40 * 48$$

In the above equation $-19.56\ and\ 1.40$ are intercept and slope. Both intercept and slope are significant on 95% level of confidence. The digit 48 is the estimated number of road traffic accidents for 2017. Based on the road traffic accidents, number of casualties will be:

$$Casualties_{17} = 48$$

To got per day probability of casualties, this estimated number is divided by 365 and converted into percentage.

$$Per\ day\ Probability\ of\ Casualties_{17} = 48/365$$

$$Per\ day\ Probability\ of\ Casualties_{17} = 13.19\%$$

There is 1.4% (5 accidents per year/ 365) probability (SVJB 2017) that there will be an accident on Kroskro on a given day and in that accident there will be 13.19% probability of casualties and there is 86.81% chance that no one will get hurt.

There is a need to split the casualties probability into killed, seriously injured and slightly injured. For this regression method is used separately for killed, seriously injured and slightly injured.

3.6.1 Regression Relationship between Killed and Road Traffic Accidents

First of all, relationship between killed and road traffic accidents for 2017 is calculated.

$$Killed_{17} = \alpha + \beta * Road\ Traffic\ Accidents_{17}$$

In this equation number of killed persons are dependent on road traffic accidents. The regression relationship is shown in the following table.

Table 9 Regression relationship between accidents and killed

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	*-1.40*	*1.81*	*-0.77*	*0.45*
Road traffic accidents by region and time	*0.07*	*0.01*	*4.81*	*0.00*

$$Killed_{17} = -1.40 + 0.07 * Road\ Traffic\ Accidents_{17}$$

In the above equation $1.40\ and\ 0.07$ are intercept and slope of linear regression equation. Slope is significant on 95% level of confidence but not the intercept. Estimated number of killed persons due to traffic accidents in 2017 will be:

$$Killed_{17} = -1.40 + 0.07 * 48$$

In this equation 48 is the estimated number of traffic accidents calculated in the previous section.

$$Killed_{17} = 2$$

On a given day, approximately 2 persons will be killed in road accident. To get the per day probability of killed persons, this estimated number is divided by 365 and converted into percentage.

$$Per\ day\ Probability\ of\ Killed_{17} = 2/365$$

$$Per\ day\ Probability\ of\ Killed_{17} = 0.52\%$$

3.6.2 Severely Injuries Due To Road Traffic Accidents in Esbjerg

In this section relationship between severely injured and traffic accident will be explored. For the regression model is developed as follow:

$$Severely\ injured_{17} = \alpha + \beta * Road\ Traffic\ Accidents_{17}$$

Table 10 Regression relationship between accidents and seriously injured

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	*2.62*	*8.09*	*0.32*	*0.75*
Road traffic accidents by region and time	*0.56*	*0.06*	*8.82*	*0.00*

$$Seriously\ injured_{17} = 2.62\ +\ 0.56 * Road\ Traffic\ Accidents_{17}$$

$$Seriously\ injured_{17} = 2.62\ +\ 0.56 * 48$$

In the above equation $2.62\ and\ 0.56$ are intercept and slope, it can be seen from above table that slope is statistically significant on 95% level of confidence whereas intercept is not significant. As mentioned above that 48 is the estimated number of road traffic accidents in 2017 and severely injured will be

$$Severely\ injured_{17} = 30$$

$$Per\ day\ Probability\ of\ Seriously\ injured_{17} = 30/365$$

$$Per\ day\ Probability\ of\ Seriously\ injured_{17} = 8.12\%$$

3.6.3 Slight Injuries Due To Road Traffic Accident in Esbjerg

In this section relationship between slight injuries and road traffic accidents are discussed. To show the relationship between these two variables regression model is developed as follow:

$$Slightly\ injured_{17} =\ \alpha + \beta * Road\ Traffic\ Accidents_{17}$$

The regression relationship is shown in the following table.

Table 11 Regression relationship between accidents and Slightly Injured

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	*-20.78*	*6.27*	*-3.32*	*0.00*
Road traffic accidents by region and time	*0.78*	*0.05*	*15.75*	*0.00*

It is shown in this table that both intercept and slope are significant.

$$Slightly\ injured_{17} = -20.78 +\ 0.78 * Road\ Traffic\ Accidents_{17}$$

$$Slightly\ injured_{17} = -20.78 +\ 0.78 * 48$$

$$Slightly\ injured_{17} = 17$$

$$Per\ day\ Probability\ of\ Slightly\ injured_{17} = 17/365$$

$$Per\ day\ Probability\ of\ Slightly\ injured_{17} = 4.55\%$$

Now all relevant probabilities of killed, seriously injured and slightly injured are calculated in and are shown in the following table.

Table 12 Probability of Casualties

P(Killed)	0.52%
P(Seriously Injured)	8.12%
P(Slightly Injured)	4.55%
P(Casualties)	13.19%
P(No Casualties)	86.81%

In the above table probabilities of casualties (killed, seriously and slightly injured) and no casualties are shown. The probability of no casualty is very high.

3.7 Casualty Scenarios of 5 Persons Involved in Accidents

It is assumed that there will be an accident at Kroskro. In that accident 5 people are involved. As in table 12 illustrated, there is 0.52% probability that someone will get killed and 8.12 % probability someone will get seriously injured and 4.55% probability that someone will get slightly injured. These casualties data is applied on Kroskro roundabout as an example for the purpose of findings of this report. However it can be used for analyzing other traffic accidents in other parts of Esbjerg. Now there is a question among five involved people what is the probability that all five will be killed, or injured seriously or slightly

There could be different casualty scenarios of the five persons who are involved in accident. There could be several scenarios of how many persons are killed or suffers injuries and with what intensity. In order to determine total number of scenarios arising from such an accident of 5 persons Multinomial distribution is used.

3.7.1 Multinomial distribution

Application of multinomial probability distribution for determining casualty type is used in this part of the report. Because probability remained constant over the time and outcome are more than 2 therefore multinomial distribution is used (R E. Walpole et al 2012).

Table 13 Multinomial Distribution for Casualties Scenarios of 5 Persons

Sample Space	P(Killed)	P(Severely Injured)	P(Slightly Injured)	P(No Casualties)	Total	Multinomial Distribution
	0,52%	8,12%	4,55%	86,81%	100,00 %	
1	0	0	0	5	5	49,2947542793%
2	0	1	0	4	5	23,0562868806%
3	0	0	1	4	5	12,9260893851%
4	0	1	1	3	5	4,8366627153%
5	0	2	0	3	5	4,3135816173%
6	1	0	0	4	5	1,4733860621%
7	0	0	2	3	5	1,3557936477%
8	0	2	1	2	5	0,6786654163%
9	1	1	0	3	5	0,5513091562%
10	0	3	0	2	5	0,4035122061%
11	0	1	2	2	5	0,3804814660%
12	1	0	1	3	5	0,3090814869%
13	1	1	1	2	5	0,0867386991%
14	1	2	0	2	5	0,0773579801%
15	0	0	3	2	5	0,0711033461%
16	0	2	2	1	5	0,0355919812%
17	0	4	0	1	5	0,0188731911%
18	2	0	0	3	5	0,0176153955%
19	1	2	1	1	5	0,0081139357%
20	2	1	0	2	5	0,0049434746%
21	1	1	2	1	5	0,0045489310%
22	0	0	4	1	5	0,0018644747%
23	2	1	1	1	5	0,0005185119%
24	2	2	0	1	5	0,0004624353%
25	0	5	0	0	5	0,0003530970%
26	2	0	2	1	5	0,0001453472%
27	3	0	0	2	5	0,0001053024%

28	0	0	5	0	5	0,0000195561%
29	4	0	0	1	5	0,0000003147%
30	5	0	0	0	5	0,0000000004%

In the above table, MD stands for Multinomial distribution. There are 30 events of sample space of Multinomial distribution and event 2 is calculated in the following way:

Event 2 calculation

$$\mathrm{MD} = \binom{\mathrm{N}}{\mathrm{x}_1\ , \mathrm{x}_2, \mathrm{x}_3, \mathrm{x}_4} \mathrm{p}_1{}^{\mathrm{x}_1} * \mathrm{p}_2{}^{\mathrm{x}_2} * \mathrm{p}_3{}^{\mathrm{x}_3} * \mathrm{p}_4{}^{\mathrm{x}_4}$$

$$\binom{5}{0\ ,1,0,4} 0.52\%^0 * 8.12\%^1 * 4.55\%^0 * 86.81\%^4 = 23\%$$

In the above equation of multinomial distribution, N represents total number of person involved in this accident, x_1 represent number of person killed, x_2 means number severely injured person, x_3 stands for slightly injured persons and x_4 represents no casualties. Relevant probabilities are represented by p. Probability of occurring this event is 23 percent. Rest of the events are calculated in the same fashion.

Event 1 with probability of 49% resulted with no casualty, which means this is out of scope for the analysis purpose of this report. Because no casualty would mean no losses or human related costs arising due to delayed response.

The second event with probability of 23% is considered for further investigation. In this event 1 person receives serious injuries whereas remaining 4 are safe. The worst event is number 30 in which all 5 persons are killed in accident but the probability of occurring that event is very low. The lives saved from road accidents naturally mean that fewer families have had to deal with the consequences of a road accident. Each accident is not just a tragedy for the individual but also to their immediate family. There are also great costs to society, such as hospital charges, associated with road accidents social security expenditures etc.

The following section explores and analyzes socioeconomic cost of casualties due to traffic accident.

3.8 Average Socioeconomic Costs of Casualties in Denmark

For socioeconomic cost "*transport economic unit prices*" are used. Transport economic unit prices are regularly calculated and updated by DTU Transport and includes key indicators and unit prices to be used for valuation in socioeconomic analyses of the transport sector. (Danish Road Safety Commission 2013)

In transport economic unit prices not only direct costs like hospital expenditures are considered but indirect costs like welfare losses are also included. The welfare loss is a cost that represents a valuation of lost of lives. Based on the transport-economic unit prices 2001, the average socioeconomic costs per casualty on the roads are given in the following table.

Table 14 Average Socioeconomic Costs Per Casualty

DKK per Injury	Per Fatality	Per Severely Injured	Per Lighty Injured
Police and Rescue	3,518	4,423	4,895
Medical Treatment	27,645	330,740	58,467
Net production loss	1,056,793	302,506	153,721
Value of individuals lost of consumption	1,652,932	-	-
loss of human value	5,481,776	212,556	14,472
Total	**8,222,664**	**850,225**	**231,555**

Source: Thomas C. Jensen and Ninette Pilegaard (2015)

In the above table14 five types of costs are shown for casualties, the first cost is related to police and rescue department, that is 3518 DKK for dead person. Similarly expenditures on medical treatment are 27,645 for fatality. The production loss is calculated using lost working days for traffic victims of dead, severely injured and minor injured. Due to injuries or in case of death, the person cannot participate in the labor market, therefore there is 1,056,793 DKK net production loss of a dead person. Consumption means usage of goods and services for the satisfaction. In modern economics, consumption has very important role in the growth of an economy. Consumption is the beginning of economic activities and it has very important role in generating employment and income. Therefore value of individual loss of consumption is 1,652,932 DKK. According to Thomas C et al (2015) the loss of human value is equal to 5,481,776 DKK. Therefore the total cost to the society of one fatality is 8,222,664 DKK and total cost of one seriously injured person is 850,225 DKK. For better representation of the socioeconomic cost of causalities, the following pie chart is developed.

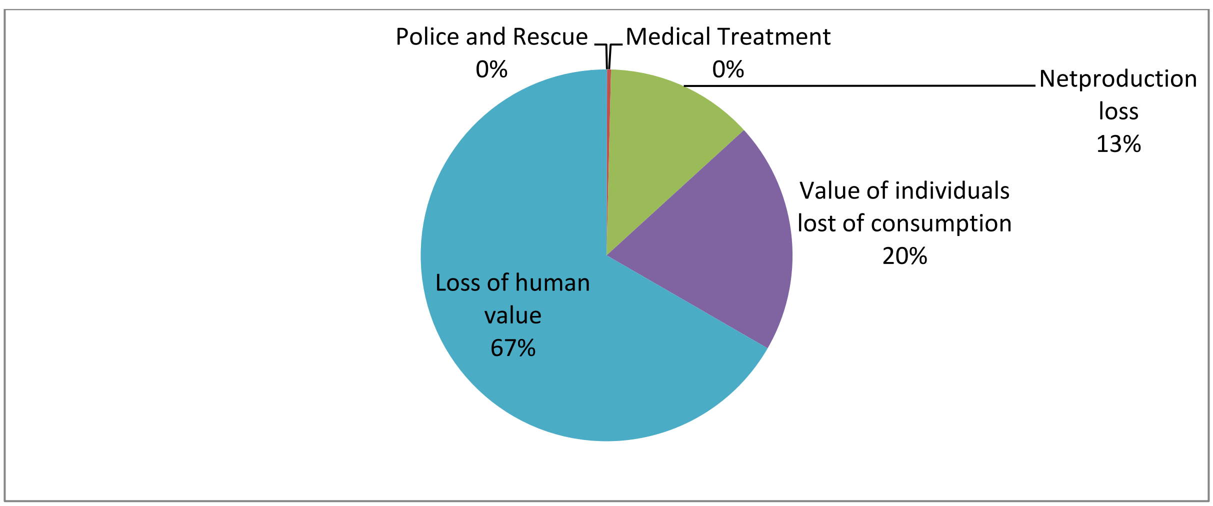

Figure 11 Pie Chart Distribution of Per Fatality Socioeconomic Cost in DKK

The above chart represents per fatality socioeconomic cost of per fatality. From the total cost of one fatality, 67 percent belongs to loss of human value, whereas cost related to police and rescue is 0.4% of the total cost. So by saving less than 4,423 DKK in police and rescue for not sending the full rescue crew in scenario II may result in cost of 8.2 million DKK
The Danish data is somewhat closer to US economic costs of fatalities due to traffic accidents. In US lifetime economic cost to society for each fatality due to road accident is $1.4 million. And the economic costs of emergency medical services account for less than 1 percent that is almost negligible comparing total economic cost of lost live due to a traffic crash as depicted in the following figure. (Blincoe, L. J.et at 2015).

The injury related costs are divided among municipalities, regions and the state, as shown in the following pie chart.

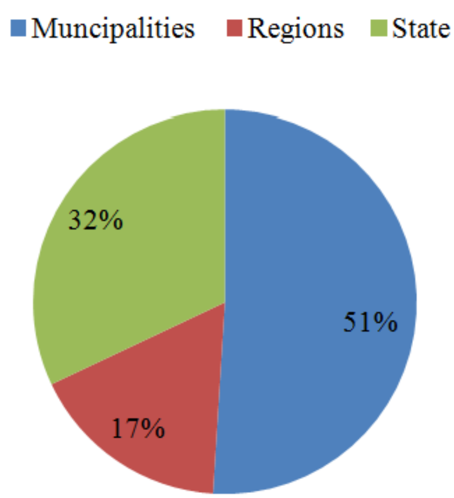

Figure 12 Chart Distribution of Cost Related to Casualties Among Danish Authorities

Source: Danish Road Safety Commission (2013)

It can be seen that the municipalities bear 51 percent of the costs associated with injuries on the roads. This is because many of the seriously injured victims of road accidents are granted early retirement pensions after a number of years, which are largely funded by the local authorities. The local authorities also pay part of the costs of hospital treatment. The remaining expenses are split roughly one-third to the state and one-sixth to the regions. which only pick up costs associated with hospital treatment. (Danish Road Safety Commission 2013)
Since the cost of one serious injured person is 850,225 DKK the Esbjerg municipality has to bear the 51% cost of for this one serious injured person which is 433,615 DKK.

Cost under both scenario for Esbjerg Municipality is 433,615 DKK for seriously injured person. In Scenario I all vehicles are dispatched whereas in scenario II initially only inspector responds and reaches at Kroskro roundabout. Though inspector can give professional first aid to the injured person, but if the inspector needs further assistance, fire and rescue trucks will further take 10 to 15 minutes to reach at site. To save the amount of around 4000 DKK by not sending rescue vehicle and fire truck at the scene of accident SVJB is compromising on safety which may result fatality. Mere saving little amount of up to 4000 DKK can cost Danish authorities up to 8.2 millions in socio economic loss due to death of a person. Similarly if seriously injured person suffers brain injuries he may need first aid in less than 10 minutes to sustains life whereas in case of cardiac arrest he needs first aid within 4-6 minutes. (Alec Momont, 2016). Due to more severe trauma, blood loss, cardiac arrest, stroke, etc. injured person can die in fairly short time. (Dan Birchall 2014) In case of a traffic accident a person may face cardiac combustion for example due to a trauma caused by steering wheel, pulmonary oedema or due to excessive blood loss. (Bartosz Puchalski et al 2014) And treating a trauma cardiac arrest is crucial within first 5 minutes to save the live. (SCA) In such cases both scenario needs to respond faster.

3.9 Conclusion

In this chapter, regression analysis is used to analyze and forecast traffic accidents and causalities Regression analysis assisted us in calculating the probabilities of traffic accidents and casualties. Casualties probabilities are used for multinomial distribution. Multinomial distribution concludes that in case of an accidents at the Kroskro, one person will be seriously injured whereas rest of the four persons will be unhurt. Furthermore seriously injured person's socio economic cost is added to see the economic impact of seriously injured person on Esbjerg municipality. One seriously injured person will cost 433,615 DKK to Esbjerg municipality whereas as a whole to society that seriously injured person will cost 850,225 DKK. It is very important to save seriously injured person life both legally and economically. If by any mean that severely injured person dies, the cost to the society will increase 8,222,664 DKK. Therefore it is very important to make quick response to save injured person life. In both scenarios inspector can reach at the site in 10 minutes and that injured person can get the treatment after 10 minutes. However under Scenario II it will take another 10-15 minutes times by rescue and fire trucks to reach at Kroskro if there is a need further assistance by these two vehicles

The result of calculations shows that among casualties there is a highest probability that the accident at Kroskro will result in a seriously injury to a person. By seriously injury means the accident was sever and that person is may be trapped inside of car as well as there could be danger of a firebreak out from the vehicle. Therefore there for the purpose of safety the rescue truck that can help release injured person trapped in the vehicle along with a fire truck that can extinguish the fire must be there in shortest time possible. Therefore scenario II poses a danger and compromises on the rule of 'safety first'.

The fire and rescue (FAR) center of SVJB of Esbjerg also turned down the application of Scenario II because of safety being compromised. Furthermore if seriously injured person suffers brain, chest and neck injuries it becomes crucial for his survival to be treated as quick as possible and in less than 10 minutes. For instance for cardiac arrest there is a need to give him a first aid within six minutes. Therefore in order to maximize safety response must further be quick. To make response further quick there is need to induct new technology such as drones that can reach faster than vehicles at the scene of accident in the emergency management system. This is discussed in the next chapter.

Chapter 4

4. Drone Technology for Emergency Response

4.1 Introduction

This chapter of the report explores and describes the alternatives to transportation means of existing traditional emergency management service of inspector vehicle. And assisting rescue and fire trucks with or without inspector vehicle. Helicopter and drone can be alternatives that can reach faster to emergency sites. Drones can be unmanned and manned. It is also important to investigate and analyze the Technological Readiness Level and Life Product Cycles of these new modes of transportation and communication to check their availability and development phases for possible induction into the emergency response service. The incorporation of drones into the system can improve the current systems for maximum safety with less cost because they can be cheap and fast as well.

4.2 Drones and Flying Cars/Objects

Unmanned Aerial Vehicles (UAVs) are basically made and designed to take flights without a pilot as compared to conventional air planes. These drones have a remote unit through which the maneuverability and flights of these drones are controlled, however some very advance UAVs are also controlled and operated from computers rather than being directly by humans. (Liza Brown Filmora 2017). Drone can also be manned with autonomous flight capabilities. Flying cars are also described in this part of the report.

4.2.1 Types of Unmanned Aerial Vehicles UAVs

It's hard to categories a particular set of drones since there are so many varieties of drones in the world that are being used for different applications. The size, design and capabilities of drones vary according to their applications. In the following sections this part of the report has categorized drones into 4 section.

1. Number of propellers of drones.
2. Size.
3. Flying range.
4. Drones with specific equipments

Table 15 Types of UAVs

Number of Propellers			Size	Flying Range	Equipment
Rotory Drone	**Multi-rotor Drones**	Tricopter	Very small	Consumer	With camera
		Quadcopter	Mini	Prosumer	With FPV
		Hexacopter	Medium	Professinal	With GPS
		Octocopter	Large	/	With stabilizers
	Single-rotor Drones	/	/	/	/
Fixed-wing Drones	/	/	/	/	/
Fixed-Wing Hybrid VTOL	/	/	/	/	/

Source: Table developed based on sources: (Liza Brown Filmora 2017 and Andrew Chapman NSW Director of Operations for Australian UAV, 2017)

1. According to Number of Propellers:

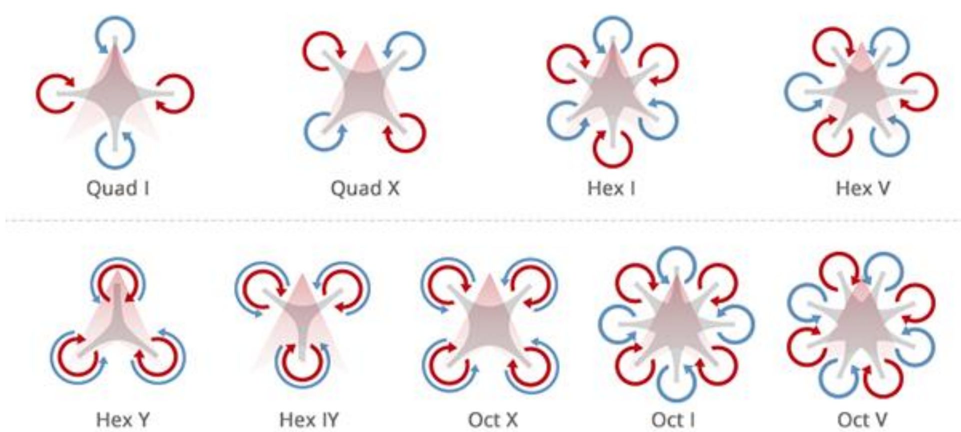

Figure 13 Drones According to Number of Propellers

Source: Liza Brown Filmora 2017

I. Rotary drones

Single Rotor Drone:

Figure 14 Single Rotor Drone

Single rotor drones are the type of drones which is most common construction in rotary type drone. It has a single rotor inside it while another tail rotor that works to control directions. But this drones is does not carry heavy loads.

II. Tricopter

As mentioned by name Tricopter, this type of drones has different types of powerful motors that are inside of it. This drone is made of only one servo three controllers and four gyros. The motors have location sensors. A tricopter stabilizes its path with its classic sensors and electronic stuff.

III. Quadcopter:

This type of drone is equipped with four rotor blades. Two motor of the drones rotate in clockwise direction whereas the rest of two rotate in counter clockwise direction helping to decide a safe landing for quadcopter. A lithium polymer battery powers this drone.

IV. Hex copter:

Hex copter can be used for different applications. This drone has six motors mechanism, three motors work on clockwise direction whereas other three move work in opposite direction that is anti clock wise. Six motors makes this drone to gain higher lifting power as compared to other drones such as quad copters.

V. Octacopter:

This drone has eight motors meaning good power life due to eight functional propellers. This drone is highly stable and has good flying capabilities especially in order to get stable footage recording at any altitude.

VI. Fixed Wing Drone

These types of drones have a wing on them making their appearance look like traditional airplanes. Unlike rotary drones these drones are not able to stand stable in air due to their limited power to fight against gravitational force. The inbuilt battery system capabilities of this drone gives it power to move forward that helps the application of this type of drone is in movement related recording.

2. Categorization According to Size

There could be following types of drones based on their size.

I. Very Small Drones

Ranging from large sized insect to a 50 CM long unit could be classified as very small drones. These can be called Mini Drones and Nano/ Micro Drones based on the way these are designed. Basically tiny drones such as Nano drones have very light weight mostly used for spying purposes.

II. Mini Drones

Micro drones are bit bigger than 50 CM but have maximum 2m dimension making them also small sized. Though most of the drones of this category have design of fixed wings type construction but these drone can also have rotary wings. However due to smaller size these drones do not have much power to have good ranges of pay loads..

III. Medium Drones:

Medium drones are heavier but are lighter and smaller than small aircrafts. The flight time of these drones is 5 to 10 minutes. The pay loads of these drones could be up to 200 KG. UK Watchkeeper is an example of medium drones.

IV. Large Drones:

These types of drones could be compared to size of aircraft being used for military applications by many armies of the world. However, these drones can also be further categorized due to their different capabilities of range and flying. These are mostly used for the operations that are not covered by normal aircrafts usually for the purpose of surveillance. Users can also classify them further into different categories depending upon their range and flying abilities.

3. Drones Classification According to Range

Followings are the types of drones according to the flight range of drones,

I. Very Close Range Drones

With 5 KM fly range and flight time of 20-45 minutes these drones can be equipped with powerful batteries and could also be toy for. Raven and Dragon Eye drones are the examples of this category.

II. Close Range Drones:

These drone can fly up to a distance of 50 KM having a battery power of 1 to 6 hours of flight. Due to good range and longer durations of flights these are used mostly for surveillance purpose.

III. Short Range Drones:

With the flight range of 150 KM of distance these types of drones are better than closed range drones. These drone also have more time of flight of 8-12 hours making them a good option for investigation, survey as well as spy applications.

IV. Mid Range Drones:

Mid range drones can have a range of approximately up to 650 KM. These drones are used for meteorological data collection as well as for surveillance purpose.

V. Drone with Endurance

Figure 15 Drone with Endurance

Drones that have impressive flight time of 36 hours with ability to fly at higher altitudes of up to maximum height of 3000 feet above sea level come under this category. However like most of other drones their application is also surveillance purpose requiring longer hours of non-stop presence in the skies at high altitudes. (Liza Brown Filmora 2017)

Fixed-Wing Hybrid VTOL

These types of drones are has the benefit of fixed wings UAV along with the ability to hover which makes these drones to vertically take off as well as land. These hybrid drones have vertical lift motors that are bolted on them. But these can also be ‘tail sitter’ drones similar to aircrafts resting on their tails on the ground and pointing towards sky for takeoff before these can be pitched over to fly. Hybrid drones can also have ‘tilt rotor’. These rotors can spin from pointing upwards for takeoff or for forward flight these can point horizontally. These were initially developed in 1960s but due to their complexity and difficulty to fly they failed. However with advancement of technology the autopilot can do the hard work to make its flights stable leaving pilots to do easy work of guiding these drones. This type has a long endurance. (Andrew Chapman, 2017 Australian UAV)

4. Drone’s Categorization According to Equipment

Drones can also be categorized according to the equipment they carry as describe in following types.

I. With Camera

A drone carrying a camera for taking classic shots is widely used by camera lovers as well as shooting experts such as film makers around the world. The industry of such drones has seen a sharp fall in the price of these drones due to popularity and wide scale production, these can now be bought with good quality with affordable prices.

II. With FPV

First Person Viewing (FPV) is the application that makes drones to record things like viewers are watching them on real time basis with a sight of control drones by a portable computer. This capability makes them favorable drone for film industry as well as for face to face interview shooting requirements.

III. With GPS

The drone with GPS capability are getting popularity to capture location information. With high stability and ability to come back home after executing their tasks, these drones can be sent to record scenes at any fixed location. These can also record their last shooting location making them more user friendly and supportive in operations.

IV. With Stabilizer

For the enhanced and better flights gyroscope technology is developed for drones. Basically having six axis type drone stabilization feature makes drone to stay more stable in air as well as manage movements at steeper turns. Drones with stabilizers helps users to enjoy easy navigation options due to central flight control mechanism.

Table 16 Pros and Cons of UAVs Drones

Name	Pros	Cons	Typical Uses	Price (DKK)
Multi-Rotor	Accessibility	Short flight times	Aerial Photography and Video Aerial Inspection	25,154-327,007 for pro drones
	Ease of use			
	VTOL and hover flight			
	Good camera control	Small payload capacity		
	Can operate in a confined area			
Fixed-Wing	Long endurance	Launch and recovery needs a lot of space	Aerial Mapping, Pipeline and Power line inspection.	126-603,706 for pro drones
	Large area coverage	no VTOL/hover		
	Fast flight speed	Harder to fly, more training needed		
		Expensive		

Single-Rotor	VTOL and hover flight	More dangerous	Aerial LIDAR (Light Detection and Ranging) laser scanning.	126-603,706 for pro drones
	Long endurance (with gas power)	Harder to fly, more training needed		
	Heavier payload capability	Expensive		
Fixed-Wing Hybrid	VTOL and long-endurance flight	Not perfect at either hovering or forward flight	Drone Delivery	TBD (To be Determined), in development
		Still in development		

Source: Andrew Chapman, 2017 Australian UAV.

The prices are given in Australian dollars and converted to Danish kroner on 15 May, 2017.

Revolutionizing Accident Response through UAVs

UAVs have many types each with its own pros and cons. For that reason different UAVs can serve different purpose in emergency management services. It is to be noted that payloads are not just cameras, in fact it is also possible to put different sensors on drones such as gas and radiation sensors as well as multispectral cameras on drones. This depends that for which emergency response or purpose a UAV is being considered, for instance for surveillance, for search and rescue etc. However UAVs should not be taken as an isolated system instead these should be considered as an integrated part of operations of a system such as emergency management services. (Andrew Griffiths)

Some examples of different UAVs in service or in induction phases of emergency services are described in the following section.

I. Tethered drone for tactical radio network

A High Antennas for Radio Communications-Tethered Drone (HARC-TD) system can help in communications by improving networks and range for radio communicators and first responders. It can provide radio communications as far as 25 miles in all directions regardless of how bad is the terrain and down into valleys and urban canyons. (Jose Antunes 2016 and UAV News 2016)

Figure 16 Tethered Drone for Tactical Radio Network

Source: Jose Antunes 2016

II. Camcopter S-100

Camcopter S-100 a product of Schiebel company based in Vienna is an unmanned helicopter in operations since last few years. It has been used to save lives of thousands of migrant in Mediterranean sea of various operations of NGO Migrant Offshore Aid Stations. (Jose Antunes 2016 and UAV News 2016)

This Vertical Takeoff and Landing (VTOL) UAS has a flying range of 200 km and it can fly in adverse weather conditions carrying different payloads. (Schiebel 2017)

It can carry up to 34 kg of payloads for a flight of up to 10 hours. (Unmanned Systems Australia 2013) However it is too expensive like a helicopter with a price of 400,000 US dollars being used by UAE armed forces for military purposes. (The Future of Things)

Figure 17 Camcopter S-100

Source: Jose Antunes 2016 and UAV News 2016

III. European Emergency and DJI test First Responder

According to the Chief inspector Gary Crowe of Lancashire Fire and Rescue, UK, drones will be used to find missing people (SAR) and get a better view of large blazes. Drones can provide real time footage by saving time, providing information and identifying hazards from distance during an emergency of fire.

European Emergency Number Association (EENA) in 2016 had conducted a research in four pilot sites of Europe to assess and understand the induction of UAVs or Remotely Piloted Aircraft Systems(RPAS) in First Responder emergency management scenarios. (Jose Antunes 2016 and UAV News 2016)

One pilot facility was greater Copenhagen's fire and rescue service (FRS). According to the FRS center of Copenhagen they consider UAVs as a strategic assets in order to get key information, and awareness of the crisis situations. (EENA / DJI Pilot Project Report, 2016) The objective of the project was to evaluate how can first responders take assistance from UAV such as DJI phantom 4.

Figure 18 European Emergency and DJI test First Responder

Source: Jose Antunes 2016 and UAV News 2016

According to the report UAV like DJI phantom 4 can be very useful to find missing persons very efficiently and quickly. UAV was used to search a missing person in a terrain of river and marsh area. By using thermal camera the missing person was found in 15 minutes and police was assisted to reach that person. It would have taken for ground rescue team multiple of this time to find the missing person.

Moreover during a case of danger of chemicals these can be efficiently used for an aerial perspective over burning buildings. Hot spots can be detected in case of a fire and first responders can be kept away from danger of heating. However the project found that there is a need for improvement in DJI Phantom's capabilities such as more powerful lifting, powerful data transmission links, integrated software development kits, weather-proof systems as well as flashlights for night flying and payload drop capacity. (EENA / DJI Pilot Project Report, 2016)

DJI Phantom 4 SPECS has maximum flight time of 28 minutes, weight of 1380 g, maximum speed of 72 km/h, maximum transmission range 4.96 KM. (DJI 2017 and Drone World 2017)

IV. Aeryon Labs UAVs Aiding Rescue Operations.

GolbalMedic used UAV of Aeryon Labs for aiding and relief operations in Nepal during earthquake in 2015. These UAVs helped to identify quickly the hardest hit regions of the country by mapping and assisted in damages. In Ecuador Aeryon was used to compile maps by helping risk management to assist them in response and make them aware of emergency situation to take informed decisions. (Jose Antunes 2016 and UAV News 2016)

Aeryon skyranger has a range of 3 km with a speed of 50 km/h with a flight time of up to 25 minutes. Its deployment is VTOL. (Aeryon skyranger 2017) It has a price range of 50,000 to 150,000 US dollars (Approximately 330,635. to 991,906 DKK based on conversion rate of 06 June 2017). (Wanderigracen Wordpress 2011)

V. Drone Ambulance UAV

Unmanned Aerial Vehicles (UAVs) have different speeds and payload specifications and these can also be used for different emergency management rescuing operations. A drone similar to a tricopter has been revealed as an Ambulance Drone prototype by Ale Momont of Delft University. This drone can carry AED defibrillator that could be used for first aiding a person suffering cardiac arrest. AED defibrillator can be applied to both cases of traumatic and non-traumatic cardiac arrests. In case of a traffic accident a person may face cardiac combustion for example due to a trauma caused by steering wheel, pulmonary oedema or due to excessive blood loss. However most of such cases are treatable in especially for young and healthy people. (Bartosz Puchalski et al 2014)

Any bystander close to the victim can also be guided by a rescuer worker who is online handling the drone to assist in first aid. It flies by six propellers with maximum speed of 100 kilometers per hour carrying a payload of 4 kilograms for a distance of 12 km. Its price is approximately 128,923 DKK.

Figur 19 Drone Ambulance

Source: Mark Prigg (2014) DailyMail Online

In European union alone there are around 800,000 people annually who suffer a cardiac arrest and only 8 percent of them survive. This is due to a delayed response time which is on average 10 minutes. (Delft University and Iflscience 2017)

The victims of cardiac arrest can be saved up to 38% if they are provided first aid by using an AED before the emergency response team arrives. (SCA 2017 and Weisfeldt, ML . et al 2010)

A small drone can be used as a drone ambulance as researched by Alec Momomt (2014 Delft University) a lay man is not that good in performing first aid techniques but with the help of instructions through video support between a lay man and the drone operator of emergency response can increase the surviving chances of victim of a cardiac arrest up to 80% . It is estimated that only 20 % untrained layman can successfully apply defibrillators but this can be increased to 90% due to a personalized and timely instructions by a professional emergency management's responsible person. The panic of the situation decreases with the presence of the emergency operator through the speaker of drone. By the inductions of a UAV such as drone ambulance that can provide emergency supplies to victims and can establish a communication in real time between a by stander and operator can surely work.

However the induction of such UAV into the system is a complex process and as rightly said by the innovative institute TU Delft the commercial exploitation of it needs time and resources and they are considering to further develop this whole system. (Iflscience 2017)

Application of Drones for Post Traffic Crash Documentation and Stopping Additional Accidents

UAVs are a faster way to survey traffic accident scenes. Drones can also be used for documentation of the scene after an accident. Documentation of accident scene response by drones benefits in four ways.

- *Drones can work very fast to make documenting accident scenes since it is hard to keep a freeway closed for 5-6 hours due to the investigation. By cutting time spent on roads by 1/5 and measurements taking time to 1/3.*
- *Drone can help reduce financial and human costs by lowering the time spent on collection of data by police* and re-constructionists and resultantly their exposure to traffic also reduces. The crash hazards also poses dangers to drivers on the roads. As it *is evident in the findings of The* Federal Highway Administration (FHWA) that the chances of additional accident increases by 2.8 percent due to every minute an accident continues to be a hazard.
- *The measurements taken after post crash by the drones can be provided as an evidence in the court. Documentation by drones makes data collection easy that needs less training skills required with the possibility of broader accessibility.* (Pix4D , Medium, (2016)

Figure 20 Application of Drones for Post Traffic Crash Documentation

Source: Jose Antunes 2016 and UAV News 2016

Summary

Different types of drones can serve different purposes depending on their configuration and what equipment they can carry.

As concluded in the third chapter there will be one person severely injured in case of a traffic crash at Kroskro. For the application of this case to drones, only one UAU can be dispatched to deliver first aid toolkit or AED deliberator along with a live video instruction by a professional for a long distance of 8.92 km. Drone Ambulance UAV seems best comparing others to serve this emergency situation. Most of the other drones are suitable for surveillance, SAR operations or fire emergencies because these drones are equipped with cameras and sensors etc but cannot take a pay load of up to 4 kg that is crucial to reach to the injured person. Or if they can carry payload of more than 4 kg like Camcopter S-100 then there are other things for considerations that make them not suitable. For instance Camcopter

S-100 is way more expensive than Drone Ambulance and DJI Phantom 4. And also it has not been used or tested like the later two drones for emergency responses like fire and delivering medical equipments in case of a traffic accident etc. Moreover its minimum price is about 2,700,000 DKK while a light helicopter like Robinson R44 costs about 2,600,000 with capability of carrying 3 persons and having higher speed, it is discussed in next chapter for this report. This makes helicopter a better option than using Camcopter S-100 in rescuing operation like Kroskro traffic crash. DGI Phantom 4 has not been tested and considered for accidents crash and its maximum range is 5 km. Its speed of 72 km/ is also slower than 100 km/h than Drone ambulance. DJI Phantom 4 is cheaper than Drone Ambulance but saving a person life is important as well as saving a person's life benefits more in economic terms to the society than the cost of buying a Drone Ambulance worth approximately 128,923 DKK. Furthermore a professional controller of drone ambulance can talk to the injured person or bystander at the scene of accident to guide them applying CPR or using first aid kit and AED defibrillation etc. He can make the emergency situation less traumatized and panicked by speaking to the bystander.

4.2.2 Manned Drones

There are different types of manned drones in different stages of development. Some drone have design and similar kind of capabilities and some have designs that look like aircrafts. Mankind has had a dream of having flying car for decades. A flying car can also be categorized under this category if it can fly and drive autonomously.

By the start of 2017 following 5 designs of manned drones were in different cycles of innovation and production.

I. Ehang-184

Ehang is one of the world's leading tech company in the field of making intelligent aerial vehicles. The company announced an innovative product, a manned drone named Ehang-184. This is an eco-friendly autonomous aerial vehicle with short-to-medium distance flight capability at low altitudes claimed by the company. (Ehang 2017)

Figur 21 Ehang 184

Source: Ehang May 2017

This is the first manned drone of the world that is about to start operations from July, 2017 in Dubai. The Road and Transportation Agency of Dubai has approved plans to launch in accordance the ruler of Dubai who set the target for UAE by 2030 to have 25 percent of passengers to commute by driverless.

This Ehang 184 has relative small size comparing helicopters but an human can easily sit in to take flights. This is manufactured in Chine and has already tested its flights in Dubai. The company also has demonstrated and tested 100 successful manned flight in Las Vegas. Basically this first manned drone of the world has not a lot of space to carry but enough space that the passenger can carry a suitcase or bag with him. This drone will be by 4G mobile Internet meaning that the passenger does not need to be trained pilot. However the passenger should have weight does not exceeding 220 pounds. (Fortune 2017)

- This drone can fly with passenger airborne for up to 23 minutes.
- Ehang's 14.4-kWh battery can be charged fully in four hours in trickle mode. It can also be charged in two hours in fast-charge.
- The Ehang's four arms have eight propellers at the end of them.
- Ehang 184 weights 440 lb (200 kg) in total. A pay load of 264 lb (120 kg) can be carried by it.
- With the maximum speed of 62 mph (100 km/h) Ehang can fly relatively at low altitudes of up to 11,480 ft (3,499 m). (Fortune and Nweatlas 2017)
- The price of Ehang is between $200.000-$300.000 (UAV Coach 2017 and Forbes 2016) around 1,696.353 DDK (Conversion rate as of 15 May, 2017)

This manned drone is getting so popular and it can be used for many purposes that it has already declared a with Lung Biotechnology PBC to automate organ transplant delivery. Lung Biotechnology PBC plans to buy 1,000 units of an evolved version of the Ehang-184. The company specializes in manufacturing lungs and other organs for transplant (The Dailymail 2016)

Lung Biotechnology PBC and Ehang have agreed to work together for next 15 years. During this time both companies plans to optimize the 184 for organ deliveries under a program called the Manufactured Organ Transport Helicopter (MOTH) system.

According to Martine Rothblatt (Ph.D) chairman and CEO of Lung Biotechnology 'We anticipate delivering hundreds of organs a day, which means that the system will help save not only tens of thousands of lives, but also many millions of gallons of aviation transport gasoline annually. The well-known locations of transplant hospitals and future organ manufacturing facilities makes the Ehang technology ideal for Highway-In-The-Sky (HITS) and Low-Level IFR Route (LLIR) programs.' (The Dailymail 2016).

Nonetheless both the firms are facing regulatory problems as Federal Aviation Administration has yet to give approval of the MOTH rotorcraft and also from the U.S. Food and Drug Administration of Lung Biotechnology's xenotransplantation organ products.

According to the CEO of Ehang Mr Huazhi Hu 'This is exactly the kind of global impact we envisioned. Partnering with Martine and Lung Biotechnology is an incredible opportunity to bring the 184 to the emergency medical space, and specifically help to revolutionize the organ delivery system in the U.S. It's also representative of our broader dedication to making the EHang 184 and its commercial drones readily available to a number of different industries today.' This initiative can help save thousands of lives in future.

II. Volocopter vc200

German company E-volo has made a drone called Volocopter VC200 that can take flights having a passenger inside of it, however it can be flown by unmanned as well as remotely or autonomously.

Figur 22 Volocopter vc200

Source: Volocopter March 2017

This manned drone is the world’s first certified Multicopter. Basically this drone functions more like helicopter. Flying and piloting by humans is not going to be an issue since learning to pilot vertical takeoff and acquiring landing skills is less costly and time demanding process of flying lessons. This makes flying with drone easy and accessible for many people.

Volocopter can be flown by a pilot through joystick and another person can sit beside him in this two seater drone. It has a good level of safety that takes the control of drone in case of failure of some units and any flying error claimed by the company E-volo.(Volocopter 2017)

On November 17, 2013, Volocopter VC200 had made its maiden flight and its flights were tested. 18 electrically driven rotors of the drone makes its flight possible. (Damir Beciri, RobAid 2013)

Desired Volocopter VC200 aircraft performance is as follows,

- It should get the speed of at least 100 km/h.
- The drone can fly at a maximum altitude of up to 6500 ft.
- It will be able to lift maximum weight of 450 kg.
- It is expected to have an hour of flight time.
- There is a roam for two persons to take flight inside of Volocopter by sitting side-by-side.

However, E-volo accepts that it has not yet achieved the performances it claims but the objectives of the drone are quite getable.

4.2.3 Flying Cars

Another potential alternative to inspector's car could be flying cars in future. Since the invention of cars and aircrafts humans have urge and tried for making cars that could also fly. There are many companies which are working on this idea of flying car.

The Airbus has recently announced making this idea possible but their work is at initial stage and no prototype has yet been made. In this regard the closest company that has managed to demonstrate and make a prototype is a Slovakian company, The AeroMobil s.r.o. That made a flying car aircraft AeroMobil 3.0.

I. AeroMobil 3.0

AeroMobil is basically a great mixture of existing infrastructures made for planed and automobiles. This can be used as a car that runs on regular gasoline and as a plane it can takeoff and land like a aircraft on any grass strip or proper paved surfaces consisting of dew hundred meters long.

Figure 23 AeroMobil

Source: Aero Mobil 2017

The AeroMobil 3.0 has regular flight-testing program since October 2014. It is built with composite material comprising of its body shell, wheels and wings. Its equipped with avionics, a parachute deployment system for safety back up and autopilot. The builders of this flying car are progressing to improve the prototype. Therefore the market price at which they would like to sale it, has not been announced yet. However a Private Pilot License (PPL) will be needed to fly this flying car beside a standard car driving license. The company hopes to start taking orders of the car by this year 2017.

- AeroMobil 3.0 has a top speed of around 99 mph on the roads with capability of an airspeed of 124 mph.

- It is a two seater car meaning two persons can take flight on it with expectedly good payloads comparable of up to a normal two seater car. (AeroMobil 2017)
- This car have as travel range of up to 700 km (430 miles). (AFP *5 June 2015)*
- Its fuel consumption per hour is 15 liters (4 gallons).
- The company expects to deliver its first flying cars orders in 2018.
- It's estimated cost is around 500,000 Euros ($560,000) or around 3,718,796 DKK (conversion rate of 07 June, 2017)

II. PAL-V Liberty

Another alternative of inspector car could be of mix or hybrid of a car and an helicopter like PAL-V Liberty. Only 90 vehicles of this car will be sold worldwide by its maker, the Pioneer Edition. The prototype of this has been tested and run. Therefore the manufactures claims to call it the first certified commercial flying car ever delivered.

Figur 24 PAL-V Liberty

Source: Pal-V 2017

The company is taking orders for the two versions of this car. The PAL-V Liberty Pioneer Edition which has personalization reserved option for Pioneer Edition owners only is offered to buyers at price of €499,000. Whereas the the PAL_V Liberty Sport model has been priced € 299,000 which has is the standard version of the PAL-V Liberty. (Pal-V 2017)

The features of PaL-V Liberty are as follows,

- Its minimum price is € 299,000. i.e. around 2,223,917 DDK (Conversion rate of 07, June 2017)

- The company expects to be able to make deliveries in Europe by end of 2018.
- It can be driven by normal car gas, however mogas (light aircraft fuel) is also suitable which is available at airports.
- It requires a a maximum roll of 180 meters/600ft meaning it would be safer to have a runway around 280meters/900ft.
- Take-off weight is limited to 910 kg. (Pal-V 2017)

Some other companies are also developing drone and flying cars. But their readiness level, prototypes or marketing of the product are not as advance as drones described above. Couple of prominent manned drone include one by Agusta Westland company ***Project Zero*** which is basically a unit of Finmeccanica, Italy. This company has made vertical takeoff and landing aircraft that is presented in Singapore's Air show. It is an electric aircraft aimed to eliminated the consumption of fuel. Therefore it can be used in low-to-no oxygen environments that can help in emergency management's services needed close to active volcanoes and it can also be used in an environment such as on Mars.

At the moment this aircraft can have a flight time of 10 minutes. However within a decade with the advancement of electric batteries the management of Project Zero hopes to achieve a flight time of up to 100 minutes. This aircraft can carry only single person or to be used unmanned. AugustaWestland only displayed the prototype named a convertiplane and they did not made its flight in the airshow. (CNBC 15-02-2016)

Project Zero has been tested so far its motor. The company aims to test the flights after installation of motor but it did not give a timeframe for its flight testing. (FlightGlobal 2016)

Airbus has also announced making a drone car. Airbus' new concept is a car, a drone, and a train all in one. This car-and-drone project is given a name Pop.Up by Airbus. However the project is estimated to come into reality not in near future. (The Verge, 7th March, 2017). Therefore it is not being taken into consideration for the purpose of analysis under this section with rest of the above machines due to its very low Technology Readiness Level.

4.3 Technology Readiness Level (TRL) of Drones

In engineering world it is important to assess the readiness and maturity level of any given technology before inducting any technology into system. For this a measurement system called Technology Readiness Levels (TRL) is used. A TRL rating can be assigned to a technology project which is assessed against the parameters of a level. This system is comprised of total nine levels where TRL 1 is the lowest and TRL 9 is the highest level.(NASA 2012)

TRL 1: Under this first level any given project's scientific research has begun. The results of the this initial research are assessed and translated into the project's future research and development.

TRL 2: This is speculative level which lacks of experimental proof. At this level the basic principles of the initial research are studied and then based on this study practical application are applied to the findings of first level

TRL 3: At this level design of the technology begins and research actively takes place. Laboratory and analytical studies are carried out at this level to see if the technology is workable and worth to dig into further development and construction phases. At this level a model of proof of concept is developed.

TRL 4: After the proof-of-concept technology of level 3 the advancement is made in the technology by testing different components of pieces against one another at this level.

TRL 5: At this level the technology goes under thorough testing than at level 4. At this level simulations close to real environment are rune to test the technology.

TRL 6: At this level a representation model or functional prototype of the technology is developed

TRL 7: At this level the demonstration of technology's representation model or prototype takes place in an environment in which it has to be used after final development.

TRL 8: At this level the technology is ready for induction or implementation of the already existing similar technology or system. During this level systems and subsystems are developed. In case of drones , a particular type of that drone is tested and gets a "flight qualified" title.

TRL 9: At this level a technology like drone is flight proven with a successful performance of its operations for which it is developed. (Nasa 2012)

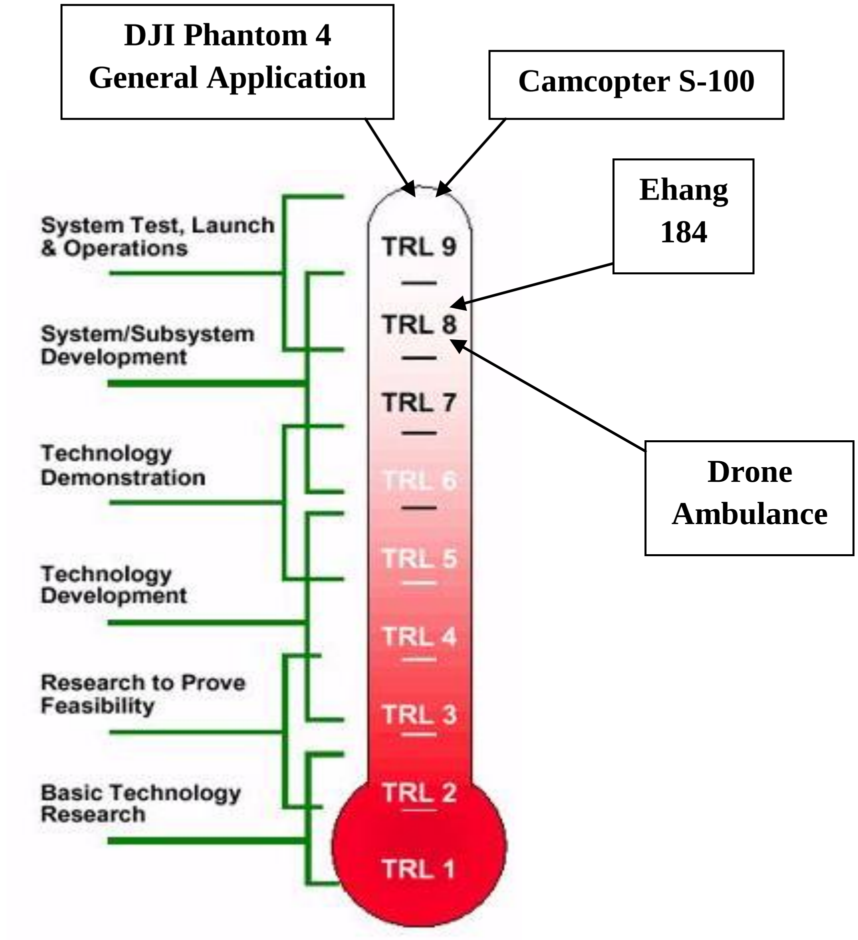

Figure 25 TRL and Drones

Source: The TRL Scale as a Research & Innovation Policy Tool, European Association of Research and Technology Organisations (EARTO) Recommendations, April 2014

I. TRL level of UAVs.

Some UAVs are at TRL 9 such as DJI Phantom 4 for general application and Camcopter S-100. Quadcopter drones like DJI Phantom are widely used for photo shoots and some military drones for surveillance are used by different militaries of the world. However the application of DJI Phantom 4 for emergency response is tested by EENA in piloted projects and it proved its effectiveness and efficiency for emergency responses such as fire and SAR operations but it needs integration into the emergency response services. (EENA Report 2016) The SVJB has a drone but they may use it with the help of a volunteer controller in cases where SVJB might need aerial viewing. (SVJB 2017)

Aeryon Labs UAVs quadcopter is also at TRL 9. Though drone ambulance UAV has been tested and but its induction into the emergency management needs to be done along with its launching and operations, therefore it can be said at that it stands at TRL 8.

II. TRL Level of Manned Drones

Ehang 184 stands at the higher TRL levels than its competitors other manned drones. Because Ehang has over 100 successful tests flights and approval of regulators in Dubai to start operations from July, 2017. While Volocopter VC200 does have prototype successful demonstration and flight tests with the German flying regulatory authority's permission of flights but within confined places only for testing purposes. The makers of VC200 are still making improvements in the systems of their drone and a clear date for sale and operations of VC200 is not been yet announced. Therefore VC 200 stands somewhere at TRL 7 and 8 while Ehang is at TRL 8 and it is going to be at TRL 9 in period of couple of months or so. Therefore Ehang 184 is a clear choice for the purpose of this report for further analysis of its induction in coming chapters.

III. TRL of Flying Cars

While the AeroMobil 3.0 and PAL-V flying cars are at TRL 8 because they are flight proven but without operations and expected date of their sales into the market are around 2018 because it seems like the prototypes of these flying objects are in the further development phase of systems and subsystems.

4.4 History Product Life Cycle

In 1966 an economist Raymond Vernon developed an economic and marketing model called or 'International Product Life Cycle' or 'The Product Life Cycle Stages. According to this model every product has a life cycle that has different stages of **introduction**, **growth**, **maturity** and these end with it decline. (Mulder, P 2012).

The duration of these stages vary a lot, one stage of the product can for short period of time like few weeks to another stage of decades long. A product's marketing instrument play a major role in determining the length of a stage of the cycle as well as the demand of the produce in the market.

Figure 26 Life Product Cycle

Source: (Mulder, P 2012)

I. The introduction stage

At this stage the product is launched and marketed by the company for sales in the consumer markets. Marketing and promotional costs are incurred for the purpose of creating demand for the product. In this stage margins of profits are very low and sales are also low with not many competitors.

Some UAVs are in introduction stage. However as far as drone ambulance is concerned it still in the first stage of development. But it is quite similar to some UAVs that have proven operations brings the confidence that it will soon be in operations if it gets approval by concerned regulators and emergency management services.

Volocopter VC200, PAL-V and Aeromobil 0.3 are in initial stage of innovation and development. These even do not come to introductory stage of Life Product Cycle. However, Ehang 184 seems to be in introduction stage as it is about to start its operation in period of a month and has already contracted to deliver units to Dubai's taxi services as well as up to 1000 units to a US firm for transporting human organs. The company is already expecting more orders. While Ehang is delivering units its competitors have announced the start of order deliveries by 2018. Therefore based on Life Product Cycles, Ehang 184 becomes an obvious choice for further consideration and analysis of its induction in an emergency management system.

II. The growth stage

In this second stage of growth the company introducing the product earns large sums of profits due to increased sales. By seeing the high sales of the product competitors enter the market to sale their products who are similar to this product being sold. However the company increases its spending on marketing to retain the market and compete with competitors who are selling products at lower price. This Product Life Cycle stage the demand for the product increases sales. (Mulder, P 2012).

Most of the UAVs are in growth stage as their demand for using in different sectors is increasing while their cost is reducing due to innovations, economies of scales and competitions. DJI Phantoms drones can be categorized under growth stage. Military drones are also being used by US armed forces for over a decade and their usage and demand by different countries is also increasing.

III. The maturity stage

In the third stage of product life cycle competition is very tough compelling the company to sale the product at low prices as much it is possible. However the product is still famous and consumed/bought by customer still at large scale. At this stage company starts to maximize or retain profits level by producing by-products as well as making innovations to the product. Customer of the company are offered different schemes to retain them loyal with the company by offering even replacing the old products with new ones by foreseeing the decline of demand of the product. (Mulder, P 2012).

Different types of cars and helicopter are used in emergency management's services. These cars and helicopters have their own pros and cons but being old, easily accessible, trusted and proven operational technologies these are widely used around the world. However with the invention and emergence of drones the maturity stage of cars and helicopters is threatened and in matter of few years car and helicopter may face end to their maturity stage.

IV. The decline stage

This is the last stage of product life cycle during which the product is not popular and market has become saturated resulting in less sales. This could be due to some factors like innovative products and new products. However the company keeps producing product for its loyal old customers (Mulder, P. 2012).

For a product to retain market for a longer time it is essential that it has low costs of production and a high demand. A product with low demand and high cost cannot survive for a long time and it starts its decline stage in short period of time.

In future different vehicles and helicopters being used by emergency management services will be called at the verge of declining stage but it has not started yet until drones and flying cars could be able to termed as substitute to these traditional mode of transportation .

4.5 Selection of Drones for Traffic Accident Response at Kroskro Roundabout

Flying cars are expected to start their sales by end of 2018 or during 2019 therefore they cannot be considered for application of emergency response. DGI Phantom 4 stands at TRL but it has not been tested and considered for responding accidents crashes and its maximum range is 5 km. Its speed of 72 km/ is also slower than 100 km/h than Drone ambulance. Therefore UAVs drone ambulance with range of 12 km and tested technology can serve the purpose of a quick response with medical equipment to help save seriously injured person's life. While Ehang-184 is at most advanced stage of TRL and Life product cycle therefore this is selected for further analysis of incorporation of it into emergency systems, therefore response time of these two drones needs to be calculated.

I. Response time of UAV (Drone Ambulance)

If Unmanned Aerial Vehicle (UAV) like Drone Ambulance responds to the emergency call. Its response will be 05:16 minutes.

Response times depends on drone specifications. For this scenario an appropriate drone could be a tricopter ambulance drone which has pay load of 4 Kg carrying first aid tools and medication such as AED defibrillator. This can also provide First View Person (FVP) live video of scene of the accident to its controller. This drone has a speed of 100 km/h (Alec Momont Delft University of Technology (2016). This drone is considered because it is build for emergency response by delivering life saving medical toolkit. It can also deliver live footage along with the facility of instructions to the bystander.

This drone can reach from Vibevej 18, 6705 Esbjerg Ø, fire station to the site of accident at Kroskro in 05:16 minutes. The details are as follow:

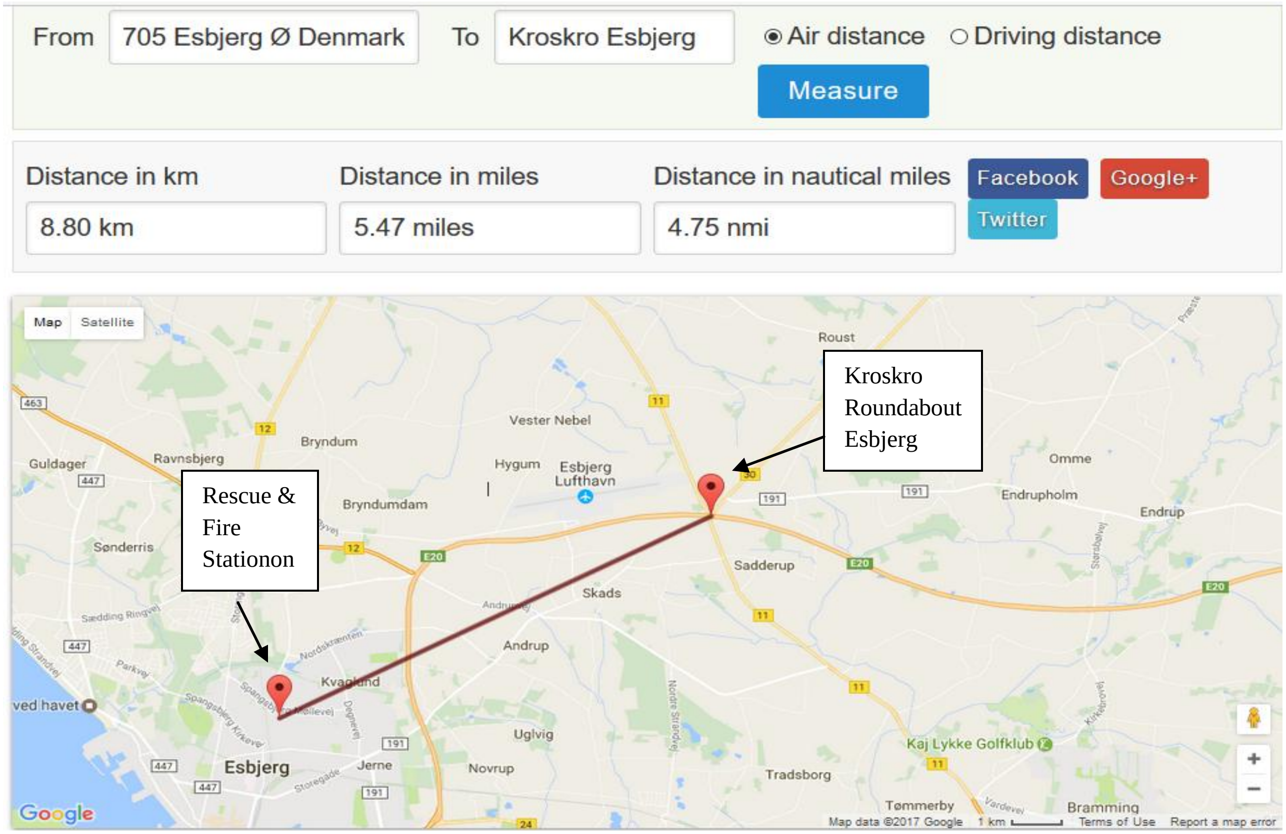

Figure 27 Aerial Distance from Fire Station to the Accident Site

The distance is calculated by Aerial Distance Measurement of Google maps.

Ambulance Drone Speed per km/minute= 100/60 = 1.67 Km in one Minute. Aerial distance from fire station to the accident site is 8.80 km, which is shown in the above figure 27. Ambulance drone can reach at the accident site in = 8.80/1.67 = 05.27. Now there is need to convert this 5.27 into minutes. The conversion 0.27 into seconds= 60/100 * 27=16.

So the response time will be equal to 5 minutes and 16 seconds 05:16.

II. Response time of Manned Drone Ehang-184

Inspector takes flight on manned drone on emergency call and reaches at the accident site. If there is someone seriously injured, he can give first aid. Response time by using manned drone is also 05:16 Minutes. The speed of Ehang 184 manned drone is also 100 Km/h. (Fortune and Newsatlas 2017). So the calculation of response time of Ehang 184 is the replication of Ambulance Drone.

4.6 Conclusion

Drones and flying cars can be used in emergency management services because of their benefits such as quick response time which is a very crucial parameter to save lives in case of accident of any sort. Drone have also advantage of aerial view over vehicles that are used in emergency management services. However their technological readiness, operational levels, cost and regulatory problems pose serious hurdles for the induction into any emergency management system.

UAVs can be used for different rescuing operations. But a UAV like Drone Ambulance that can carry payload of 4 kg of life saving drugs or AED deliberator, with a speed of 100 km/h and can provide also live video footage back to emergency management center is at TRL 8. However some UAVs similar to that of drone ambulance stand at TRL 9 and initial stage of Product life Cycle. EENA and Fire and Rescue Service of Copenhagen have tested successfully DJI Phantom 4 for SAR and fire responses in a pilot project. But it needs integration into the with some developments and improvements in configuration of the drone as well as in the emergency services to fully incorporate it. The employees of emergency services also need to get trainings and educations about UAVs. DJI Phantom 4 is also slower in speed and it can maximum fly a distance of 5 kilometers with a speed of 72 km/h. The distance from fire station to the site of accident Kroskro is 8.92 km so drone ambulance having a covering area range of 12 km with a faster speed of 100 km/h is suitable for the application of this example.

This chapter has presented Ehang-184 as possible option to inspector's vehicle in case of an accident. The inspector can go on this manned drone to accident site in less time comparing a vehicle. Among its competitors Ehang stands at higher TRL level as well as at Life Product Cycle.

Different drones can be used for different emergency situations such as surveillance, search and rescue operations and in fire emergencies, disaster management, surveying site of accidents etc. While drone ambulance stands at TRL8. Other manned drones and flying cars/objects stand at TRL 8 or lower except Ehang-184.

Based on above discussion, it is concluded that UAV such as drone ambulance and manned drone Ehang-184 are considered for further investigation.

Chapter 5

5. Application of Multi Criteria Decision Analysis (MCDA) for Choosing Best Alternative

5.1 Introduction

In the previous part of this report two scenarios of assistance in case of traffic accident are discussed and concluded, that, in case of a traffic accident at Kroskro Esbjerg, there is a need of further quick response to minimize the loss of life. There are four modes of transportation that can be used namely,

- Inspector vehicle
- Helicopter
- Unmanned Aerial Vehicle (UAV)
- Manned Drones.

These alternatives can reach at the accident site to help the injured persons. To check the effectiveness of these alternatives, this section is developed. For effectiveness of alternatives multiple criteria decision analysis method is used.

Multiple criteria decision analysis method is applied by many academics in various fields, like Espen Løken (2007) has used MCDA for energy planning problems. Joonas Hokkanenand and Pekka Salminen (1998) applied MCDA for solid waste management system in the Oulu region, Finland. Prof David J Nutt et al 2010 applied multi criteria decision analysis (MCDA) modeling to a range of drug harms in the UK. Igor Linkov et al (2007) used MCDA and environmental risk assessment for nonmaterial. Flávio Fonseca Nobre et al (199)) used MCDA for setting priorities in health care.

Various authors used MCDA for different fields. In order to find the best option among given alternatives, this part of the report applied Multi Criteria Decision Analysis (MCDA).

Multi Criteria Decision Analysis (MCDA) is basically a form of Multi Criteria Decision (MCA) that is applied in both public as well as in private sector organizations. MCDA is used for decision making process. It is applied to find out the best option available in set of different alternatives. This method covers analysis and ordering of all options that includes from the most acceptable to least acceptable option making decision process comprehensive. Importantly the most acceptable option has to depend on the objective of decision making team, however sometimes most preferred option are either costly or riskier or both (Communities and Local Government, UK 2009).

This method could be applied to different problems that are characterized by mixture of monetary and non monetary parameters. By definition, monetary parameters are the cost related expenditures and non monetary parameters are response time, assessment, first aid and availability. These parameters are analyzed and discussed in detail in the following sections of this report.

The purpose of MCDA is to help in decision making. Keeney and Raiffa (1976) It is widely applied in United State at local, state level as well as at federal level. For instance the US authorities used this method for the analysis of alternative sites for the disposal of nuclear waste. In this case the authorities picked five potential sites for analysis using MCDA, which resulted in an overall ranking of the sites and helped them make a best decision. (Communities and Local Government, UK 2009).

5.2 Stages of MCDA

There are eight different stages of MCDA as follows, (Communities and Local Government, UK 2009).

- Establish the decision context
- Identification of the options that are to be appraised
- Identification of objectives and criteria
- Scoring of options/ alternatives
- Allotting Weights to options
- Combination of the weights and scores
- Examination of results
- Sensitivity Analysis

5.2.1 Establish the decision context

MCDA starts with the first stage by analyzing that what is the current situation related to problem being analyzed with its option as well as what goals are to be achieved? This stage sets the tone of strengths that could help get things done along with the threats and weaknesses that could be hurdles or slow down the achievement of objectives. Findings to these things could broad the scope of MCDA but brain storming of all this and answering helps to pay a way to establish a context that provides a setting for the analysis that in fact affects subsequent steps of the method.

For the application of the case of emergency management scope of this report, establishing the decision context is the first step of MCDA. In case of a traffic accident at Kroskro, Danish emergency department responds with full capacity to minimize the loss of life, injuries and other damages. If we basically segregate the two response scenarios of this report, they could be as follows,

Today: 112 is called and a full crew respond to the call with three vehicles going to the accident site. This results in effective and an adequate response, meaning less fatalities, less long term injuries.

Future: 112 is called and an inspector goes to inspect the emergency situation at site either on manned drone or helicopter or he simply assess the situation by sending an UAV. After assessment through UAV he either dispatches more resources and vehicles from the fire station to the site or acts according to situation. However these responses could not fully be equipped and without much support and in case the emergency is assessed to be serious an extra rescue team is called. This would result in prolonged recovery phase and increased risk of added injuries as well as financial losses.

In both cases the objective of MCDA is to maximize safety by rescuing injured people with minimum cost of rescue operation. This object has to be very clear since the analysis is based on the objective of MCDA. Based on the objective, the number of parameters and weight to different parameters are determined. The strength of drones and helicopters is that, they are fast in response but with limitation of less equipment loads, lack of proven history especially in case of manned drone. And in case of full operation as of now with the three vehicles standard procedure of rescue operation gets expensive but it is slow with better effectiveness depending on the scale and nature of accident. The main objective of the whole study of this report is to minimize the loss of life on dispatching minimum resources. This clarity about the aims of the MCDA and elaboration of the traffic accidents available options helps to define the tasks for subsequent stages and keeps the analysis on track.

5.2.2 Identification of the options that are to be appraised

MCDA's second stage is the identification of options to a situation or solution which is difficult to do because the options/alternatives are the product of human thought. Therefore these are susceptible to biasing influences. In the case of this report four options are selected after research and discussion with the relevant person. These four options are selected considering the context of this report. In the first part of the report, different scenarios are created to see the impact of emergency management facilities on the hypothetical accident at Kroskro Esbjerg. The four options are given in the following table.

Table 17 Different Options for MCDA

Number	Alternatives/ Options
1	Inspector Vehicle
2	Ehang-184 Manned Drone

3	Robinson R44 Raven I Helicoptor
4	Ambulance Drone UAV

Before considering pros and cons of above selected alternatives, it is necessary to identify an implicit assumption here. In response to a traffic emergency SVJB dispatches rescue vehicle, inspector vehicle and fire truck. However for the purpose of further investigation of this report only inspector vehicle is considered. Because rescue and fire trucks cannot be replaced by drones or helicopters but they can either replace inspector vehicle or assist in emergency response management. Therefore in the table above mentioned alternatives can replace inspector vehicle. The pros and cons of selected alternatives are discussed one by one in the following segment.

The first option in rescuing the injured person by help of inspector who reaches there by his vehicle. There is 80 percent probability that inspector will reach at the site in 10 min. Most of the time it works very well as concluded in second chapter of this report. But considering specifically the context of this report, this vehicle is slower and can be expensive than drones. As discussed before response time of saving seriously injured person is 4 to 6 minutes (Alex Momont, Delft University 2016). Therefore, there is need of faster medium than inspector vehicle in order to save a life of severely injured person.

Considering the criticality of the situation, Ehang-184 manned drone is suggested as the second option. Ehang 184 has faster speed and can reach at the site of accident within 6 minutes. But this manned drone has its own limitations like it cannot lift weight more than 100 KG. This will have a 23 minutes flight time roughly allowing a 10 miles, though 10 mile flight is enough in the case this report. This manned drone will cost $200.000 – $300.000 (dronethusiast / Ehang 2017) which is too higher. This drone is at the TRL 8 level, but with initial stage of its product life cycle.

A small light helicopter like Robinson R44 Raven I could be an alternative to the manned drone because the helicopters are at approximately last stage of its product life cycle. Its pay load is 351 KG much better than manned drone. It has fastest speed of 200 KM/H (robinsonheli / r44-raven-i) as compared other alternatives in the MCDA. However its price, operational and maintenance cost is very high comparing to manned drone and inspector vehicle.

The ambulance helicopter in services of Danish emergency medical services is very expensive to operate with around 22 million DKK yearly cost of operations and averaging per flight expenses of 35,000 DKK. (Pia Kurstein Kjellberg et al 2012). A Light weight helicopter like Robinson R44 is more comparable to manned drone for the purpose of carrying first aid toolkit and at least one person to the incident site.

Considering the aspect of speed, price and assessment and ambulance drone is introduced as the fourth option. This drone can fly with automated external defibrillator (AED) at speed of up to 100 KM/H.

This drone uses the GPS to navigate and tracks emergency mobile calls. Once at the incident site, an operator, like a paramedic, can watch, talk and instruct those helping the victim by using an on-board camera connected to a control room via a live stream webcam (daily mail, UK) However, emergency ambulance drone has its own limitations, successful AED usage by lay-persons is currently at 20% (TUDelft, Netherland 2017), though with help of instructions and communication on the Ambulance Drone, this can be increased to 80%. The ambulance drone is also at the initial stage of product life cycle.

Resultantly, four options/ alternatives are inspector vehicle, Ehang 184 manned drone, Robinson R44 Raven I Helicopter and Ambulance drone are included in MCDA method to make a decision which options could be the best for rescuing operation at accident site of Kroskro.

5.2.3 Identification of objectives and criteria

The third stage in the MCDA is to identify the objective. For the objective identification the following fundamental objective hierarchy (FOH) is developed. The FOH is a tool that helps to structure the fundamental objectives into a hierarchy that indicates the overall objective of decision (Clemen & Reilly, 2013). The FOH helps the decision maker to keep the decision making process on the right track. The FOH is the same for all scenarios of this report. The FOH is presented in the following figure.

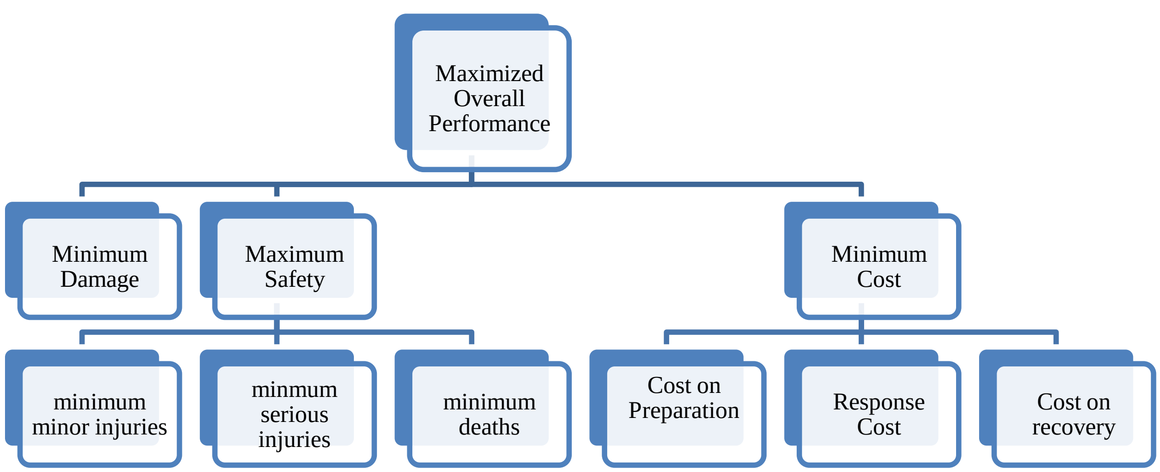

Figure 28 Fundamental Objective Hierarchy

The main objective in the FOH is to maximize overall performance of the Danish emergency management services with maximum possible safety by spending minimum expenditures. Or in other words, the decision of MCDA method has to provide the maximum level of safety with minimum cost.

Cost in the case of traffic accident at Kroskro could be split into three parts; cost on preparation, cost on response and cost on recovery. Cost of preparation means the cost spent by the Danish emergency management and municipal authorities to perform rescue and emergency operations. This includes money spent on relevant vehicles such as rescue trucks, fire trucks etc and building such as fire stations and wages of relevant crew. Response costs are the costs that are beard by the emergency management to respond to an alarm of accident and perform the rescue operation. In case of accident at Kroskro whether the fire station at Vibevej 18, 6705 Esbjerg Ø sends inspector's vehicle, drone or helicopter, the money spent on this whole response and rescue operation will be the response cost of this accident.

Cost on recovery means the cost spent by the relevant Danish authorities like Esbjerg municipality to cover medical expenses of injured person, any other costs such as insurance costs, losses of the injured or dead persons as well as any other financial losses and material damages to the property and vehicles involved on roads. In case of serious injury at Kroskro traffic accident the loss is 850,22 DKK (Thomas C. Jensenm Ninette Pilegaard 2015 and DTU). This recovery cost would be spent to normalize and offset the damages as well as losses arising out of the accident.

With the application of a best available option, Esbjerg emergency management performs rescue operation for maximum safety of the persons involved in traffic accident with minimum resources dispatched. Resultantly the overall performance of emergency management will improve to meet its prime object of maximized safety with minimum cost as depicted in the figure FOH.

For the purpose of the clarity and hierarchical classification of objectives of MCDA's this stage, the Influence Diagram has also been developed .

I. Influence diagram

With the fundamental objectives defined, prepared, and sorted out from the means objectives, we can turn now to the process of structuring the various decision elements, uncertain events and outcomes, and consequences. The tool of influence diagram is based on the fundamental objective hierarchy. An influence diagram provides a simple graphical representation of a decision problem. The elements of a decision problem are decisions to make, uncertain events, and overall outcomes. Squares represent decisions, circles represent chance events, rectangles with rounded corners represent values and diamond represents overall performance. These shapes are linked with arrows in specific ways to show the relationship among the elements (Clemen & Reilly, 2013).

There is developed one diagram for all scenarios, as the objective of these scenario is the same. The influence diagram for the accident case of MCDA method is depicted in following figure.

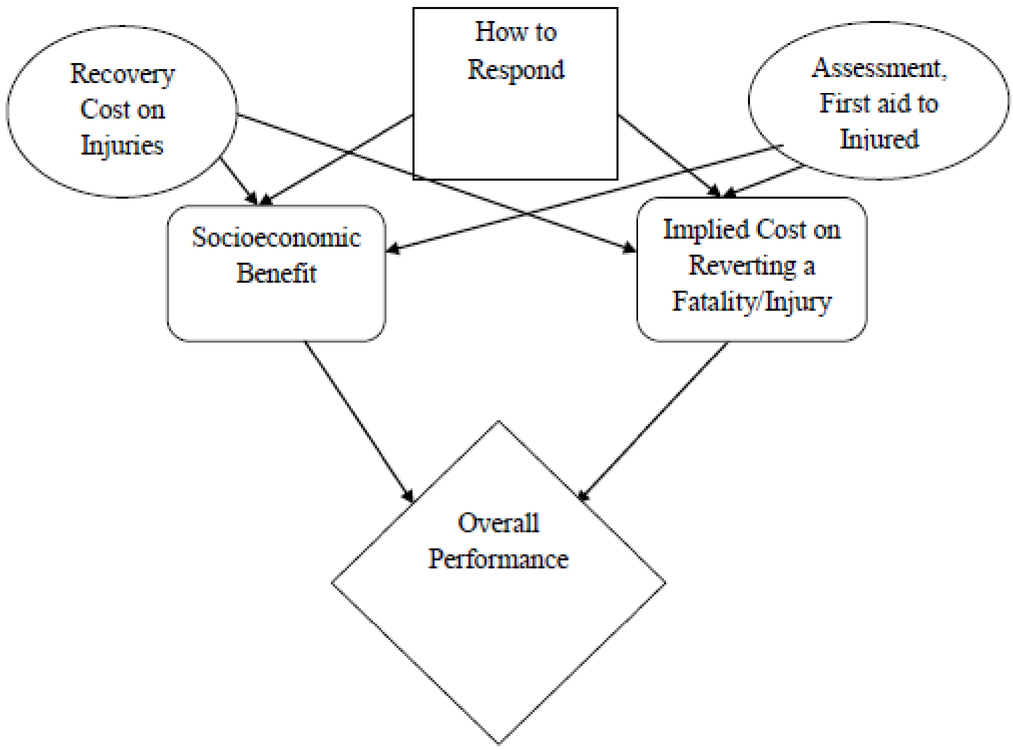

Figure 29 Influence Diagram

In the above picture response is a decision to make that is shown in the square node. Socioeconomic benefit and implied cost on reverting fatality are shown in the value nodes. There are some uncertainties related to these values those are shown in the circle nodes. Uncertainties in this case are cost on recovery, and number of injured persons, provision of first aid to those injured and assessment of the incident. These chance nodes have direct impact on the socioeconomic benefits and cost of reverting a fatality/ injury, therefore these chance nodes are connected with the value nodes by arrows. Furthermore cost and benefit nodes are connected to overall performance, because both parameters have significant impact on the overall performance.

In the case of this report, some parameters are selected as decision criteria. The parameters are assessment, first aid, response time total cost (price and operational cost) and availability. For the selection of these parameters has certain reasons. These reasons helped to chose some parameters that lay downs the foundation of selection of available options.

Response time has a paramount importance. As in UK 35 people died in past 5 years due to ambulance delays (The Guardian UK 2016). Only three out of 32 ambulance services of England reach within eight minutes. Experts say that 3,000 more heart attack victims could be saved each year if 90 per cent emergency calls were answered in that time. (Paul Kendall 2017)

The European standard response time for emergency response services is 10 minutes but in cases of serious injuries such as cardiac arrest and brain injury the time available for saving a life is 4 to 6 minutes. (Alex Momont, Delft University 2016) This is also something endorsed by The Sudden Cardiac Arrest Foundation(SCA 2017) that in case of sudden cardiac arrest the victims can only survive if they are treated within 3 to 5 minutes after the victim collapses. Quick response means quick first aid resultantly higher chances of saving the life of injured persons. Without treatment on every passing minute the victim's chance of survival of severely injured person suffering a cardiac arrest decreases by 7-10% (SCA Foundation 2017). This treatment could be by bystander or by inspector who can arrive at the site by one of the three options (i.e. vehicle, helicopter or manned drone) available to him to reach there. If an ambulance drone carrying automated external defibrillator (AED is sent to the site and bystander uses it for the treatment of victim then the survival chances increases to 38% before the arrival of a professionals (Weisfeldt ML, Sitlani CM, Ornato JP, et al 2010). In case of manned drone Ehang 184 inspector can carry this with him and by his professional treatment this percentage might be even further better. This percentage of 38% survival by first aid treatment of bystanders is also cited by SCA.

Based on the above description and facts it is important to include parameter of response time and first aid for the MCDA analysis of Kroskro accident case.

There are two aspects of assessment. One related to the second scenario of this report. The second scenario represents a situation where in case of an incident, inspector reaches at the sight and assesses the intensity of the incident and decides, whether to call for further assistance or not. This type of assessment could be extremely costly in case of a real accident, as the assistance reaches at the site very late and it could be the reason for the death of severely injured persons. The second aspect of the assessment is assessment of the injuries of victims. For saving lives, it has a paramount importance. This assessment could be assessed by a bystander, inspector and assessment through surveillance cameras that could be drone's camera. Recognizing the injury whether it's of delicate organs such as chest injury that could be heart's and brain injury is very vital. Since these two organs have the least time available to revive through first aid as discussed before. However other body injuries are important as well but their time to treatment is a bit more than these two organs. Assessing the injury rightly with appropriate treatment can either save or loss a life. However the assessment by inspector could be more authentic and professional than any immediate person to the victim. Resultantly assessment parameter is also very important for decision criteria. This assessment must be quick which again means the response time must be quickest possible.

There is a huge difference among the prices of selected alternatives. Similarly, operational cost is also variable among four alternatives. For instance helicopter has the quicker response time than vehicle and carrying more loads on it makes it favorable than drones. But its cost is very high, therefore criteria of cost included for decision making. In order to keep costs low, use of helicopters in emergency services might not be optimal. The cost criteria is included to achieve the second part of the main objective.

Availability means in time of accident, whether all alternatives are available or not, for example in case of an accidents in rush hours, inspector vehicle will take longer time to reach the accident sight. In the same way if there is a bad weather like a storm, drones may be not be able to fly.

In short all parameter are important but response time is the most important one. Late response time could jeopardize the lives of seriously injured people involved in an accident such as in case of traffic accident at Kroskro. All parameters with relevant attributes are shown in the following table.

Table 18 Parameters for Decision Making

Parameters	Attributes
Assessment • Assessment based on caller's information inputs • Assessment by inspector	Undefinded
First Aid • First aid through immediate person near injured. • First aid by inspector.	Undefinded
Response time	Minutes
Total Cost	DKK
Availability (Weather, Rush Hours/Traffic Jam/Exposure to Risks)	Undefinded

In the above table five parameters are selected for decision making process and its relevant attributes are also given. The parameter response has its natural attribute called minutes. The attributes for assessment and first aid are unidentified, but these two parameters are dependent upon quick response.

If there is a quick response, assessment and first aid would be beneficial in case of a traffic accident. In decision making process cost (price and operational cost) is also an important parameter. The cost attribute is in Danish kroner DKK. The last parameter is called availability, the availability attribute is also not defined.

5.2.4 Scoring

Scoring are the important to combine different attributes. As described earlier some parameters are monetary and some have non monetary nature, and these parameters cannot be combine together, therefore scoring is introduced. The scoring is given on the following basis.

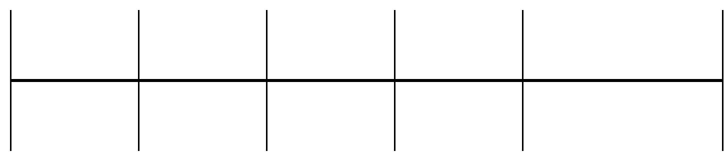

Figure 30 Preference Criteria

In the above figure, it is explained that least preferred option will receive minimum scoring whereas most preferred option will get maximum scoring. Relative scoring are determined based on most preferred option. In this report relative scoring is used to replace the consequences with the numbers. All parameters are scored accordingly and it is explained briefly.

I. Response Time

Table 19 Response Time and Scoring

Options	Response Time Minutes	Scoring
Inspector Vehicle	10	24
Manned Drone	05:16	46
Helicopter	02:38	100
UAV	05:16	46

In the above table helicopter response time is fastest therefore received 100 scoring points. Relative scoring is determined based on most preferred option which is helicopter response time. For instance for Inspector vehicle's is 24 (2.38/10)*100=24).

Response time for inspector vehicle is 10 min. Response time for manned drone and UAV is 05:16 min taken from chapter 4 page 71. Helicopter flies with higher speed as compared to manned drone and UAV. The helicopter flies with 200 KM (Robinsonheli, 2017) per hour. Aerial distance is 8.80 km given in the previous chapter figure 27. The total response time for this helicopter is 2 min and 38 seconds.

II. First Aid

First aid is also an important parameter. First aid can be decomposed into two parts, first aid by the bystanders and first aid by relevant personnel. There is no any basis to score the first aid given by bystanders. For the scoring purpose, first aid given by the relevant personnel will be considered. In this case first aid is dependent on the response time, as with quick response first aid can be given quickly. Therefore response time scoring is given to the first aid.

Table 20 First aid Scoring

First aid	Scoring
Inspector Vehicle	24
Manned Drone	46
Helicopter	100
UAV	46

III. Assessment

Assessment can be decomposed into two parts, one assessment by the person who informs emergency department about the incident and second is when the inspector reaches at the site he also assesses the situation (scenario II) and he provides appropriate treatment to the injured. As assessment is also dependent on the response time, if an inspector reaches quickly at the site, he can assess quickly, assessment scoring is the same as response time.

Table 21 Assessment scoring

Assessment	Sccoring
Inspector Vehicle	24
Manned Drone	46
Helicopter	100
UAV	46

IV. Cost

Cost is an important parameter, therefore both price of alternatives and operational cost is considered for decision making process.

Table 22 Price scoring

Alternatives	Price in DKK	Scoring
Inspector Vehicle	450,000	29
Manned Drone	1,696,353	8
Helicopter	2,612,383	5
UAV	128,923	100

The price for manned drone, helicopter and UAV is in dollar and converted into DKK. The conversion rate is 6,89 on 15-05-2017. Price estimate for the manned drone is $200,000 to $300,000 (Dronethusiast 2017) an averaged of the price is taken and converted into Danish kroner. The price for helicopter is $ 385.000 (Robinsonheli 2017) and also converted into Danish kroner. Similarly, the price of UAV $ 19.000 (dailymail 2017) and converted into Danish kroner.

UAV has receive highest number, the reason is that, its price is lowest among all alternatives.

V. Operational cost

Operational cost includes maintenance cost and per rescue operation.

Table 23 Operational Cost and Scaling

Operational Cost Per Rescue Operation	Cost DKK for 3 Hours	Scoring
Inspector Vehicle	1,500	80
Manned Drone	2,895	41
Helicopter	4,458	27
UAV	1,200	100

The emergency operation lasts about 2 to 4 hours (Jens Mølgaard SVJB 2017). For this report, it is assumed that, emergency management will take on average 3 hours. The operational cost is multiplied with 3. Per hour cost for the car inspector will be around 500 DKK (Jens Mølgaard SVJB 2017). UAV per hour cost will be 400 DKK, this is our own estimate, based on its nearer competitors. Helicopter per hour operational cost will be 1486 DKK (Robinsonheli 2017) and multiplied by 3. Per hour Operational cost for manned drone is calculated 965 relatively to the price per hour of its nearest competitor which is helicopter in this case as shown in the following table.

Table 24 Operational Cost Manned Drone

Robinson R44 Raven I Helicopter Total Price	2,612,383 DKK
Robinson Operational Cost (Per hour)	1,486 DKK
Manned Drone Price	1,696,353 DKK
Manned Drone Operational Cost (per hour)	(1,486 /2,612,383)* 1,696,353 =965 DKK

Per hour operational cost will be 965 DKK. This is own estimate based on its nearer competitors, In sensitivity analysis, this operational cost can be changed to check the impact of operational cost on the overall performance.

VI. Availability

Availability is also an important parameter which means whether the option selected for emergency management response can reach the site of emergency to and be present there to execute its operations. Whether is it possible for helicopter to land and take off at scene of emergency, how is the weather, and whether the person flying in manned drone or helicopter is being exposed to some danger or not such as heating due to fire, chemicals or radioactive etc are vital deciding factors that can hinder the use of selected option and subsequently whole rescue and emergency response. There is however only 4 % probability that the weather conditions would be extreme. (Weather Spark 2017)

For the purpose of scoring of this parameters following table is produced.

Table 25 Availability Scoring

Availability (Assumed)	**Scoring**
Inspector Vehicle	80
Manned Drone	60
Helicopter	30
UAV	80

In this table inspector vehicle received 80 scoring point. There is 80 percent probability that inspector will reach in 10 minutes (SVJB 2015). The assigned scoring of helicopter is 30, the reason for this is that it is very difficult to decide by the emergency responder whether the helicopter can land take off at a particular site of accident. Helicopter needs some specific surfaces and open area to land and fly. However it can withstand stronger winds and rains than drones but inspector vehicle does not have these issues of bad weather. There is big issue of landing and taking off. The manned drone and helicopter can put humans flying in them to dangers of heating and chemicals depending on the type of emergency meaning that these two cannot be used in some emergency situations but UAVs does not have this issue in fact it is a big advantage of UAV that it does not exposes its controller to dangers. The scoring number for the manned drone is assumed to be 60 because of its reasons of bad weather, putting flying person at exposure to danger in some cases, low technological readiness level and product life cycle. Availability for UAV is assumed 80.

To check the impact of availability on the overall performance, sensitivity analysis has been carried out to leverage and see the impact on results with different scoring. Because some experts may not be agreed on the assigned availability scoring of an option. By changing the scores the results can be examined in the attached Excel file in sensitivity analysis section.

5.2.5 Weighting

The preference scales still can’t be combined because a unit of preference on one does not necessarily equal a unit of preference on another. Equating the units of preference is formally equivalent to judging the relative importance of the scales, so with the right weighting procedure, the process is meaningful to those making the judgments. The concept of the weight depends on the subjective knowledge of the experts, therefore It always needs to be handled with care. Some time some weight assigned to some parameters may be influenced by the personal biasness (Local Communities and Government, UK

2009). Therefore, for the purpose of remaining unbiased equal weights are assigned to all parameters. Resultantly if the total weight is 100 then it becomes 17 % by dividing it equally among 6 parameters.

5.2.6 Combination of Weights and Scores

The overall preference score for each option is simply the weighted average of its scores on all the criteria. The calculation equation is as follows,

$$TS_i = W_1 S_{i1} + W_2 S_{i2} + \cdots + W_n S_{in} = \sum_{j=1}^{n} W_i S_{ij}$$

In the above equation S stands for score and W stands for its corresponding weight. It is a simple multiplication of relevant score with its weight, then sum the products to give the overall performance score for that option. Then repeat the process for the remaining alternatives.

The overall calculation and results are given in following table,

Table 26 Overall Scoring

Alternatives	Response time	First aid	Assessment	FC	VC	Availability	Total scroing
Inspector Vehicle	24	24	24	29	80	80	43
Manned Drone	46	46	46	8	43	60	41
Helicopter	100	100	100	5	27	30	60
UAV	46	46	46	100	100	80	70
Weight	17%	17%	17%	17%	17%	17%	100%

In the above table overall performance of all alternatives with criteria is shown. All parameters are given the same weight. It is shown from the above table ambulance drone UAV outperforms the other alternatives.

5.2.7 Examination of the Result

Under this stage of the MCDA the examination of results of previous stage is carried out. As UAV's overall scoring is higher than the other options. Helicopter cost is too high that cannot be reduced. Manned drone price does not seem to be final , it will decrease since it's not available for operations and sales in the market having lower life product cycle. However, if the manned drone price decreases once it gets established itself in the market, the decrease in high costs may affect on the overall performance of it. Similarly if response weight, first aid weights gets changed then the overall performance will also be changed.

For the purpose of a better examination of results a Cost versus Benefit figure for four options is drawn based on the table 26 of overall scoring of the options. This figure of benefits versus costs of the four options can be instructive because it depicts a relative value-for-money picture that can help taking decision process become more profound. The outer surface of the plot depicts the most cost-effective option like UAV in the following figure of the four options.

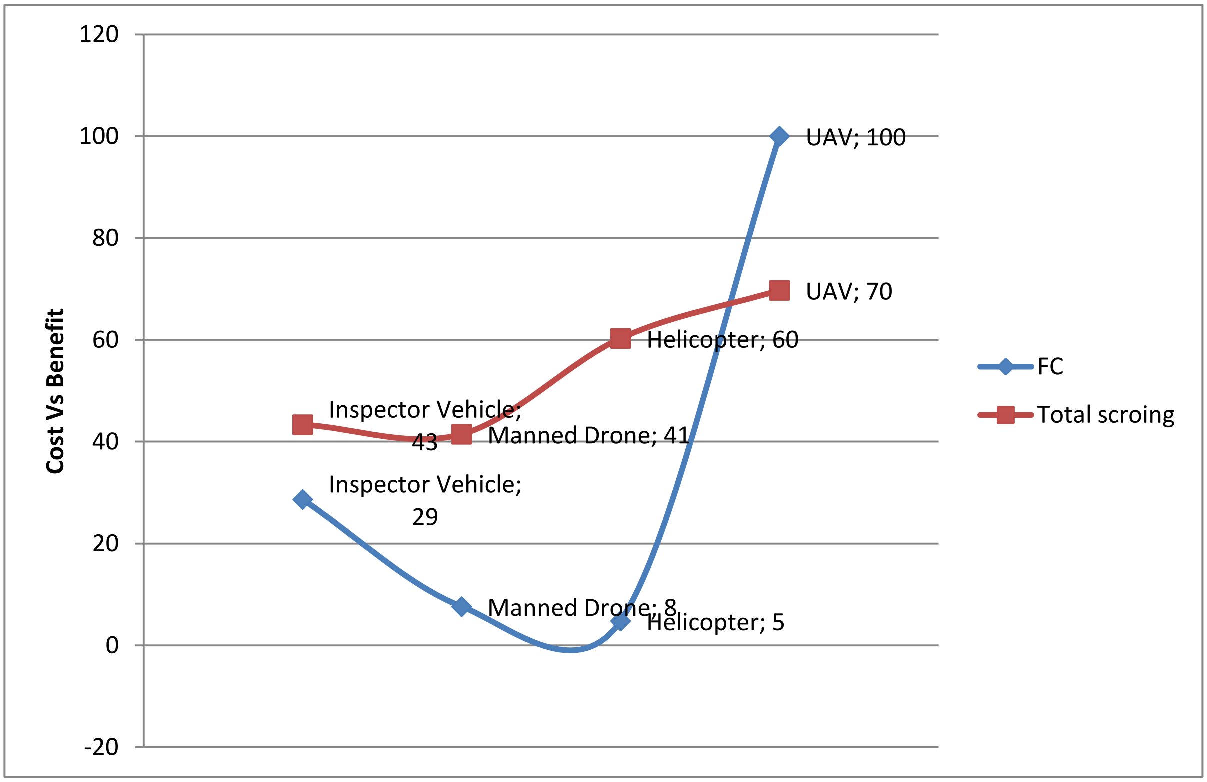

Figure 31 Cost Vs Benefits

In this graph, cost VS benefit is shown. The blue line represents the cost and red line represents the benefits. The graphs shows that in terms of both costs and benefits UAV gets higher score than other alternatives.

To check the robustness of selected alternative sensitivity analysis is carried out.

5.2.8 Sensitivity analysis

Sensitivity analysis provides a means to what extent the impact of parameters is on the overall performance. The choice of weights and assumed number of scoring may be contentious. Experts involving in decision making can generally have different views of the relative importance of parameters and especially weights are subject to disagreements. Theses disagreements cab be solved by using sensitivity analysis. Experience shows that MCDA can help decision makers to reach more satisfactory solutions in tough situations (Communities and Government, UK 2009).

In the case of this report, as mentioned earlier, response time has a paramount importance. Therefore its weight is increased to see the overall impact of response time with higher weight. Similarly, first aid has a crucial role in saving human life, therefore it has been assigned a higher weight. The parameters availability and price are also important, therefore their weight has increased. Rest of the parameters are important but perhaps not as important in saving human life, therefore their assigned weight are decreased. However by assigning different weights, UAV still outperforms other alternatives, this is shown in the following table.

Table 27 Sensitivity Analysis

Alternatives	Response time	First aid	Assessme nt	Pric e	Operational Cost	Availabilit y	Total scroing
Inspector Vehicle	24	24	24	29	80	80	42
Manned Drone	46	46	46	8	43	60	41
Helicopter	100	100	100	5	27	30	60
UAV	46	46	46	100	100	80	69
Weight	25%	20%	5%	20%	10%	20%	

Helicopter price and inspector vehicle price is established and it cannot be changed, whereas due to fast developments of Manned drone and UAV technology price does not look final, it will decrease. In future these drones prices may decrease giving more positive impact on the preferred alternative. The exercise of assigning different weights and parameters score does not change the final result. This exercise of changing weights and their impacts can be seen and practiced to confirm the final result of sensitivity analysis of *MCDA Chapter 5 excel file*. This sensitivity analysis is also shown in the following diagram.

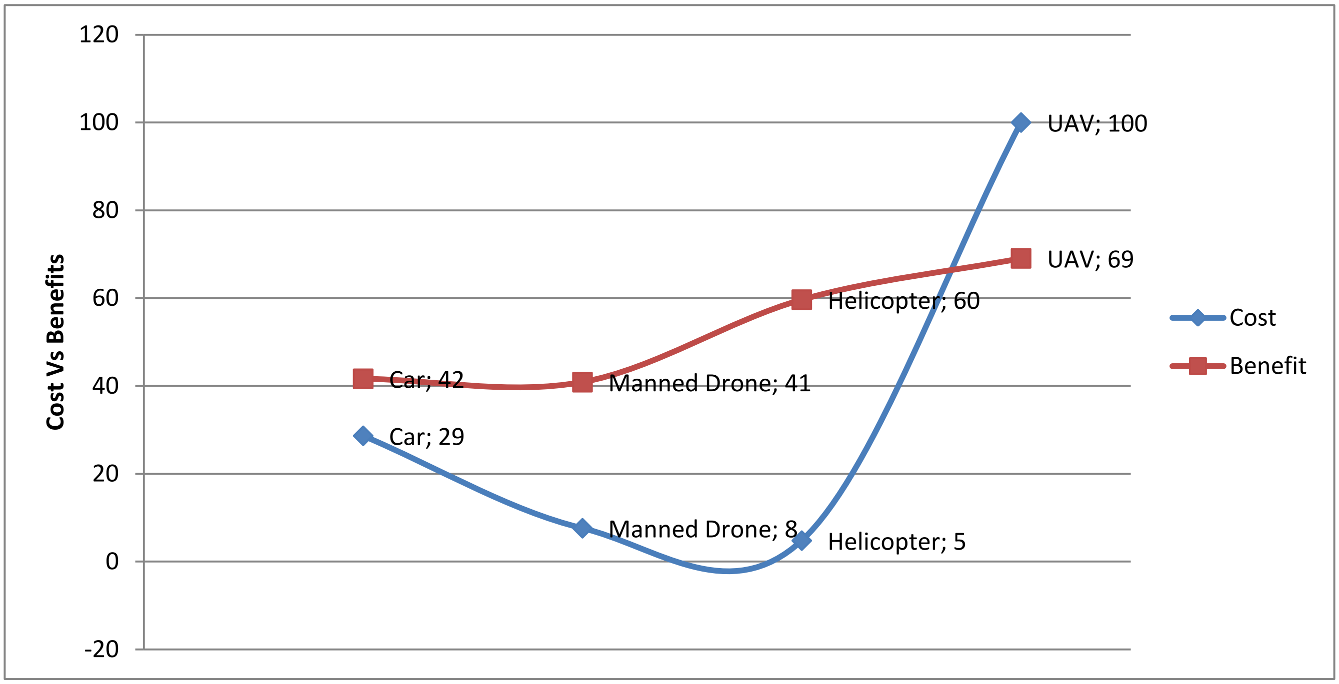

Figure 32 Sensitivity Analysis

In the above graph sensitivity analysis is shown. Y axis represents cost and benefits both. The blue line represents the cost and red line represents the benefits. The graphs shows that in terms of both costs and benefits UAV gets higher score than other alternatives. By making changes in the weights of different parameters in sensitivity analysis, UAV option having maximum scoring comparing others remains consistent as it can be noticed in excel sheet of MCDA chapter 5.

5.3 Summary

UAV's overall performance out performs rest of the three options. Now there is a question of overall impact of inducting UAV into emergency management. For this two parameters are required: the implied cost of averting a fatality and socio economic benefit of saving a human life. The implied cost of averting a fatality is the price of ambulance drone and its operational cost. The price of ambulance drone is 128,923 DKK, and its operational cost is assumed 1200 DKK for one operation. To get the socio-economic benefit of preventing a fatality is relatively straightforward to calculate, socio-economic benefit is the difference between death cost and cost on seriously injured. Cost on death and seriously injured is taken from chapter 3 table number 14.

$$Socioeco\ Benefit = Socioeco\ cost\ of\ per\ fatality - Socioeco\ cost\ of\ per\ Seriously\ Injured$$

$$7{,}372{,}439 = 8{,}222{,}664 - 850{,}225$$

The cost of inducting UAV in Danish Emergency management service is way too lower than saving the human life. If a life of a seriously injured person could be saved by using UAV due to quick response than existing standard emergency response, the total socioeconomic benefit will be equal to 7,372,439 DKK.

However, UAV can be used to assist the process of emergency management rather than replacing the duty of inspector's vehicle. Because UAV in some cases may perform some tasks but not all tasks of inspectors as well as UAV may not be able to fly for instance in extreme bad weather conditions. For this purpose ambulance drone and Inspector vehicle can operate simultaneously in case of emergency. But this will increase the implied cost of preventing a fatality. In the following section impact combined alternatives on overall performance is checked.

For this purpose total cost of averting a fatality of selected alternative over a one year is computed to see the impact of including ambulance drone in emergency management for short term to medium term. Total cost for one year consists of price, operational cost and depreciation cost. In total cost, depreciation cost is not included, because depreciation cost is dependent on life expectancy and, there is lack of data of life expectancy of drones. However overall the final result seems to remain same by not including depreciation cost. Operational cost is multiplied with the estimated number of accidents. According to SVJB the operational cost of inspector vehicle is 1500 DKK per response to an accident and it is multiplied with 48 as estimated number of accidents in 2017 will be 48. Similarly, operational cost of other alternatives are taken from table 24 and multiplied with the estimated number of accidents. The socioeconomic benefits of saving severely injured person from dying is 7,372,439 DKK as calculated above. Professional first aid means a first aid given by the inspector of the emergency response or by a paramedic.

Total cost of Averting a Fatality for One Year = Price + Operational Cost for One Year + Depreciation Cost

In case of Manned drone Ehang-184 total cost will be

$$\text{Total cost of averting a fatality} = 1{,}696{,}353 + 138{,}945 + 0 + 0$$

$$= 1{,}835{,}313$$

Now with the least minimum chances it could be assumed that by the use of Ehang-184 only one person's life is saved out of 48 times and if more than one person life will be saved, the socio economic benefit would be much higher. This same method is applied for other of alternatives and following table is produced for further analysis.

Table 28 Per Year Cost VS Saving Comparison of Selected Alternative

Alternatives	Price	Per year OC	Total Cost	Socio Economic Benefit	Difference
Manned Drone	1,696,353	138,945	1,835,297	7,372,439	5,537,142
Helicopter	2,612,383	213,975	2,826,358	7,372,439	4,546,081
UAV+ Inspector Vehicle	578,923	129,600	708,523	7,372,439	6,663,916

In this table another alternative UAV + Inspector vehicle is included. The reason for this inclusion is that, in the above section, it is concluded that unmanned aerial vehicle can assist inspector vehicle therefore the new alternative is developed. However manned drone or helicopter cannot be added along with vehicle because it would mean two person responding same emergency in two different modes of transportation. The cost of the UAV and vehicle alternatives are added together to determine their net effect as shown in the above table. It is obvious that by inducting ambulance drone in emergency management will increase the cost, but its net benefits are much higher.

The explanation and descriptive analysis of the above table is as follows:

I: ***Manned drone*** is the second cost effective alternative by inducting it into emergency management. However due to the following limitations this option cannot be considered.

- It is not flight proven and operational yet.
- It may not take flight in extreme weather conditions.
- It can also not be used in many other emergency situations where there is a hazard that can harm humans flying in it. For instance, chemical and radioactive emergency situations.

II: Helicopter is the least cost effective alternative. It has a good response time but it has limitations, that hinders him incorporating into the emergency management system.

- Helicopter would require SVJB to hire a professional pilot and related administrative resources that are not included in the analysis.
- The medical emergency response (EMS) service does have ambulance helicopter to respond, though the operation costs of that helicopter is 35000 DKK per trip that is too high.

- Helicopter may not be able to take flights due to extreme weather conditions. Helicopter may face takeoff and landing issues at a scene of accident. For instance location of landing zone must be clear with not less than 20 feet horizontal clearance between the landing and takeoff area and trees, telephone poles, fences and buildings or anything can hit or struck the rotors of helicopter. The landing areas size should not be smaller than the twice the size of rotor diameter of helicopter. Surface composition that could bear at least one and half times the weight of helicopter and approach and departing paths etc. (Sandra Henninger, Jack Thompson. (1991) U.S Deportment of Transportation, Federal Aviation Administration)
- It can also not be used in many other emergency situations where there is a hazard that can harm humans flying in it. For instance, chemical and radioactive emergency situations.

III: Combination of UAV along with inspector's vehicles is the most cost effective alternative with the maximum safety. Maximum safety means severely injured person gets first aid less than10 min, whereas standard safety is current procedure of the safety system of Esbjerg emergency management. It has following advantages.

- The response time is as good as UAVs with an option of the inspector's first aid.
- The UAV can anyway also be used for documentation of accident scene response.
- It requires minimum human resources to operate it.
- it can be used to other emergency response such as in fires and search and rescue operations (SAR), chemical, biological and radioactive hazardous emergencies without putting humans to danger.
- In case of bad weather UAV may not be able use, but inspector vehicle can be used to mitigate the consequences of the accidents. Over the entire year, in Esbjerg there is 4 % probability that the weather will be extreme. (Weather Spark 2017) The extreme weather is not appropriate for UAV whereas this UAV can be used in rest of 96 percent of the time. In case of bad weather the standard safety procedure will be adopted and inspector will reach at the sight by conventional means.

The implication of the above table is discussed in the following table.

Table 29 Comparison of Alternatives

Alternatives	**Cost Effectiveness**	**Advantages**	**Limitations**
Manned Drone	5,537,142 DKK	Maximum Safety due to quick response and professional first aid. Pay load capacity of 1 person.	Not operational yet. Its application into emergency response needs to be tested. Risk perception in public Unavailability due to bad weather.
Helicopter	4,546,081 DKK Least cost effective	Maximum Safety due to quick response and professional first aid. Higher pay load that can carry up to 3 persons.	Too costly to operate. The EMS can use its ambulance helicopter but that's even more costly to operate. It is only called to rescue to severely injured person by providing them first aid after initial assessment by rescue and EMS staff. Difficult to have a whole operational management

			system. It needs bigger space for landing and taking off. It cannot be used in many other emergency situations that pose danger to humans. Unavailability due to bad weather.
UAV+ Inspector Vehicle	6,663,916 DKK Most Cost Effective	Standard safety in case of bad weather of 4 % chance. Maximum safety due to quick response with 96% chances of good weather. Either first hand professional first aid or first aid through live professional instructions. Less resources needed to incorporation. Easy to adopt with current standard procedure.	Risk perception in public. Unavailability of UAV due to bad weather. Bystander may not be able to fully utilize first aid capacity of UAV. Integration of UAV in standard operating system of emergency management service.

		Easy to operate. Can be used for other emergencies to avoid exposure to humans from hazards and danger. Can also be used for post crash documentation by doing so quickly it can help reduce additional accidents by 02.4 %	

5.4 Conclusion

In this chapter, Multi criteria decision analysis is used to identify the best alternatives among selected alternatives. The selected alternatives are inspector vehicle, a helicopter, manned drone and unmanned aerial vehicle. Decision was made based on some criteria and criteria for decision making was the response time, first aid, assessment price and operational of all alternatives. Overall MCDA favors the UAV. To check the robustness of selected alternative, sensitivity analysis is made. Sensitivity analysis favors to the UAV. But UAV itself cannot replace inspector vehicle, therefore it is better to use UAV to assist the inspector rather than replacing. To check the application of new alternative called UAV+ inspector vehicle, further cost VS savings analysis is made. The Emergency management can save 7,372,439 DKK by saving seriously injured person from dying. The cost of incorporating UAV into standard emergency procedure along with inspector's vehicle with its total cost of 636,523 DKK that is lower than the socioeconomic benefit of saving a human life.

It is better to start using UAVs and integrating as part of the system along with inspector's vehicle and assist emergency response for maximum possible safety and third in ranking of being a cost effectiveness alternative. This alternative can lay down the foundations for future manned drone replacing most of the operations of UAV if not all. Because in some emergency situations UAVs would be more suitable as well as cost effective. At the end it is concluded that by incorporating UAV into emergency management response though increases the cost a little but it can pay back by saving an human life along with huge economic benefits.

Chapter 6

6. Drones Risk Perception, Regulations and Risk Communication

6.1 Introduction

The previous parts of the report weigh in favor of inducting unmanned aerial vehicles UAVs into the emergency management services. However this is a relatively new and beneficial technology but it comes with baggage of some hurdles mainly risk perception and tough regulatory requirements.

This part of the report is based on surveys, analysis or description of following points,

- The risk perception of public towards drones.
- The Danish rules and regulations concerning drones.
- Some risk communication recommendations that could pave the way for usage of drones at mass scale by changing public view of psychometric factor of fear to confidence, sense of security and protection of their privacy etc.

6.2 Usefulness of UAVs in Broader Fields

Before considering the risk perception of drone technology for the induction into emergency management, it is necessary to develop the understanding of potential usage of drone technology for the emergency management services. Since public perception of drones is not only confined to seeing drones in rescue operations, moreover the rules and regulations concerning drones are not made for specifically emergency services but for all means and purposes. UAV technology is well suited for local and regional emergency management and can be augmented to state level.

A clear advantage of drone technology in comparison with other conventional means is unique observation angles (Darren E. Price 2016). Drone can be used for agriculture inspection, inspection of oil and gas field, detecting fire in forest, determining location of victims, transporting medical equipment for instance defibrillators.

Assessment becomes further important after the explosion or natural disasters like flood, hurricane or earth quick. It poses huge risk for emergency workers to enter in the collapsed building to rescue, UAVs offer real time audio video facilities and better view for inspection and assist further the responders for better response whereas conventional inspection is much costly and time consuming.

In case of oil and gas monitoring, UAVs can be really beneficial, currently companies are monitoring oil and gas fields by conventional means to detect the methane leak. It is really dangerous for workers and also costly and time consuming. There are more than 500,000 hydraulically fractured gas wells in the United States (Darren E. Price 2016), UAV can easily do air monitoring with fairly low price and in safer mode.

Fire in the forest poses big challenge for firefighters to hold back, UAV can be used to identify the area where fire suppression activities need to be expanded. In future UAV could also be used to detect the fire before spreads and becomes very difficult to control.

UAVs can be used for Search and rescue operations especially in densely populated areas or confined space environments. As a case in point, in July 2014, UAV operator located missing old person in the forest of Virginia (Darren E. Price 2016). That old man was missing for three days, search dogs, a helicopter and other hundreds of other responders failed to locate him, whereas by the help of UAV missing person was located within 20 minutes (Darren E. Price 2016). Danish emergency management authorities also located a missing girl with UAV assistance.

With potential uses of UAVs, it is necessary to discuss barriers that may hinder the induction of UAVs into emergency management system. some examples are discussed in the following segment.

6.3 Risk Perception

According to Renn and Benighaus (2013) "Risk perception' is a process of "physical signals and/or information about potential hazards and risks associated with a technology and the formation of a judgment about seriousness, likelihood, and acceptability of this technology." Physical signals refer to direct observation by human senses and information refers to verbal and nonverbal exchange of messages about uncertain consequences of the substances or the event. Whereas 'Risk assessment' is one of the many factors influencing public acceptance of a technology. (Clothier et al., 2015)

General public perceives drones as risky for mainly two concerns,

- Privacy
- Connotation

General public may consider every UAV mission as invasion to their privacy. Therefore in Washington a UAV mission was canceled due to potential privacy concerns ((Darren E. Price 2016). The induction of UAV into emergency management system becomes critical considering privacy concerns of general masses.

The second concern of the general public about UAVs is their connotation, that UAVs are military and law enforcement centric. To help in mitigating connotations surrounding the use of UAVs long term public awareness and education program should be initiated .

For the purpose of analyzing the risk perception and conducting survey as well as making a persuasive risk communication mechanism that could make public acceptable to drone technology, it is important first to know, what are the factors on the basis of which perception of people towards a technology is build.

For instance, heuristics play important role in making decision about the riskiness of new technology. Generally human being makes decision based on small number of samples. The psychometric paradigm and psychometric risk factors are well known factors for perception of masses about new technology for instance UAVs.

There are basically multiple factors that impact the perception of drones in people minds, there level are benefit, control, knowledge, voluntariness, fear/dread, newness and consequences. Since conventionally piloted airplanes (CPA) are the ones that are similar known devices and these could be compared with drones, the people's perception of UAVs can be judged on the above mentioned seven psychometric factors

Table 30 Factors and Their Hypothesized Impact on Public Risk Perception of Drones Compared to CPA.

Factor and its Influence on Risk Perception		**Difference in Factor**	**Impact on Perception of the Risk of Drones Relative to CPA**
Benefit	Higher perception of the benefits, lower perception of the risk.	The public is likely to perceive the benefits associated with CPA to be higher than that of drones.	Perceive the risks to be higher
Knowledge	More knowledge, and public certainty in that knowledge, leads to a lower perception of the risks.	Public have more knowledge for CPA, and through their experiences are likely to place more trust in the information available to them and in	Perceive the risks to be higher

		the knowledge they hold themselves. For drones there are limited sources of information available to the public. The accuracy of the information that is available is variable, can be biased, and often un-verified. The information is likely to be difficult for the layperson to understand	
Control	More control an individual has over their exposure to the risks, the lower the perceived risk.	The members of the general public over-flown by UAS operations are largely unable to influence the level of their exposure. Whereas passengers of CPA have greater control over the level of risk they are willing to tolerate through the number and type of aircraft operations they partake in, and through choice of a particular air	Perceive the risks to be higher

		service provider.	
Voluntariness	Involuntary exposures lead to higher perceived risk.	The primary risks of concern due to CPA operations are to the crew and passengers on-board the aircraft. The individuals exposed voluntarily undertake these risks in return for a direct benefit. For drones, the primary risks are to members of the general public over-flown who are largely involuntarily exposed to the risks	Perceive the risks to be higher
Fear / Dread	Higher fear leads to higher perceived risk.	The capability and behaviour of CPA are well known to the public. For drones, potential fears associated with high levels of autonomy, perception of a “Terminator-like” capability, potentially lead to greater fear or “gut reaction” to the hazard.	Perceive the risks to be higher
Newness	The newer or more novel the risk, the	Small drones pose unique hazards (e.g.,	Perceive the risks to be Higher (for smaller

	higher the perceived risk.	cutting and penetration) to people not usually exposed to the hazards of CPA (e.g., at low altitudes in built up areas, at sports stadiums, indoors, *etc*.).	drones)
Consequence	The higher the likely magnitude of the consequence, the higher the perceived risk.	Small drones are less likely to cause fatal injury to a single person. Whereas large drones and CPA are more likely to cause multiple fatalities.	Perceive the risks to be lower (for smaller drones)

Source: Clothier, Reece A., Greer, Dominique A., Greer, Duncan G., & Mehta, Amisha M.(2015)

The seven factors that could impact on Perception of the Risk of drones relative to conventional planes paved the way to build and understand the basis of survey's response as described in following sections of this part of the report.

6.3.3 Survey I

The first survey designed for Australian public to explore the drone perception. This survey is based on a sample of 200 Australians aged from 18 to 65 years old. There was 100 men and 100 woman who were asked to answer survey's question. These people proportionately represented rural and urban dwellers across the whole nation. The people who participated were invited to complete an online survey with the instruction to respond as quickly as possible since there were no wrong or right answers to get a general trend rather than getting individual response of the participants. A summary of the Survey is given in the above table.

Tabel 31 Survey I

Question	N	Mean	SD
1.Describe your immediate feeling toward the technology pictured (1 = very negative, 11 = very positive).	200	6.26	2.349
2. To what extent do you agree with the following statements? (1 = strongly disagree, 11 = strongly agree).			
A. This technology is safe.	200	6.19	2.377
B. This technology is risky.	200	6.44	2.397
C. This technology is beneficial to my family and me.	198	5.19	2.240
D. This technology is beneficial to society	199	6.31	2.323
E. This technology is threatening to my family and me	200	5.42	2.529
F. This technology is threatening to society	198	5.66	2.609
G. This technology is as safe or safer than other technologies that perform the same task	194	6.04	2.173

Source: Clothier, Reece A., Greer, Dominique A., Greer, Duncan G., & Mehta, Amisha M.(2015)

Based on the above survey the following figure is developed for better presentation. In this survey 1 stands for very negative perception whereas 11 represents very positive perception of drone. Responders response was generally neutral.

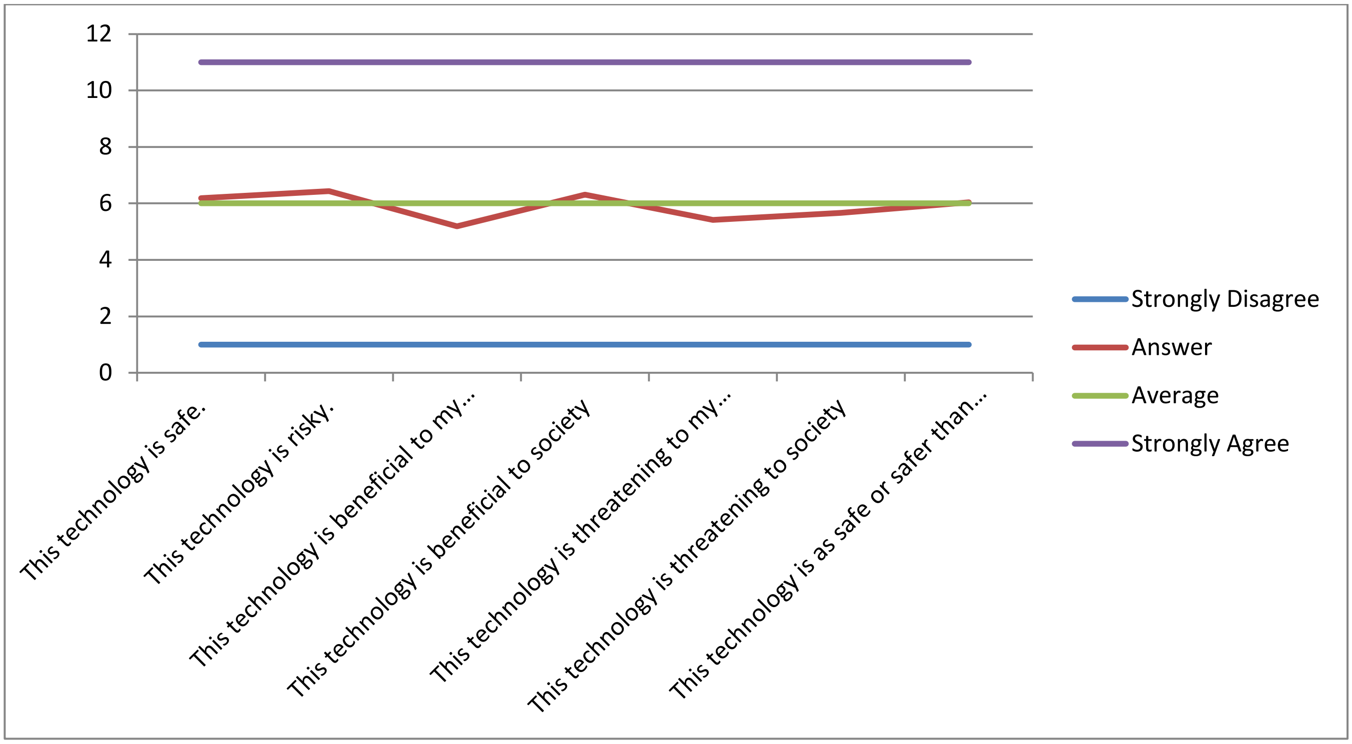

Figure 33 Australian Survey Drone perception

In the above figure, questions are shown on horizontal axis and their answer is shown on vertical axis. Generally survey responders were fairly neutral about the safety riskiness of drone technology. In the above picture blue line represents negative perception and the purple color line represents positive perception about drone. For better representation average line is also drawn. Responders answer was closer to the average line. Responders did not consider the drone technology is excessively unsafe or risky, beneficial, or threatening. Though, respondents considered drone technology will be more beneficial to the society than themselves. This is very promising, it means people are open to accept the benefits of this technology. The respondents of this survey reported a neutral response seeing drone technology operation by comparing the safety risks of drone technology to other similar technologies that can perform the same tasks as drones. (Clothier et al., 2015)

6.3.2 Survey II

Monmouth University (2013) survey suggest 80 percent of the participants of United Sates public showed concern about the privacy for law enforcement missions using high resolution cameras. This survey reveals a challenge for emergency management agencies as the common people cannot differentiate between surveillance mission and disaster response related activities. This poll was conducted on July 25 to 30, 2013 by Monmouth University. With 1012 adults the survey had a national random sample of people either 18 old or older. This survey was conducted on live interview of 708 individuals via landline phone calls while 304 people were interviewed by mobile phone.

For the purpose of patrolling US borders, drones have been developed by the Department of Homeland Security. Moreover another US government department of Federal Aviation Administration has been involved not only revising and making revising rules to fly drones for patrolling borders but also for the other uses of drones. Therefore they have designed the survey to investigate the public perception about drones.

Monmouth University 2013 arranged a poll to find public perception about drone technology and they came to know that American public continue to support many applications of UAV technology. First question was about whether public heard about drone or not and around half of the survey responders either heard great deal or somewhat.

I. *How much have you read or heard about the use of unmanned surveillance aircraft, sometimes called drones, by the U.S. military overseas– a great deal, some, just a little, or nothing at all*

A Great Deal	29%
Some	31%
Just Little	25%
Nothing at All	15%

Around half of the population have already heard about drone technology.

American public overwhelmingly support the UAV technology for search and rescue purpose. The question about whether to support or oppose drone technology for search and rescue operation and survey 83 percent survey responders voted in favor of supporting drone technology for search and rescue operation.

II. *Do you support or oppose the use of drones to help with search and rescue missions?*

Support	83%
Oppose	11%

Do not Know	6%

Survey responders was very much concerned about their privacy. The use of drone by law enforcement agencies could raise the privacy concern among general public. Around half of the American would be very much concerned and one fifth would be very much, and another 15 percent would be just a little concerned if the law enforcement agencies are using drone with high tech cameras and recording equipment. Whereas rest of the population was either unconcerned or did not know about privacy issue.

III. *How concerned would you be about your own privacy if law enforcement starts using unmanned drones with high tech cameras and recording equipment? Would you be very concerned, somewhat concerned, only a little concerned, or not at all concerned?*

Very Concerned	49%
Somewhat Concerned	20%
Only a Little Concerned	15%
Not at All Concerned	14%
Do not Know	2%

Public is not so confident that law enforcement agencies will use drone appropriately, this is shown from the following question.

IV. *How confident are you that your LOCAL police department will use drones appropriately – very, somewhat, not too, or not at all confident?*

Very Confident	12%
Somewhat Confident	32%
Not too Confident	19%
Not at all Confident	32%
Do not Know	5%

General public is not so confident that local law enforcement agencies will use drone appropriately therefore 76 percent population is agreed with the question about obtaining warrant from judge before using drones.

V. *Should law enforcement agencies be required to obtain a warrant from a judge before using drones or should agencies be able to decide on their own when to use drones?*

Obtain a Warrant	76%
Decide on Use	14%
Depends on Use	6%
Do not Know	4%

Generally public support the usage of drone for search and rescue operation, but they are very much concerned about their privacy.

Summary of the Surveys

According to the first survey either public does not see safety as a very big concern or they yet have to form a clear stand of opinion towards drones. The study of survey further concluded that the public perception about drones also depends on the application of technology. The Australian survey identified public concerns with the application of drones for surveillance and military purposes.

- The Australian public was neutral about drone technology.
- One interesting point was that the survey respondents considered drone technology more beneficial to the society than themselves.
- In the Monmouth University survey, American public overwhelmingly supported usage of drone for search and rescue purpose.
- According to MacSween, George public has different perception and acceptability of drones for different application of drone. Though American public is very much concerned about their privacy.

Based on both surveys it seems that generally public will support the UAV technology but for the application of emergency response. The percentage of support can though be little bit higher or lower than 83 percent support of US survey but it is deduced that the result will be in favor of acceptability of the technology in Denmark. As mentioned earlier that Australian public will consider this technology more beneficial to the society, its mean they are ready to accept new technology for better purpose. If public is concerned about privacy then there is a need of strong regulations as well as better risk communication to persuade public to accept the technology.

6.4 Danish Law and Regulation

After determining that most likely Danish society will accept drone technology being applied for emergency management services. This part of the report focuses on whether the Drone Ambulance UAV and manned drone Ehang-184 could be allowed to fly under laws and regulations. And what are these laws and regulations in force in Denmark.

Danish drone law was changed in the summer 2016. Rules about usage of drone in populated area came into effect and rules about outside of populated areas will be expected by July 1, 2017. There is still a law to inform police prior to all flights. Failure to comply with the new rules can result in fines and in jail. (Peter Gustav Olson 2017)

6.4.1 Rules For Small Drones

There are four categories of small drones as follows,

- 1A: Drones weighing less than 1.5 kg
- 1B: Drones weighing between range of 1.5 kg to 7 kg
- 2: Drones weighing between 7kg to 25 kg
- 3: Drones weighing between 250 gram and 25 kg and operating beyond visual line of site (BVLOS)

It is a law, for 1B and 2, that drone pilots must have had minimum 15 successful flights in populated areas, whereas For category 3, the pilot must have had 50 successful flights in populated areas throughout the last 12 months.

Populated areas

Since September 1, 2016, in populated areas, professional drone pilots are allowed to operate. This is applicable for all size of drones.

- Drone pilot must have license, which one can get after an examination
- There must be a drone license plate.
- All drone owner must have drone liability insurance.

Unpopulated areas hobbyist and minors

Rules about unpopulated area are expected to be applicable from July 1, 2017. Hobbyist must have a drone certificate by passing an online exam. Even children can get certificate if their parents allow them.
However drones that weigh under 250 gram may be exempted from most rules.

How to inform about and apply for drone flying

Drone operator must inform local police in writing 24 hours prior to all flights. Additionally there are some high-risk drone flights that should only be made with prior permission from the Danish Transport Authority. (Peter Gustav Olson 2017) These high-risk flights are as follows,

1. Drone flights planned at night time
2. Expected flight that may fly on crowd or large number of people
3. Flights of drones that have jet motors
4. Drone flights with fast speed of more than 50 km/h
5. Drone flights over a distance of 120 meters
6. Fixed wing drones weighing 1.5 kg
7. If the more than one drone has to take flight the same station
8. Drones flights of beyond visual line of site (BVLOS)
9. Drones fights that are Autonomous
10. Drone flights that are planned indoors but there public have also access there.
11. Where some items have to be dropped from drone flights
12. And lastly flights on enclosed areas that are private.

Since a UAV such as Drone Ambulance weighs less than 7 kg with a pay load of 4 kg comes under law of number 2, that requires from the drone pilots that he must have had minimum 15 successful flights in populated areas. Whereas manned drone Ehang 184 weighing more than 100 kg comes under category 3, for which the pilot must have had 50 successful flights in populated areas throughout the last 12 months. However Ehang-184 is autonomous but it can also be controlled by professional pilots through drones stations it may come under this category. It is not clear whether a manned drone is covered by law under these clauses or not. A clear regulation concerning this should be made by regulators. Permission for SVJB, Esbjerg from police might not be sought in this case since police themselves are part of emergency management services. Or in other words police knows that SVJB can fly drones in advance.

Both types of drones will be either flown directly or BVLOS will be controlled or flown by professionals. Therefore both drones can fly if the pilots Drone pilot have a license, a drone license plate and a drone liability insurance that SVJB can get.

6.5 Risk Communication

This part of the report deals with the risk communication in order to make public aware and accept the drone technology by considering their psychometric risk factors.

Risk communication is an exchange of information in an appropriate way to minimize and regulate the risk. As mentioned earlier that general public is neutral about the drone technology, but many people are showing their concern about privacy. It is important to know that 'how risk is communicated and presented has decisive impact on understanding of risk messages and subsequent choices for treatment and individual behavior'' (Anja Leppin Lecture notes Risk Communication, 2015).

As discussed before the psychometric factors that influence public risk perception of drones are seven factors comparing aviation aircrafts namely benefits of drones, knowledge, control, voluntariness, newness, consequences and fear or dread of the drones. If people are made aware that the UAV will benefit them such as in rescue operation then they will accept it. Therefore there is a need of risk communication in such a way that these factors give a positive picture of drones in public mind. The law and regulations concerning drones should also be made and conveyed in such a way that there should not be any misuse of drones and the public can be confident that their concerns are met by the authorities and they do not develop negative perception of drones in their minds.

According to risk communication experts, communication should be in an effective way to minimize public concerns. Their focused is on hobbyists, the reason is, responsible authorities will not misuse the information gathered during drone operation, but there is a probability that hobbyist may misuse information gathered by UAVs about public privacy. Therefore the Danish traffic ministry communicated law and regulations about drone in comprehensive way.

For the purpose of objectivity of removing concerns comprehensively and easy to understand pictures have been produced to convey the message by the Danish regulators. The public can not know that a drone flying near or over them is flown by a hobbyists or by some professionals for rescuing or any other purpose. They can generally fear their privacy. In the following eight figures rules and regulations concerning drones are communicated and illustrated in a way that are easy to understand and can relieve public concern about privacy.

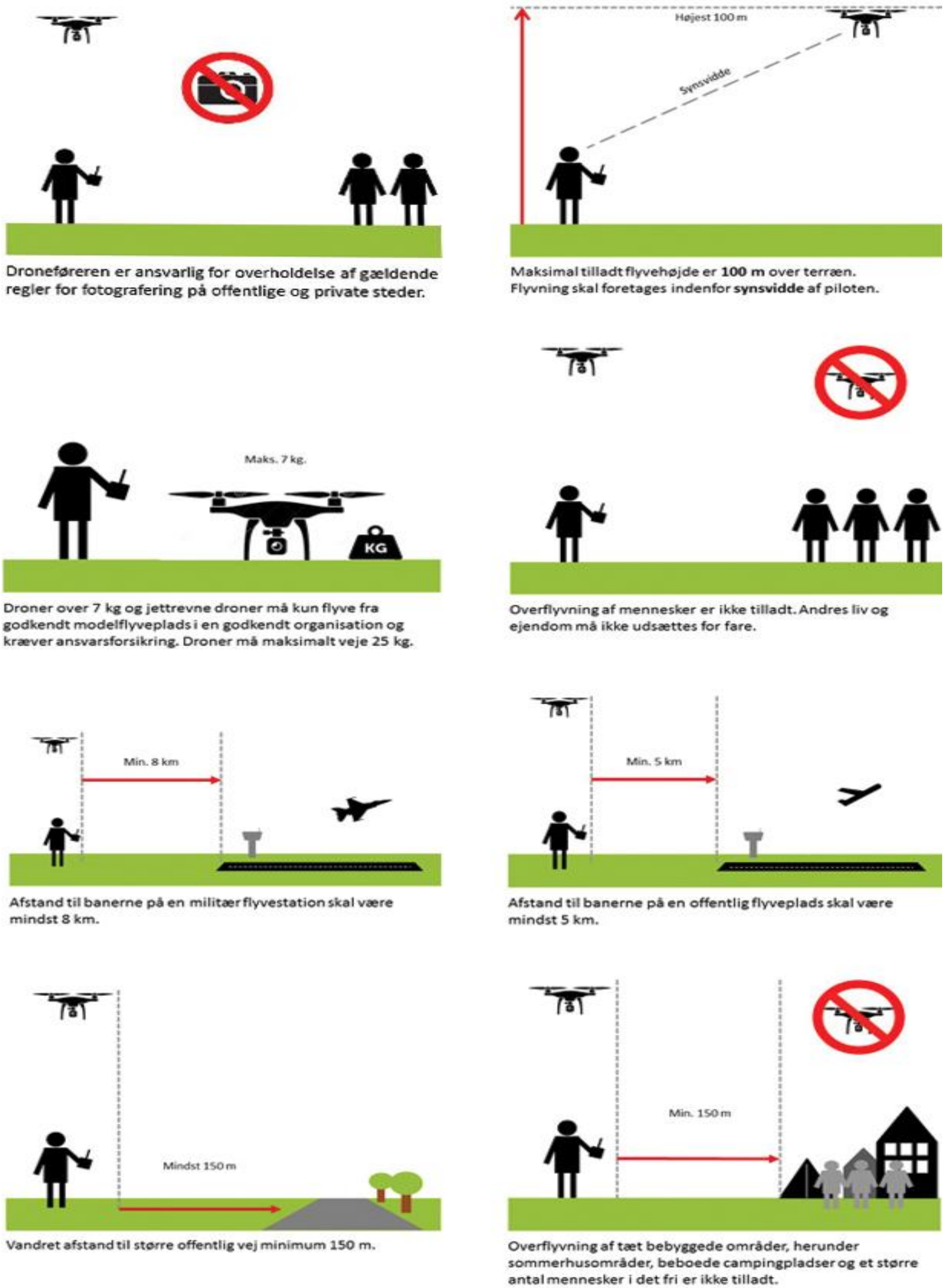

Figure 34 Drone Legislation

Source: Trafikstyrelsen, Droneregler

Translation from Danish to English of figures is as follows from left to right going downwards in sequence,

- Drones weighing over 7 kg and jet drones should only fly in an approved aerial field and in an approved organization and it should be insured. Drones can maximum have a weight of 25 kg.
- Maximum permitted altitudes are 100 m above ground flight must be made within sight of the pilot.
- The kind of Drones weighing above 7 kg and jet-powered drones are allowed to take flights only in model airfields in an approved organization. And these drones have to be insured and must not exceed 25 kg.
- Flying above people is not permitted. Other people's lives and property should not be put to danger.
- Distance to the lanes of a public airport must be at least 5 km.
- Distance to the lanes of a military aerodrome must be at least 5 km.
- There should be kept at least 150 meter horizontal distance to major public road
- Flights near residential areas including holiday homes, residential camping sites and where there are large number of people are not allowed.

These figures make it easy for drone owners to follow and public to know that their privacy is not compromised.

6.5.1 Ways of Communicating Public about Drone Technology.

It is of high importance to know that how much people can trust a communicator conveying about risk along with how the data about risk is presented and framed.

I. Framing of Messages of Risk Communication

Framing means how message or information is constructed. It means sentences describing risk should be easy to understand conveying right message because sometimes one risk can be constructed in different ways and people will interrupt them differently. It mainly depends on the message content whether it's about their benefit or loss. Drone's application for the purpose of emergency response should be constructed in messages in way that is according to understanding of general public. For instance based on the above survey's it can be concluded that if people are told that the drones are being used for policing and arrests criminals they might fear seeing drones near them while they would perhaps be more willing to accept the drones if they are told that the drone is trying to save someone's life by rescuing him/her for emergency response.

II. Numeracy of Risk

Communication of risk should be conveyed in mathematical expressions since it has assertive impact on people's mind how it is based on the condition that the audience being targeted can understand these mathematical expressions such as probabilities. (Peters et al., 2006) For instance, in case of UAV drone ambulance people should be told that it can save life by up to 90% of victim of cardiac arrest. This 90% can make a decisive affect on people's acceptability of the technology.

III. Trust and credibility of Risk Communicator

For affective risk communication of drones it is important that the communicator in this case SVJB and Esbjerg Municipality have trust and credibility in minds of public. If they trust and have credibility in SVJB then they will comprehend and accept the technology. Due to a lack of trust of the source of risk communication the public will not comprehend. There are also chances that the public will react angrily if a high risk is not conveyed to them by government authorities properly and promptly.(Renn, 2010)

IV. Medium of Risk Communication for the Acceptability of Drone Technology

Moreover mode of selection of risk communication is also important. It should be targeted specifically to get maximum result, for example communicating risk to people of certain age. ((Anja Leppin Lecture notes Risk Communication, 2015 and Ahsan, D 2015). For instance for old people newspapers, radio can be used to inform them about the usefulness and friendliness of drones so that they can accept the technology and in case of an emergency event like Kroskro traffic crash they should avoid being panicked.

Young generation pays more attention to social media and listens to celebrities. Workshops and meeting of student unions can also be used. Young people can be warned of emergency situations along with drones as part of rescue services. SVJB and Esbjerg Municipality have already presence on twitter and Face book that could be used for this purpose. Moreover celebrities like popular Danish singers Medina and Nick and Jay for instance have a big say if they communicate messages of drones being useful and life savers instruments in rescues,

Similarly middle aged people can be conveyed through workers unions, Television, magazines and in social gathering the friendliness of drone technology and its usefulness to the society. Moreover, how can they use drone such as drone ambulance in providing first aid in case they are bystanders near an injured person. This is the persuasive and affective way of communicating risk.

6.6 Conclusion

Risk perception in public about a technology is based on some psychometric factors of benefit of technology, control on it, newness, consequences of using that technology and fear and dread etc. These factors influence people's perception and on the basis of which they build an opinion about any technology such as drones.

The first survey based on Australian research concludes that people have a neutral view about the use of drones. However people's perception changes with the application of drones which is evident in case of American survey which is based on the application of drones in rescue and search operations. The results showed a major support to use drones for emergency management services. With the application of these results on it is deduced that the Danish society will support the technology may be not by 83 percent but with some margin of difference that can still be in favor of accepting the technology. The public authorities like SVJB and Esbjerg Municipality are supposed to have a credibility and trust in local population. However these two drones i.e. UAV drone ambulance and manned drone Ehang 184 might face some regulation and risk perception hurdles. According to existing Danish regulations regarding drone, it seems like drone ambulance can be given permission to flights due its specific configuration of weight and a clause already present in the regulatory act. However manned drone Ehang-184 may be allowed permission for flight but prior permission from authorities due to weighing more than 25 kg but the law itself does not state manned drone specifically. Therefore a law concerning manned drones should be adopted because current regulation does not state its implication specifically about manned drones.

The risk perception can be made positive and the acceptability of drone technology in public views through persuasive and affective risk communication. Which can pave the way of incorporation of drones into emergency management system in near future.

Chapter 7

7. Conclusion

Emergency management cycle is well applied by the Danish authorities to cope with emergencies in Denmark. In case of a traffic accident at Kroskro Esbjerg, the fire and rescue service (FARS) SVJB will response by dispatching 3 vehicles. The inspector vehicle will take 10 minutes to reach there with 80 percent chances. Fire and rescue trucks are followed by him with a response time of 15 minutes. This is the standard emergency procedure.

However in case of a seriously injury at the scene of accident this response time should be reduced. A seriously injured person may suffer brain, neck or chest injuries by first aid in less than 10 minutes to sustains life whereas in case of cardiac arrest he needs first aid within 4-6 minutes. Due to more severe trauma, blood loss, cardiac arrest, stroke, etc. injured person can die in fairly short time. In case of a traffic accident a person may face cardiac combustion for example due to a trauma caused by steering wheel, pulmonary oedema or due to excessive blood loss. Therefore there is a need to further improve response time. In case of a cardiac arrest only 8 percent people survive but the survival chances increase to 38 percent with application of AED defibrillator. These survival chances can be increased to 80 percent, if injured person receives first aid and is applied to CPR from a bystander with the live instructions of a professional.

A UAV drone that can reach in less time and carrying first aid toolkit or AED defibrillator etc such as Drone Ambulance can be a good choice to induct into emergency response. However UAVs are not the only alternative to make response time quicker, helicopters and other flying objects such as flying cars can also be alternatives. To make a choice from the alterative a Multi Criteria Decisions Analysis MCDA is applied that reveals the UAVs as the most cost effective and better option than others.

Manned drone Ehang-184 is expensive comparing UAVs and has same speed of 100 Km/h as UAV drone ambulance and it has also not been tested for the application of emergency responses. Moreover Ehang-18 along with helicopter exposes airborne persons to the dangers of heating, chemical and radioactivity in case these are applied in particular related emergencies. Helicopters are a proven technology at higher TRL and Life Product Cycle but it cannot be ascertain in every emergency situation whether there is a place worth landing and taking off helicopter besides some other limitations. The emergency medical service (EMS) of Denmark has helicopter ambulances in use but their operational costs are too high and these cannot be used as a first response to the site of accident due to limitations.

There are 4 percent chances that weather in Esbjerg will be extreme hindering the flight of UAV. Inspector on ground can give first aid, apply CPR and use ARD professionally to the injured person that can save a life and thereby improving safety. The report finds that UAV should not replace inspector vehicle instead it should be integrated to assist as part of the emergency response along with inspector's vehicle for maximum possible safety and being a cost effective alternative.

UAVs have hurdles of getting approval from regulators and biased and lack of knowledge based risk perception present in public's mind. An Australian research survey concludes that people have a neutral view about the use of drones. However the American public supported UAV in assisting emergency operations by up to 83 percent suggesting that the public views regarding UAV differs according to its application. Heuristic and psychometric factors of this risk perception can be dealt with better risk communication to turn public views of privacy, dread and fear into positive acceptability towards drone technology.

The findings of this report supports the efficacy of UAVs for the welfare of the society. UAVs are rapidly evolving and these would be more advanced equipment wise and cost effective with passage of time. The incorporation of UAV into emergency response service should not replace anyone including inspector of FARS of SVJB, firemen, helicopter crews or police officers. UAVs should rather assist them by integrating into the system for delivering first aid toolkits or AED defibrillators, for documenting accident scene response faster as well as fostering decision making process along with better outcomes of maximum possible safety for a overall robust emergency management response.

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9. Appendix

Copy of audio interview of Jens Mølgaard head of SVJB Esbjerg is attached.