Rescue Emergency Drone (RED) Network for Assessment of Traffic Accidents in Denmark

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Rescue Emergency Drone (RED) network for assessment of traffic accidents in Denmark

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ABSTRACT: Onsite real-time video streaming of traffic accidents covering condition of inflicted person can help overcome problem of under and over-triage by emergency services. A network of Rescue Emergency Drones (REDs) that could transmit live video to emergency services is proposed to be mounted at the sites prone to frequent accidents in Denmark. A risk mapping for placement of RED docking stations at suitable places of southern Danish city, Esbjerg and its outskirts has been designed using Geographical Information System (GIS) tools ArcMap, and ArcGIS 10.5.1. The result demonstrates the robustness of RED into emergency services by providing high quality footage that helps to assess the scene of crash faster than the standard existing procedure.

1 INTRODUCTION

Lack of clarity of the condition of patients or injured persons can lead to wrong decision taken by Emergency Medical Dispatcher (EMD) and Emergency Medical Service (EMS). For instance, in Denmark 'Unclear Problem' of level B-E emergency was the chief complaint involving 66 deaths in period between 2011–2012. Because in many cases appropriate resources were not dispatched to handle the emergency which leads to degree of over-and under triage. (Andersen et al 2014)

Under and over-triage is a major problem that costs not only financial losses but also human lives. For instance, in Denmark 18 deaths could have been prevented if EMD had dispatched a targeted response. (Andersen et al 2014)

Drones have many applications in emergency services. For instance, drones can reach at the scene of the road accidents faster than conventional means of transportation. The aim of this study is to explore the potential benefit of a drone system to transmit live video footage covering the condition of the inflicted/patient that may improve the decision making of EMD. For application of drones in this regard, this study considered traffic accidents, because traffic accidents top the list of human casualties' statistics of non-natural cause of fatalities. Around 1.25 million people lost their lives and 20–50 million people suffered injuries due to traffic accidents. (WHO 2017)

Although Denmark is relatively safe country for commuters, there were 211 people killed, 1,796 suffered serious injuries and 1,432 suffered slight injuries in traffic accidents in 2016. (Statistics Denmark 2017)

Emergency medical dispatcher finds it difficult sometimes to comprehend the situation and condition of the emergency. First responders usually rush to the emergency sites with limited information that can sometime jeopardize the rescue operation. Therefore, if EMD and EMS can see and assess the severity of injuries of an inflicted person in traffic accident, it will facilitate a targeted response via live video footage.

The Danish Emergency Medical Communication Center (EMCC) receives medical emergency calls to respond and rescue patients and injured persons. EMCC staff responds the calls according to the Danish index care into five categories. Category "A" represents a life-threatening or potentially life-threatening condition; therefore, it requires immediate response. Category "B" means that a patient or injured person requires urgent help, but his/her condition is not life threatening, whereas category "C" requires an ambulance in a

non-urgent condition. Under "D" category EMD needs to send a patient transport while under "E" category no ambulance is dispatched instead taxi or other transportation is advised.

Category "A" has a pre-hospital time of 08:12 minutes, but sometime EMD can make a wrong decision in dispatching targeted response. In one of the case of an audit study, it was found, that EMD categorized an emergency as category B, however, when the ambulance arrived at the scene, a Mobile Emergency Care Unit (MECU) was summoned due to the severe condition of the patient. The life of patient would have been saved if the ambulance along with MECU could have been dispatched. (Andersen et al 2013) Therefore, fast response with right resources dispatched in saving human lives is crucial. The Danish pre-hospital median time for all emergencies is 10:27 minutes. (Andersen et al 2013) The average minimum response time of fire and rescue services (FRS) is 10 minutes and it could be 15–20 minutes depending on the location of accident sites. (Sydvestjysk Branvæsen 2015)

Rescue Emergency Drones (REDs) can reduce time of onsite assessment of the condition of inflicted person by reaching to the patient/injured person faster than the conventional means of transport and transmitting 'live video' that can help to cope with the problem of under, and over-triage.

2 RED NETWORK IN DENMARK

Providing visual aids by a drone will improve the prehospital process in case of a traffic accident this aim of the project will meet the need to reduce fatalities.

There are many potential benefits of incorporation of RED into emergency services and their improving the decision making as follows,

- Real time visual feed from the scene of crash will assist in better assessment of severity of the emergency by dispatcher.
- The sufficient of amount of resources will be saved by emergency services by overcoming problem of over and under-triage.
- A targeted and quick response will increase survival rate of inflicted persons.
- A targeted response will improve the quality of life by decreasing the severity of injuries of causalities and thereby saving them to live without physical impairments.
- Dispatcher would be able to better guide caller to handle emergency properly while the ambulance is on its way.
- Dispatcher can calm down the panicked caller.

Denmark map is developed in GIS based on the data of traffic accidents in Denmark between 2012–2016.

In Figure 1 the black dots represent the accidents, which are more frequent in populated areas of the country. There were 87,787 total accidents in Denmark recorded between 2012 to 2016 (Danish Road Directorate 2017). Majority of the accidents are reported in bigger cities for instance, Copenhagen, Odense, Aarhus and Aalborg.

Based on the audit study it is assumed that the onsite live video streaming aid would help to mitigate the consequences of accidents. For visual aid, network of REDs is proposed for Denmark. For RED network Esbjerg municipality is considered as a case study with the broader application for the rest of the country.

2.1 *Esbjerg municipality*

This study is carried out in Esbjerg municipality, which covers a total area of 794.5 km² (Sydvestjysk Brandvæsen 2015). The total population of Esbjerg municipality is 115,905. (Statistics Denmark 2017) The density of the population is 116 (individual/km²). The municipality consists of both rural and urban areas. Esbjerg municipality observed 2,515 total number of traffic accidents between 2012 and 2016. The accident data is extracted from the Danish Road Directorate and accidents coordinates are shown in the following Esbjerg municipality map.

Most of the accidents were recorded in the residential area. A total *of n* = 2515 cases of traffic accidents were reported in Esbjerg municipality between 2012 to 2016. The traffic accident casualties during this period are given in Table 1.

Table 1 shows that in 2016 total 63 casualties were recorded, among them six persons were killed, 38 injured seriously and 19 were injured slightly. One death due to traffic accidents costs Danish society up to 17.3 million DKK. (Transportministeriet 2010). To avoid such a huge loss, it is necessary to improve the pre-hospital response

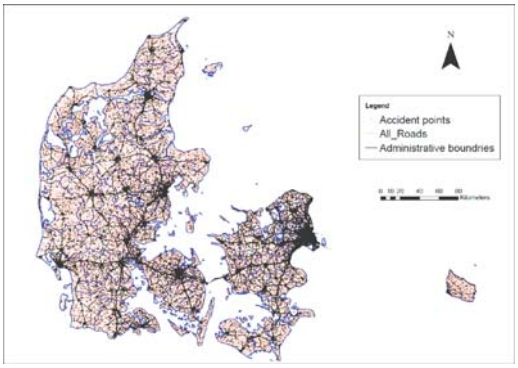

Figure 1. GIS mapping of traffic accidents coordinates on Danish roads.

Table 1. Traffic accidents casualties in Esbjerg municipality.

Years	Casualties, total	Killed	Seriously injured	Slightly injured
2012	102	7	49	46
2013	61	1	32	28
2014	83	2	47	34
2015	86	7	42	37
2016	63	6	38	19

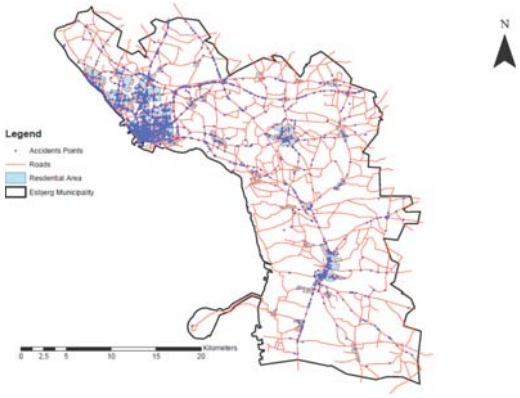

Figure 2. GIS mapping of traffic accidents coordinates on Esbjerg municipality roads.

time. There is a robust evidence for an association between short response time and survival rate for traffic accidents. (Sánchez-Mangas 2010)

Currently in Denmark, total pre-hospital median time for category "A" is 08:12 minutes whereas for B, it is 13:27 minutes. For "C" category, it is 16 minutes and 5 seconds. Similarly, for "D" category the time is 19:46 minutes. The Danish pre-hospital time median time for all emergencies is 10:27 minutes. (Anderson et al 2014). The detail of prehospital time is given in Figure 3.

Moreover, fire and rescue service (FRS) has also a crucial role in saving human lives as first responder along with EMS. As far as fire and rescue services are concerned in case of Esbjerg municipality, their time to reach at the site of accident in the municipality is depicted in the Figure 4.

Fire and rescue station of Vibevej 18, 6705 Esbjerg Ø is mainly responsible for urban area of the Esbjerg municipality. The emergency team is comprising of 7 rescues workers on 3 vehicles that is incident commander vehicle, fire truck and rescue truck. (Sydvestjysk Branvæsen 2015)

The green area of the map shows a response time of 10 minutes while yellow area represents 15 minutes of response time and rest of the area represents 20 minutes of response time. (Sydvestjysk Brandvasen 2015)

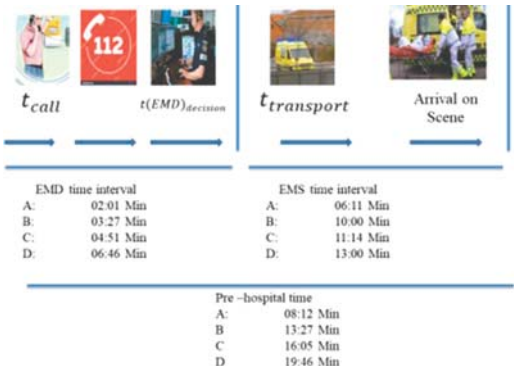

Figure 3. Current pre-hospital emergency time.

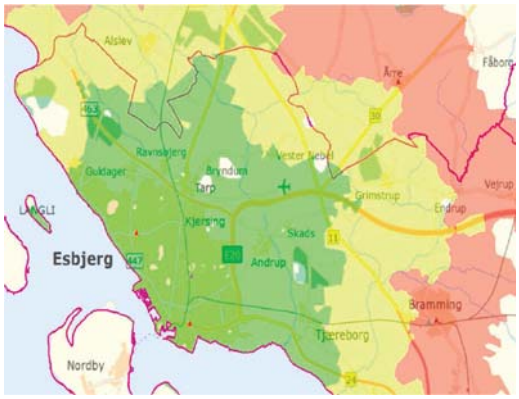

Figure 4. Esbjerg fire station response time to emergency calls.

RED can assist in emergency operations by reducing the FRS onsite assessment via video streaming by reaching faster than their time of 10 to 20 minutes depending on the location of accidents from FRS station.

2.2 *Identification of RED placement*

For optimal placement of RED networks, a spatial analysis was performed using geographic information system (GIS) tool ArcMap, and ArcGIS 10.5.1 to analyze and visualize the results. (Law & Collins 2015)

For application of RED network, DJI M210 Matrice drone is considered, which is one of the most advanced drone to date with broader industrial applications. The cruise speed of this drone with A mode is 82.8 kph. During vertical ascent, it has a speed of 5 m/s and vertical descent the speed is 3 m/s. (DJI 2017)

This drone can transmit footages with camera such a Zenmuse X4 and Zenmuse X5 s along with

Zenmuse Z30. The range of the drone is 7 km. Because of its agility, water proof and along with other specifications, it fits best to be considered as RED for building network to quickly assess the site of accident crashes and support EMD and EMS to make correct and quick decisions. RED can also assist fire and rescue team via video streaming.

Esbjerg municipality is considered for this explorative study. Esbjerg municipality is divided into urban and rural areas.

In Figures 5 and 6 optimal locations for placement of RED network are shown. To cover the urban area of the Esbjerg municipality five placements are identified to mount RED network. Similarly, five placements are also identified for rural area (Fig. 6). Each placement is the center point of the circle shown on the map. The drone range is 7 km; therefore, each circle represents 7 km of radius. The origin of the circle is for the docking station of the drone. As each UAV location covers a radius of 7 km, several traffic accident cases in the analysis are overlapping. A total *of* $n = 2515$ cases of traffic accidents were reported in Esbjerg municipality between 2012 and 2016. Out of these 2,029 were in the urban area and 486 were reported in the rural area of the municipality. For each location's (both rural and urban) median time, maximum time and minimum time is depicted in the following Tables 2 and 3.

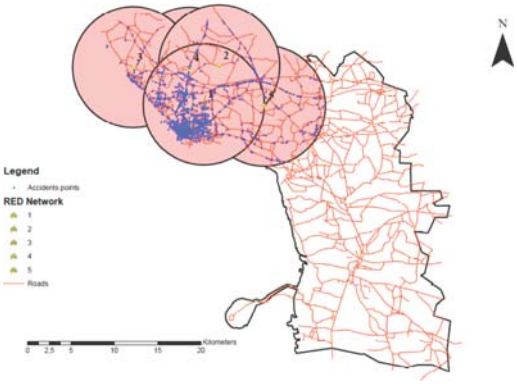

Figure 5. RED Network placement across Esbjerg municipality urban area.

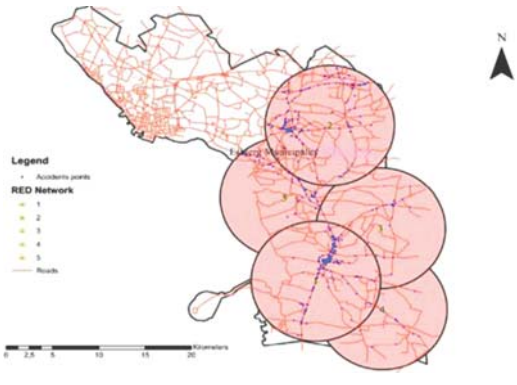

Figure 6. RED network placement across Esbjerg municipality rural area.

Each location is identified based on the number of accidents in the radius of 7 km of circle. The origin of the circle is the location for the drone placement. From drone placement to wherever accidents occurred in the circle, the distance is measured. The following formula is used to measure the distance between longitudinal and latitudinal coordinates.

$$d = \sqrt{(x_1 - x_2)^2 + (y_2 - y_1)} \quad (1)$$

Considering the speed of the drone total time between two locations is calculated and subsequently that total time is used to calculate the median time, maximum time and minimum time for each location. The preparation time for launching the drone is not considered, as this time is approximately 3 seconds. Claesson et al 2017) whereas airborne time of the drone is considered for median time calculation.

Maximum time for both urban and rural location is approximately 5 minutes 57 seconds, whereas minimum time and median time is varied across the locations.

Table 2. RED network median time to reach at the scene of accident in urban area.

Location urban	Median time	Maximum time	Minimum time
1	03:25	05:57	00:59
2	04:48	05:57	01:59
3	05:01	05:57	01:07
4	04:57	05:57	01:03
5	04:54	05:57	01:31

Table 3. RED network median time to reach at the scene of accident in rural area.

Location rural	Median time	Max time	Min time
1	03:21	05:55	01:05
2	04:22	05:56	00:53
3	04:53	05:57	01:39
4	04:03	05:56	01:01
5	04:05	05:57	01:47

3 DISCUSSION

Real time video from the scene of crash is powerful tool in supporting quick and right decisions. (Fig. 7) Due to many reasons bystander cannot clearly define the health status of the patient/injured persons. Danish medical staff supports the concept of live video streaming to deal with problem of over and under-triage. (Gerdstrøm 2017)

To have a safe operation of the live video streaming via RED, precautionary measures needs to be considered. There should not be any safety concerns for bystanders or any harm to the surroundings environment. DJI M210 has collision avoidance sensors, however, bystanders onsite must be informed of RED approaching to them. Moreover, rotors of RED should be shut down once the EMS or FRS reach at the site of accident.

Building and integrating RED Network in Denmark may bring new challenges for the emergency services to get training and implement the system as well as the interaction among EMD, bystander or inflicted persons at the site of crash.

There are some risks associated with this novel idea of RED network such as public perception of the drone technology, differentiation (colour/appearance) between the emergency drones and other drones for the public, risk of falling of a drone, risk of drone docking unit stolen or damaged, risk of data/information stolen, charging issues with the drone, bad weather and environmental effects of the drone technology etc.

Nevertheless, the pre-hospital phase of emergency services would benefit from RED due to live mutual visual inspection of the emergency. The real time video feed will help cut down the costs of the resources that are not needed at the site of crash. For instance, a procedural protocol to respond to a traffic accident alert involves dispatching of fire truck, incident commander vehicle and a rescue truck that may or may not be needed. Inter departmental and intra departmental communication of emergency services is expected to be improved. Another worth mentioning benefit of RED networks is that the implantation of the system to traffic accidents will pave the way to scalability and application of it to other emergencies.

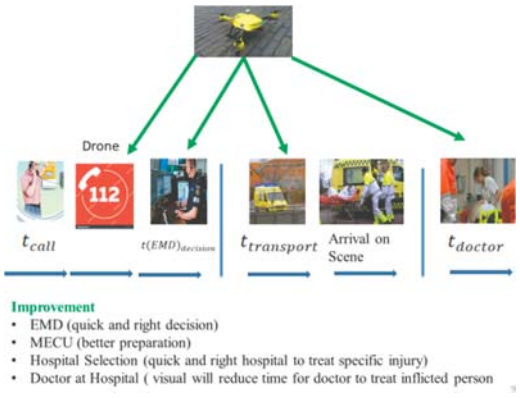

Figure 7. RED network assessment of emergency scene via live video.

4 LIMITATIONS

Beyond Visual Line of Sight (BVLOS), flight operations of drones are not allowed in Denmark.

It is important to know the acceptability of drone technology in local population, for which a there is a need to have comprehensive risk perception study.

DJI M210 drone was considered having a range of 7 km with area of network coverage of 14 km; many accidents in the analysis are therefore overlapping. The configuration of the drone along with range would have resulted different results if we would had considered another drone.

The real test flights are yet to be performed.

5 CONCLUSION

The application of GIS model results in the identification of appropriate placement of RED networks across Denmark. The real-time video transmission via RED networks can enable emergency services to take immediately right decision and dispatch a targeted response to treat injured persons. Therefore, RED could be the key to overcome the problem of under-triage and over-triage in saving lives besides cutting budgets.

ABBREVIATIONS

BVLOS: Beyond Visual Line of Sight; EMCC: Emergency medical communication center; EMD: Emergency Medical Dispatcher; EMS: Emergency medical services; FRS: Fire and Rescue Services; GIS: Geographical information systems; GPS: Global positioning systems; MECU: Mobile emergency care unit; RED: Rescue emergency drone.

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