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HOW INNOVATIVE TECHNOLOGY CAN BE USEFUL FOR THE CRISIS MANAGEMENT

Nokia Saving Lives (NSL) Case

Master´s Thesis
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ABSTRACT

Innovative technology includes LTE connected drones with payloads, portable LTE network and portable data center for data analysis and storage for emergency and rescue situations. Portable LTE network can be setup anywhere even where the network does not exist which helps rescuers to get information at the right time to save the lives from disaster. Disasters are unpredictable and might affect the infrastructures and put the lives into danger. In such a scenario, an innovative technical solution is useful to save time during the critical period where life and death of people depends on a fraction of second. A literature review identified different phases of disaster management and showed a use case of drones and LTE network, challenges and solutions in natural disaster situations

The thesis presents the Nokia Saving lives (NSL) case which includes the analysis of Nokia innovative technical solution to manage the disaster which was deployed in Philippines live demo on 23rd Nov 2018. This research also shows how three different parties (Nokia, Smart and Philippine Red Cross) collaborate together with their own expertise to manage the disaster.

The use case of LTE connected drones and portable LTE network was developed based on mixed research approach (both qualitative and quantitative) to develop a framework for organizations to manage the disaster by using the Nokia portable technology. The deeper understanding of real time data from LTE connected drones in support of portable LTE network will further enable humanitarian actors and other non-governmental organizations to take effective measures in the disaster relief operations.

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LIST OF ACRONYMS AND ABBREVIATIONS

3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
5G	Fifth Generation
CAA	Civil Aviation of Authority
CAAP	Civil Aviation Authority of the Philippines
CCTV	Closed Circuit Television
CR	Cognitive Radio
DHS	Department of Homeland Security
DMO	Disaster Management Organizations
DRN	Disaster Response Networks
DSA	Dynamic Spectrum Access
DWDM	Wavelength Division Multiplexing
E2E	End to End
EASA	European Aviation Safety Agency
EMTEL	Emergency Telecommunications
ETSI	European Telecommunication Standard Institute
FAA	Federal Aviation Administration
FEMA	Federal Emergency Management Agency
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSMA	The GSM Association
HA	Humanitarian Actors
HA/DR	Humanitarian Actors/ Disaster Response
ICRC	International Committee of the Red Cross
ICT	Information and Communication Technologies
IDMC	Internal Displacement Monitoring Centre
IFRC	International Federation of Red Cross and Red Crescent Societies
ISDR	International Strategy Disaster Reduction
LIDAR	Light Detection and Ranging
LTE	Long Term Evolution
MAC	Medium Access Control
MDRU	Movable and Deployable Resources Units
MESA	Mobile Broadband for Emergency and Safety Applications
MSF	Medecins sans Frontieres
NGO	Non-Governmental Organizations
NRA	National Regulatory Authority
NSL	Nokia Saving Lives
PPDR	Public Protection and Disaster Response
PRC	Philippine Red Cross
QoS	Quality of Service
RPAS	Remotely Piloted Aircraft Systems
RR	Radio Regulations
TIA	Telecommunications Industry Association
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UN	United Nations
UNESCAP	UN Economic and Social Commission for Asia and the Pacific
VLOS	Visual Line-of-sight

1 INTRODUCTION

This chapter introduces the Nokia Saving Lives (NSL) case and the use case of NSL innovative technologies which includes LTE connected Drone with payloads, portable LTE Network and portable data center for the crisis management and also provides the background and motivation for the research. Further, it discusses the contribution and outcomes of the research and shows an outline of the structure of this research.

1.1 Introduction of disaster and innovative technology

Disaster is an unpredictable phenomenon that cause massive damage or loss of life by its unwanted consequences (Ghafoor et al. 2014). The international mission group appointed by Department of Humanitarian Affairs of United Nations defines disaster as ¨ a serious commotion on the operation of the society, which is out of the hand of affected society to cope using only own resources, causing extensive human, material or environmental losses. Natural disaster is an unexpected scenario that occurs due to natural processes such as earthquakes, tornadoes, tsunami, freezes, blizzards, extreme hot or cold, drought, or insect infestation (Kamal 2015).

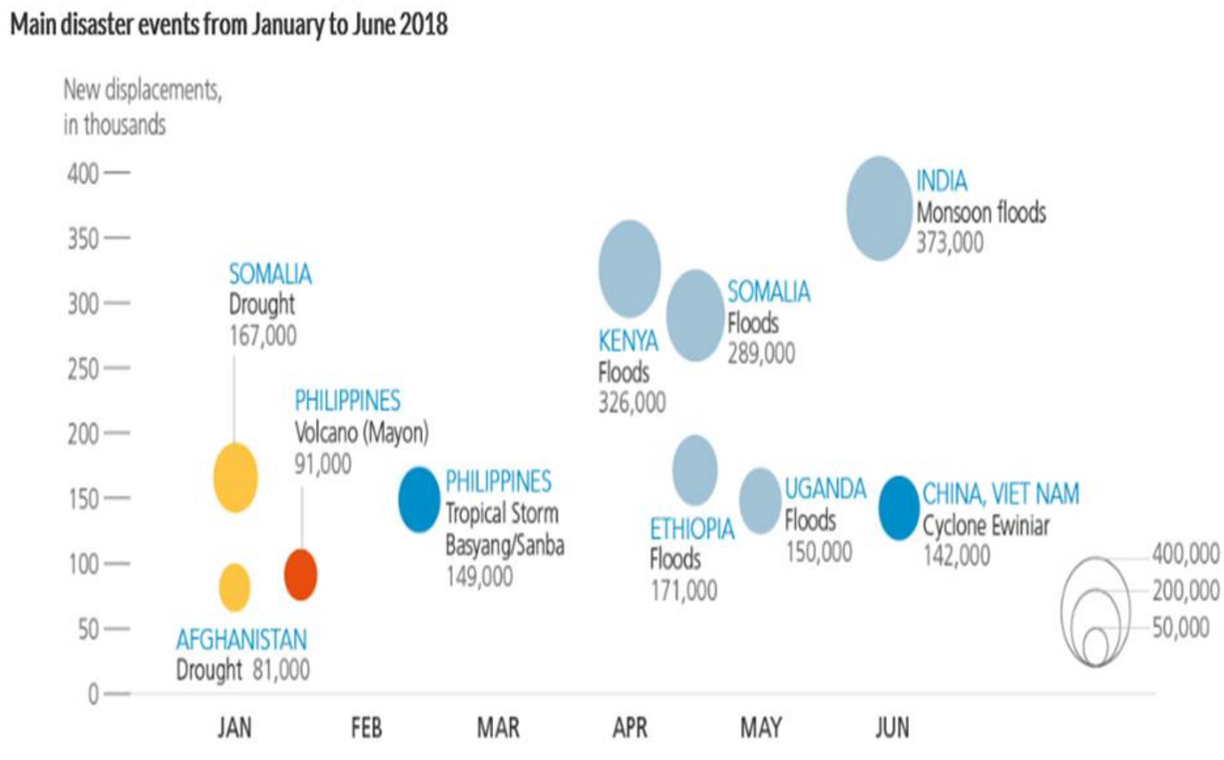

Figure 1 Main disaster events from January to June 2018 (Source: www.internal-displacement.org/mid-year-figures).

The latest diagram from the Internal Displacement Monitoring Centre (IDMC) from **Figure 1** reveals that millions of people around the world are displaced within their own country since January 2018. According to IDMC, almost 3.3 million displacements related with disasters were recorded in 110 countries and territories. Only in the Philippines, volcano and the tropical storm made a significant displacements of 2.4 million people (https//www.internal-displacement.org). The increment of crisis and displacement of people around the world has also increased the advancement of technology that makes easier to authorities, relief groups and individuals to prepare for and respond to emergencies, said Claire Thwaites, head of the UN Foundation and Vodafone Foundation Partnership. The study also acknowledged; innovation in technology is reshaping communications during a crisis as well dictates how far innovative technology can be taken to scale. Information plays a crucial role to effectively handle the results from emergency and relief (Apvrille et al. 2014). Aerial or satellite images are predictably used as a data source for geospatial data collection, map creation and updating purposes (Koeva et al. 2016). However, it can be expensive and time-consuming to obtain information (Koeva et al. 2016). Currently, Unmanned Aerial Vehicles (UAV) are emerging as appropriate technology which has the prospective to provide information with a very high spatial and temporal resolution at lower cost (Koeva et al. 2016). Innovative technology like drones improve situational awareness, surveillance, mapping, and assessment by assisting Humanitarian Actors (HA) superiorly by three scenarios (Apvrille et al. 2015):

1. Communication and coordination of operations
2. Topography coverage
3. Search operations

Drones are effectual in gathering information by scanning and covering a disaster-affected area that assists to guide rescue teams in most crucial situations to rescue the people and the property (Apvrille et al. 2015).

Disasters are unpredictable and cause severe damage to life and property. There is a high possibility of the destruction of communication networks components that cause the telecommunication failures (Ghafoor et al. 2014). Like, the tsunami in Japan (2011) has damaged approximately 1.9 million fixed communications lines and 29,000 base stations (Gomez et al. 2014). The knockout of networks and increased traffic demand delay the recovery process. This affects the proper communication flow among rescuers (Ghafoor et al. 2014). There will also be a problem for the overall coordination among humanitarian actors and operational coordination on the ground within the rescue teams in an emergency area (Ghafoor et al. 2014). Hence, there is a necessity to deploy the proper infrastructures that provide faster services and interoperate with heterogeneous technologies (Ghafoor et al. 2014).

To sum up a dedicated network for the rescuers for e.g. portable LTE network may be beneficial for effective communication to rescue the people. It also maintains the coordination of drones and other user equipment to pass the captured information of drones to Humanitarian Actors for the efficient management of emergency (massive negative large-scale impact by a specific scenario on people have been incoherently named ¨emergency”), and to save people as well as resources.

1.2 Purpose of the research

This thesis is assigned on a Nokia Saving Lives (NSL) case. NSL will deploy its innovative technical solution to manage the disaster in the Philippines in collaboration with the Philippines Red Cross (PRC) and Smart Communications network operator. The NSL innovative solutions include LTE connected Drone with payload, portable LTE network and portable data center for data analysis and data storage.

The purpose of this research is to discover how the solution can be successfully implemented in the Philippines for emergency management in coordination with PRC and

Smart Communications. Additionally, this research is to analyse the innovative technology i.e. LTE connected drones and portable LTE network whether effective or not for the crisis management and to rescue people in the Philippines. The goal of this thesis is to understand and answer the following research questions:

1. How different organisations collaborate to save the lives from the disaster?
2. Are LTE connected drones being beneficial to manage crisis management?
3. Is portable LTE network being beneficial to support crisis management?
4. What are the challenges faced by NSL technical solution and how to overcome them?

The following heading (**1.3**) introduces the Nokia Saving Lives (NSL) case.

1.3 Nokia Saving Lives (NSL) case

Nokia has a lot of stories since its establishment (1865) to till date. Once upon a time Nokia used to sell more cell phones than anyone else in the world. Time being that did not last long. The **Figure 2** below explains about the Nokia successful integration and transformation. In 2014, Microsoft agreed to buy Nokia's mobile phone business and by the end of the year stopped using the Nokia brand (www.wired.com). After the sale of the best-known part of the company, the Nokia group focused on selling high-end networking gear and software to telecommunications companies and Internet service providers (www.wired.com). The acquisition of Alcatel-Lucent in 2016, further intensified and outspreads its global reach. Bell Labs, a division of Alcatel-Lucent, brought an unparalleled history of technological innovation including: lasers, transistors, and UNIX. Bell labs researchers led analogue, digital and mobile shifts in communication technology; the development of the internet; and the innovation of the wavelength division multiplexing (DWDM) enabling huge increases in network capacity. Bell labs pioneered the mobile revolution-from the first ever hand-held mobile phone in 1973, to the first-ever calls on GSM and LTE (www.nokia.com).

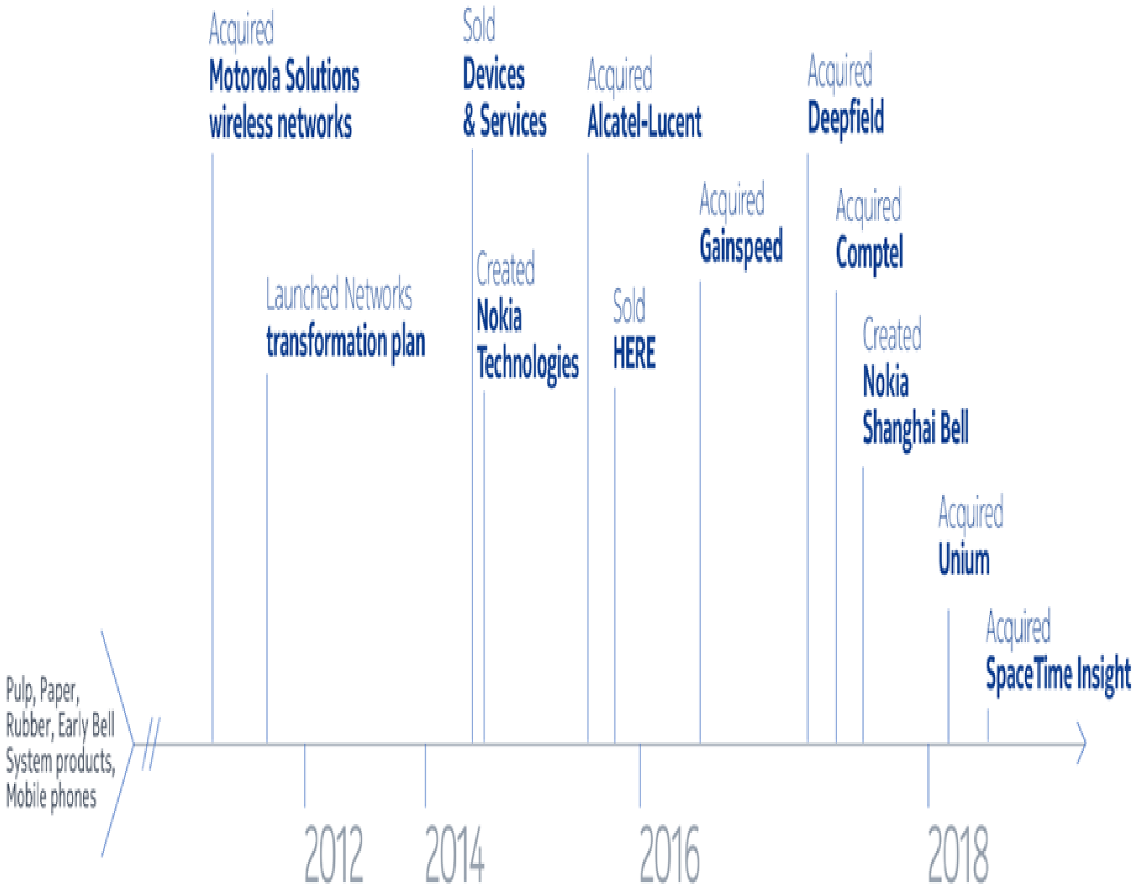

Figure 2 Nokia Successful integration and transformation (Source: www.nokia.com)

Nokia Saving Lives (NSL) started as a program to bring innovative technology into the use in natural disaster cases. It was then set up as a non-profit initiative to allow the fastest implementation with non-profit partners started in 2016 in support of the UN sustainable goals. The innovative technology **use cases** are the portable LTE Network, LTE connected drones, and portable data center for data analysis and storage capabilities.

NSL is working in collaboration with Humanitarian Actors and NSL technical experts who bring and operate innovative technology in a disaster area to rescue the people and to manage the crisis. This approach allows Nokia to bring innovative technology faster in the field of crisis management, where otherwise lack of understanding of operational processes and technology might delay the use of technology in the emergency area.

1.4 The structure of the study

The **Figure 3** below describes the structure of the study. The study is divided into five chapters and the content of each chapter is described more precisely in the diagram below. The **first chapter** is the introduction part. It covers the background of the research and presents research purposes, goals and problems. Then the case company NSL and the structure of the study are introduced. **Chapter two** includes the theoretical background of the study. It presents the process of disaster management; use case of drones and LTE network. This chapter ends with the challenges and requirements of the technical solution in the disaster area of the study. **Chapter three** describes the research methodology. It presents a case study design and components and a summary of the methodology. **Chapter four** presents result of the empirical study; NSL technical solution deployment in the Philippines, Phases of NSL for the disaster management, a collaboration of three parties to manage the disaster, use case of Drone and portable LTE network in NSL. Further, this chapter summarises the whole use case of NSL technical solution. The end of the chapter presents a synthesis of findings. **Chapter five** cover conclusions, theoretical implications, managerial implications, and recommendations for Nokia and topics for further research. Finally, the chapter ends with the summary.

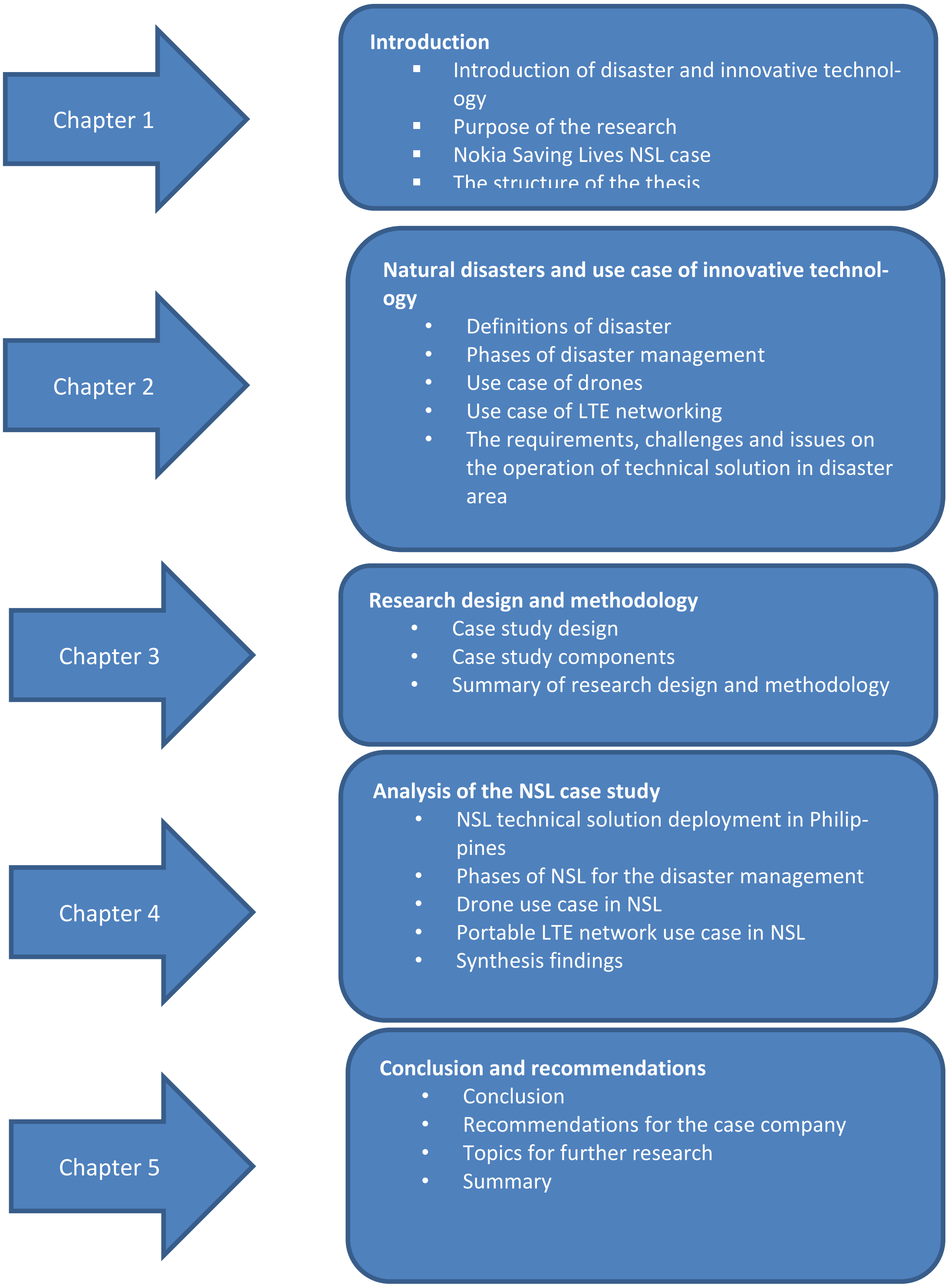

Figure 3 Structure of the study.

2 NATURAL DISASTERS AND THE USE CASE OF INNOVATIVE TECHNOLOGY

This chapter emphasises on a brief definition of disaster, the phases of disaster management, and the **use case** of innovative technology i.e. drones and LTE network. Understanding of the different phases of disaster management and the implementation of drones and LTE network build the foundation of this study.

2.1 Definitions of disaster

Massive negative wide-ranging impact by a specific scenario on people have been incoherently named ¨emergency¨, ¨hazard¨, ¨catastrophe¨, ¨incident¨, ¨disaster¨, and ¨crisis¨ in the literature (Schryen & Wex 2014). Being consistent with the terminology of the International Federation of Red Cross and Red Crescent Societies (IFRC, 2010), the U.S. Federal Emergency Management Agency (FEMA) and the UN International Strategy Disaster Reduction (UN/ISDR, 2004a), we use the term ¨ disaster¨ in the following sense (IFRC, 2010): According to Schryen & Wex 2014 “A disaster is an unexpected, catastrophic event that seriously disrupts the functioning of the society or community and causes human, material, and economic or environmental losses that exceed the community’s or society ability to cope using its own resources.” The IFRC disaster definition is broad and covered natural, manmade, and technological disasters. According to Schryen & Wex (2014), Natural disasters are naturally arising physical phenomena caused by scenarios such as earthquakes, landslides, tsunamis and volcanic activity, avalanches and floods, extreme temperatures, drought and wildfires, cyclones and storms/wave surges or disease epidemics and insect/animal plagues. Technological disasters comprise industrial accidents, transport accidents, nuclear accidents, among others. Manmade hazards include famine, food insecurity, displacement of populations, environmental degradation, pollution, and terrorism (IFRC). Some disasters may be connected to or caused by each other, as the recent 2011 Japanese earthquake, the tsunami, and the nuclear accident shows (Schryen & Wex 2014) which are presented in **Table 1**.

Table 1 Emergency Response Spectrum (CISCO 2012)

Safety and Security	Examples
Natural disaster	Earthquake, fire, hurricane, tsunami
Crisis management	Tunnel disaster, medical emergency
Urban security	Citizen protest, bank robbery
National security	Civil unrest, terrorist attack
Border control	Illegal immigration, smuggling
Mass venues and events	Crowd violence at sporting event, Olympic security, national convention security
Transportation	Train crash
Critical infrastructure	Nuclear power plant, refinery

2.2 Phases of disaster management

A natural hazard is an unpredictable and out of hands to control. However, precautions can be taken to mitigate their effects and save lives and resources. Disaster management is a continuous process that aims at mitigating the effects of natural hazards (Poser & Dransch 2010).

Most researchers agree that disaster management consists of four phases of the cycle as delineated in **Figure 4**. Appropriate steps on all phases of crisis management cycle enhance the performance in future cycles and reduce the risks of hazards and mitigate the impact of disasters (Haddow et al. 2011, p. 97-250). A fifth phase namely communications were introduced by the authors Haddow et al. 2011. In this paper, the focus is found on communications especially through technical means and is seen, an integral part of all other phases. Although the division between different stages of the management cycle is sometimes fuzzy, due to the interwind activities happening in distinct stages, in the following paragraphs the core phases will be briefly introduced (Haddow et al. 2011).

Figure 4 The phases of disaster management cycle and examples of related activities (Source: Poser and Dransch 2010).

Mitigation: Mitigation can be described as all means intended to reduce, or even eradicate, the risks to people and infrastructures from previously discussed hazards (Haddow et. al. 2011, p.69). Since it is misleading in its implicit suggestions that eliminating all risks from such hazards is possible. Mitigation embraces all measures taken to reduce both the effects of the hazard itself and the vulnerable conditions to it to reduce the scale of a future disaster (https//www.ndma.gov.in). Especially in this stage, any participants are involved like politicians and land use planners. These participants are involved mainly in identifying and mapping hazards and present solutions by constructing applications, planning of land use and providing incentives to mitigate the exposed risks (Haddow et.al. 2011, p. 75-80).

Preparedness: Preparedness involves plans or arrangements made to save lives and to assist response and rescue operations team. This target is achieved by planning, training, and providing equipment to improve the technical and organizational capabilities of governments, organizations, and communities (UNESCAP, 2010). Hence, planning should be done according to the nature of disasters scenario. Similarly, training is important to prepare the organizations and individuals on how to overcome the challenges (Haddow et. al. 2011). Basically, technical training skills are important to maintain the coordination among different partners to exchange the information on real-time, which makes the disaster management convenient and effective. Apparently, the right equipment deployment is also necessary for the proper planning of a specific crisis. Regarding this paper, the use of innovative technology is of major concern due to the ability to provide means of collecting, analysing and disseminating information on real time.

Response: response includes action taken to save lives and prevent more property damage in crisis. The response is putting your preparedness plans into action and the most visible part of the disaster management cycle (Haddow et. al. 2011). First responders to disasters are local authorities like humanitarian actors and they request for the help from others when the management of emergency exceeds beyond their capabilities (Haddow et al. 2011). The effectiveness of response is highly depending on other steps in the disaster management cycle: mitigation and preparedness (UNESCAP, 2010). The response to disasters depends on the range of training, logistics, and communications among all participating agencies and all of them grounded on the above two steps (UNESCAP, 2010). The impact of innovative technology is particularly profound on this phase.

Recovery: recovery includes action taken to return to a usual or even safer situation following an emergency. The hardest part among four stages might be to determine the start and end of the recovery phase and there is no distinct time where response switches to recovery (UNESCAP, 2010). Though putting lots of efforts into the recovery phase, it might be hard to determine the end of recovery and the beginning of mitigations and preparedness. However, the results of current disasters are beneficial to provide valuable data for further crisis analysis and modelling and the establishment of warning systems (Reddick 2011). The logistics, equipment and efforts, which are used to manage the one disaster, provide valuable insights to similar challenges, if they are collected, processed and distributed accordingly.

The following headlines discuss the use case of innovative technical solution (drones and portable LTE network) for disaster management.

2.3 Drones

The drone is more generally the common name of Unmanned Aerial Systems (UAS) (Apvrille et al. 2014). In many cases, we can find other appearance such as UAV (Unmanned Aerial Vehicle) but in Europe, the Remotely Piloted Aircraft Systems (RPAS) is also commonly used name. The author is sure, the name ¨drone¨ is understandable by everybody and however, many experts wish to call with UAV, UAS or RPAS (Blyenburgh 2010). The use of drones' applications to support the different cycles of disaster management can be thematically separated as shown in **Figure 5**.

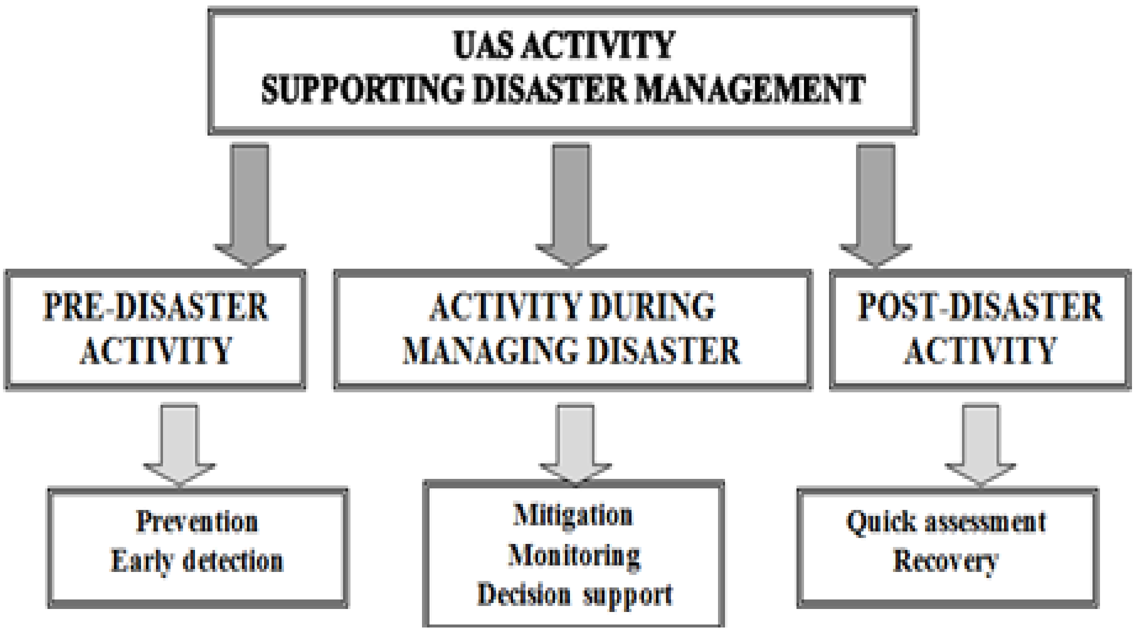

Figure 5 Drone activity in the time scale of disaster eruption (Restas 2015).

On a pre-disaster scenario, drone application can support by early detecting the affected area from disasters and can take steps for the possible prevention. In the case of man-made disasters like a chemical accident during illegal transport, early prevention can be done with the support of drone equipped cameras by doing road observation. Similarly, a toxic smoke spreading belongs to early detection (Restas 2015). The author also states that while mapping an escalated forest fire by drone flight patrol can belong to both prevention and early detection. After the eruption, the drone can support disaster management with real-time monitoring that helps to provide quick and relevant information regarding the intervention or mitigation. The information captured by drone decrease the effect of disasters and can be mitigated more effectively and all relevant information can support to take better decision. Clearing the main interventions after the disaster, the drone can support the quick damage assessment and help for recovery (Restas 2015).

The above activities can be totally different depending on the nature of the disaster, the affected area, severity etc. Drone applications also depend on the level of managing the disaster. The need for information also depends on the level of the hierarchy. At the higher-level management require strategic information and end users need information immediately about the scenario. Hence, drone applications management level can be divided into 3 groups such as strategic, operational and tactical levels (Restas 2015).

Drones can provide a superior deployment on three types of humanitarian assistance scenarios: 1) communication and coordination of operations, 2) terrain coverage, and 3) search operations (Apvrille et al. 2015). Drones for example help to locate the electromagnetic emissions of personal belongings of victims buried under ruined buildings or hiding in dense forests at a faster pace and with better precision (Apvrille et al. 2015). The autonomy of drones is central to the acceptability of a solution by search and rescue teams. The **drone4u** project (Apvrille et al. 2015) has developed functional building blocks supporting an autonomous operation, and convinces that the abovementioned scenarios can be implemented:

1) Autonomous navigation based on the 3D reconstruction of the drone environment to detect obstacles
2) Victim detection and tracking

Further, the use of automated swarm drones may broaden the range, flight duration and maximum payload for applications (Burkle et al. 2011). For instance, using a swarm of drones, one drone might take a task from another drone with drained battery. This way, the flight range can be prolonged beyond the scope of the first drone. Burkle and company also states that drones that fly beyond the control signals or are damaged during their flight can be replaced by other drones. In some cases, a heavy load can also be distributed over several drones, outperforming the payload of one drone (Burkle et al. 2011). However, when a swarm of drones follow several disaster areas, a problem may arise when they are divided. So, when flying swarm of drones, every drone has to follow the one specific drone rather than following randomly. The technological issues to overcome is that drones in swarm have to communicate with each other besides communication with ground control, which requires many more communication channels (Vergouw et al. 2016).

The usefulness of drones in humanitarian settings are numerous and there are numbers of use cases; the one described hereafter is just a small subset of these for illustration purposes.

2.3.1 Regulation and legal aspects

Although this research paper presents the use case of drones and its benefits and drawbacks, it is necessary to consider the regulatory framework that controls the use of UAVs. Indeed, this legal framework is different from country to country. Globally, it is rapidly revolving and trying to find the midpoint between a highly restrictive approach that prohibits most UAV operations that are not declared by a certified pilot and a freer one (Tanzi et al. 2016). The Federal Aviation Administration (FAA) defined a new set of rules (Washington, DC 20591) in June 2015. The drone's operational limitations like maximal weight (less than 25 kg), visual line-of-sight (VLOS) over rural or unhabituated areas during daylight, the maximum ground speed of 100 mph, maximum altitude of 400 feet above the ground, minimum weather visibility of 3 miles from control station etc. are were briefly explained (Koeva et. al. 2018). The rules concerning the responsibilities and certification of drone pilot were also set. On Same year, the European Aviation Safety Agency (EASA) also developed a notice of proposed amendment 2015-10 dividing the drones into three classes: open (low risk), specific operation (medium risk), and certified (higher risk). European level regulations consider the following three fundamentals: i) the security and technical specifications of the UAV (ability to perform the safe flights and the weight of the UAV) ii) the proficiencies of the pilot (who must be certified), and iii) the surveyed area which can be uncritical (without humans or important infrastructure) and critical (with humans, etc.) (Koeva et. al. 2016). Similarly, producers must include no-fly areas in embedded software to avoid sensitive secured area fly-by and pilots are requested to keep their drone in the line-of-sight (Federal Aviation Administration 2015).

Further, the regulations of frequency also need to focus on the use of a drone. The international regulation of the use of frequency comes under the Radio Regulations (RR) (Vergouw et al. 2016). For small drone's specific frequency allocations has not made on an international level. Drone flights that require large flying distances, for instance for the observation of dykes, woodlands, disasters and borders, it is not possible to make use of the license-exempt bands mentioned (Vergouw et al. 2016). In this case, use of drones is possible by having a dedicated license frequency, which is the competence of the National Regulating Authority (NRA). If communication is required during a flight payload, in case of fire, natural disaster or border control, additional frequencies are needed (Vergouw et al. 2016).

These rules could be severe barriers against the concept of drones which is presented on this paper. However, when a disaster strikes such restrictions may not apply and those regulations are meant for the normal circumstances. Under such a crisis scenario, special authorizations can be obtained in a framework, which is handled by all side's experts: rescue teams, governments, communication providers, local authorities etc. A good example of such a specific process crisis scenario is in hurricane Katrina (Tanzi et al. 2016). During that time many specific exceptions were made in multiple domains and more particularly frequencies allocations, communications routing and flight regulation. There is no uncertainty that this framework can be updated to allow the use of autonomous drones and this must be integrated at the early stages of the project (Tanzi et al. 2016).

2.3.2 Search operations and terrain scan

Emergency situations require appropriate overtime monitoring and rely on a more detailed analysis using very high-resolution data. For such analysis, a thematic map is appropriated for the relief operations. This thematic map is dependent on the sensor i.e.

¨Light Detection and Ranging¨ (LIDAR) that uses laser pulses to generate large amounts of data about the physical layout of terrain and landscape features. All types of LIDAR operate on the same principle (Tanzi et al. 2014). Another non-conventional approach to detect buried victims is to search from the electromagnetic emissions from their mobile devices. Search and rescue operations can be clear from drones if we fly from the lower altitude. But safety issues arise in this application. The low altitude and autonomy of navigation of a UAV may potentially harm nearby victims or rescuers in case of an accident. So, from the early stage of its design, drones must encompass this dimension and embed safety mechanisms to manage possible hardware and software failures (Tanzi et al. 2014).

There are three types of fleet architecture for the search operations and terrain scans. They are a) **Blimps-** have a higher autonomy and stability, b) **Fixed-wing drones** – present also good energy efficiency and can fly to a relatively high altitude, which makes their vision angle larger than the ones of vertical axis drones c) **vertical axis drones**-even if they present lower energetic efficiency, have a better manoeuvrability and can adapt their speed to the characteristics of the terrain (Tanzi et al. 2016). **Figure 6** shows the schematic flow of the detection cycles.

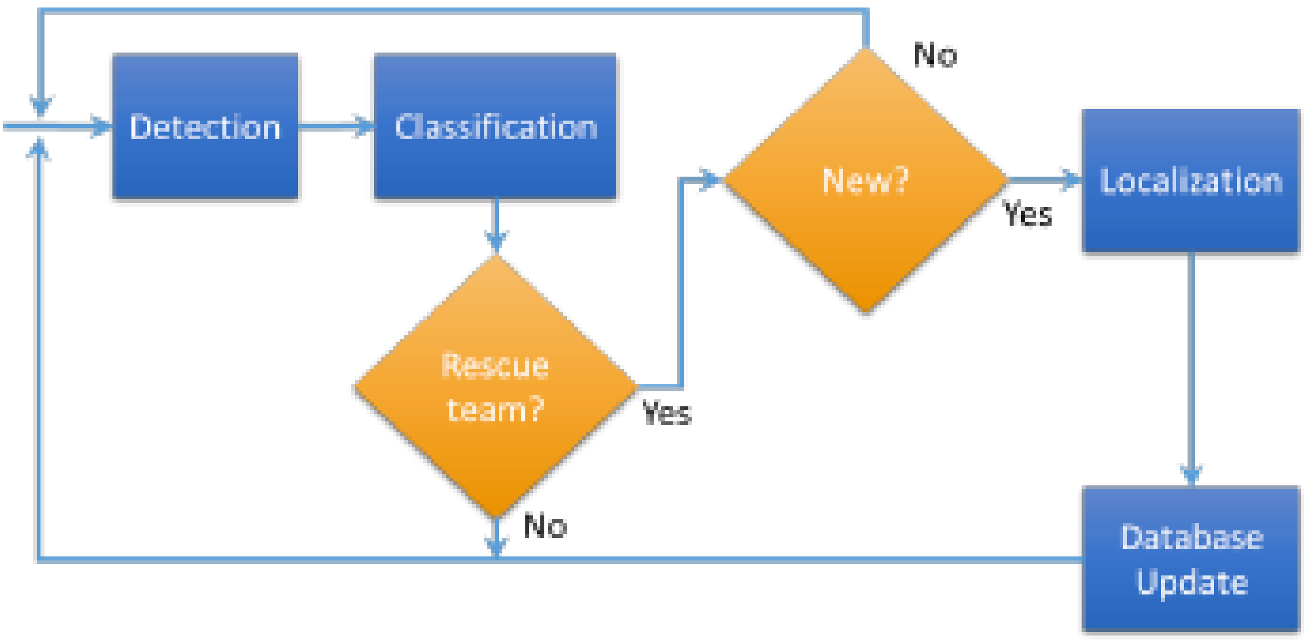

Figure 6 Detection cycle (Tanzi et al. 2016).

2.3.3 Payload

Payload is another attachable part of drones for the search and rescue operations. The restricted features of payloads are the weight, model, energy source and size of payloads, which influence the performance of drones on maximum altitude, flight duration, flight range, and maximum payload (Vergouw et al. 2016).

An important category of payloads is sensors. The most common payloads for drones are cameras and microphones. Such cameras might enable night vision and heat sensing. Other sensors include biological sensors that can trace microorganisms, chemical sensors that can measure chemical compositions and meteorological sensors that can measure wind, temperature, humidity, etc (Vergouw et al. 2016). Cameras can also be useful payloads for the prevention, criminal investigation, criminal prosecution, and sentencing of criminal behaviour. Drones equipped with WIFI hotspots may provide hints about people position and can be used for tapping phone and Internet use (Vergouw et al. 2016).

According to the experience of specialists from the disaster intervention (French ¨Protection Civile¨, Medecins sans Frontieres (MSF), International Committee of the Red Cross (ICRC), etc) drones help to focus on the three main specifications for rescue teams among the set of applications. However, the main goal of the rescue teams is to support victims in the shortest period as possible. The three specifications are as follows:

1. To detect the people affected by the disasters
2. To identify the possible accesses (e.g. safe roads and practicable paths) towards the disaster area and victims
3. To perform the continuous assessment of the evolution of the situation in the impacted area

The first class use case of drones sensing payloads is related to the systematic coverage of an area to perform a ¨rapid mapping¨ of the target zone and to detect and classification of victims (Tanzi et al. 2016).

2.4 LTE Networking

The first set of standards for LTE was published in 4Q08 in 3GPP Release 8. The world's first commercial LTE network went live in December 2009, when Telia launched LTE (4G) services in the Stockholm, Sweden (Delaney & Efimova 2018). The higher data capacity of 4G compared with 3G satisfied a great deal of pent-up demand for mobile broadband connectivity, and as a result, we have seen the uptake of 4G by end users proceed faster than was the case when 3G was introduced (Delaney & Efimova 2018).

At the end of 2017, eight years after the first appearance of commercial 4G services, 44% of all mobile network connections in Western Europe were 4G and that by the end of 2020, 4G will account for 68% of mobile network connections. As the **Figure 7** makes clear, LTE is now the mainstream standard for public mobile networks, quickly superseding 3G for mobile data connectivity services (Delaney & Efimova 2018).

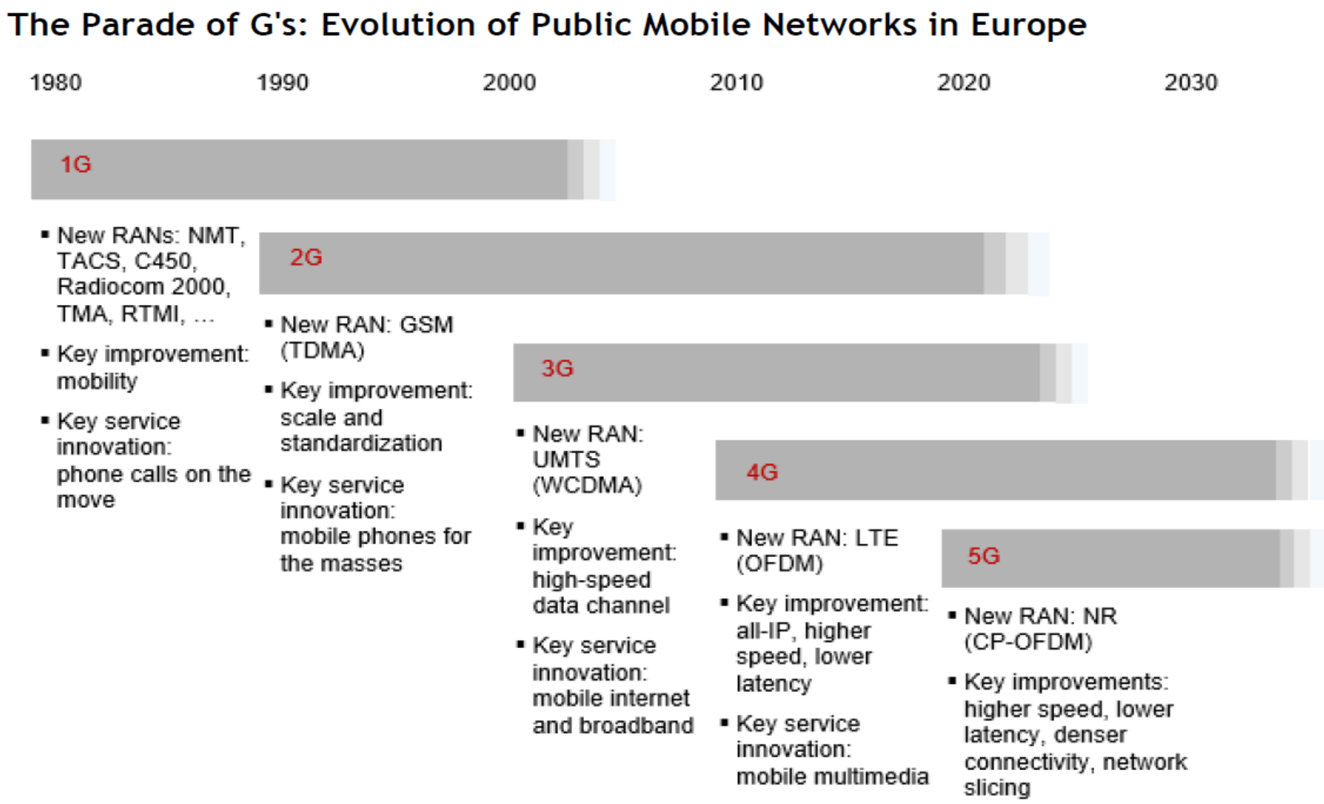

Figure 7 Summary of mobile generations that have emerged from 1G to 5G (Source: Delaney & Efimova 2018).

According to Harbor Research 2017, private LTE networks are going ahead of the current market complexity about wireless connectivity and re-defining how value is created from devices and data. The users can be benefitted from private LTE by reliable and secure service quality-as challenges that can be used by a single, scalable wireless networking solution that leverages LTE's technology and ecosystem benefits (Hill 2018). A disaster resilient network architecture using specially designed, movable and deployable resources units (MDRUs) as a portable container includes modularized equipment for networking, information processing, and storage (Sakano et al. 2013).

LTE is the family of technologies adopted by 3GPP as the basis for 4G mobile networks. However, the terms 4G and LTE are interchangeable but the ¨ G¨ designation is specially related to public mobile networks (Delaney & Efimova 2018). Information and communication technology deployed to a disaster relief operation promises a high value to coordination efforts (Coyle Meier 2009, p.27). The dynamic and uncertain situation at the beginning of a disaster scenario demands high coordination. The different probabilities exist to deploy ICT in disaster relief and in various cycles of disaster relief (*Disaster management handbook 2008*), ranging from terrestrial radio communication, terrestrial wireless communication (like hastily formed networks), and commercial satellite communication to social networks and Internet portals (Mecella & Russo 2011). Applying all these multiple technologies to disaster relief missions carry the threat of interference because there is limited bandwidth (Wentz 2006, p.51). Common to all research about ICT in HA/DR (Humanitarian Actors/ Disaster Response) missions is that information and communication technology is a necessary enabler of inter-and-intra-organizational communication and information exchange (Lundberg & Asplund 2011). In this context, the success of disaster management is dependent on effective sharing and use of valid and timely information among a large no. of stakeholders in the society, including government authorities, non-government organizations (NGOs), private sector organizations and the public (Yang et al. 2011). Similarly, disaster management faces challenges for data collection, data management, translation integration and communication and that all crucially supported by the IT (Kamal 2015). Unfortunately, the response to Katarina Hurricane revealed that due to inefficient information and communication technologies (ICTs); it failed to effectively support the disaster management organizations (DMOs) in times of crisis, as well as in day-to-day emergency response operations, which urgently required coordination between several different public safety agencies (Yang et al. 2011).

According to IHS market forecasts; the critical communications broadband LTE market-which encompasses the private LTE for mission-critical communications as well as public safety LTE-will grow at a compound annual growth rate of 20% until 2020 and reach $2,6 billion in revenues at that point. The demand for broadband capability on mission-critical systems and in specific public safety or Public Protection and Disaster Response (PPDR) agencies is in hype with the strength to provide an end to end solution key to a successful migration (https://technology.ihs.com/580532/whitepaper-lte-in-public-safety).

Today's public carrier networks are ill-equipped to handle the volume and velocity of calls that occur in the hours and even days -after a planned event or unthinkable emergency. Given the rise in cellular traffic and data consumption by citizens, an optimized Private Safety LTE network is needed to assure priority communications the moment they are needed. An optimized network also provides end-to-end encryption, safeguarding sensitive information transmitted over the air wirelessly (htpps//www.motorolasolutions.com/content/damn/msi/MOT_LTE_WP_A4_EN_102414.pdf). Public career network is unreliable for the disaster management such as ferry disaster, natural disaster, massive earthquake, and etc. Therefore, Private LTE is the key difference between "**Always available" and "Often not**" for the disaster management.

2.4.1 Benefits of LTE networking

Private LTE delivers the benefits of the prioritized service, economies of scale, derived from an integrated network approach which removes duplication, a reduced total cost of ownership, and allows funds to be directed to network hardening. LTE networking is flexible enough to interoperate with legacy systems and heterogeneous technologies. The ability to self-organize is critical to minimize any delays associated with manual configuration. LTE networking could be robust and reliable enough to support mission-critical applications (Ghafoor et al. 2014). In a crisis, every second counts. Potentially life-threatening situations change in a heartbeat, and decisions must be made in seconds (CISCO, 2012). Private LTE network helps to take the decision faster at the right time with the assurance of guaranteed network access at broadband speeds without having to worry about commercial users saturating network capacity, particularly during the crisis (https://technology.ihs.com/580532/whitepaper-lte-in-public-safety) which shows from **Figure 8 and 9.**

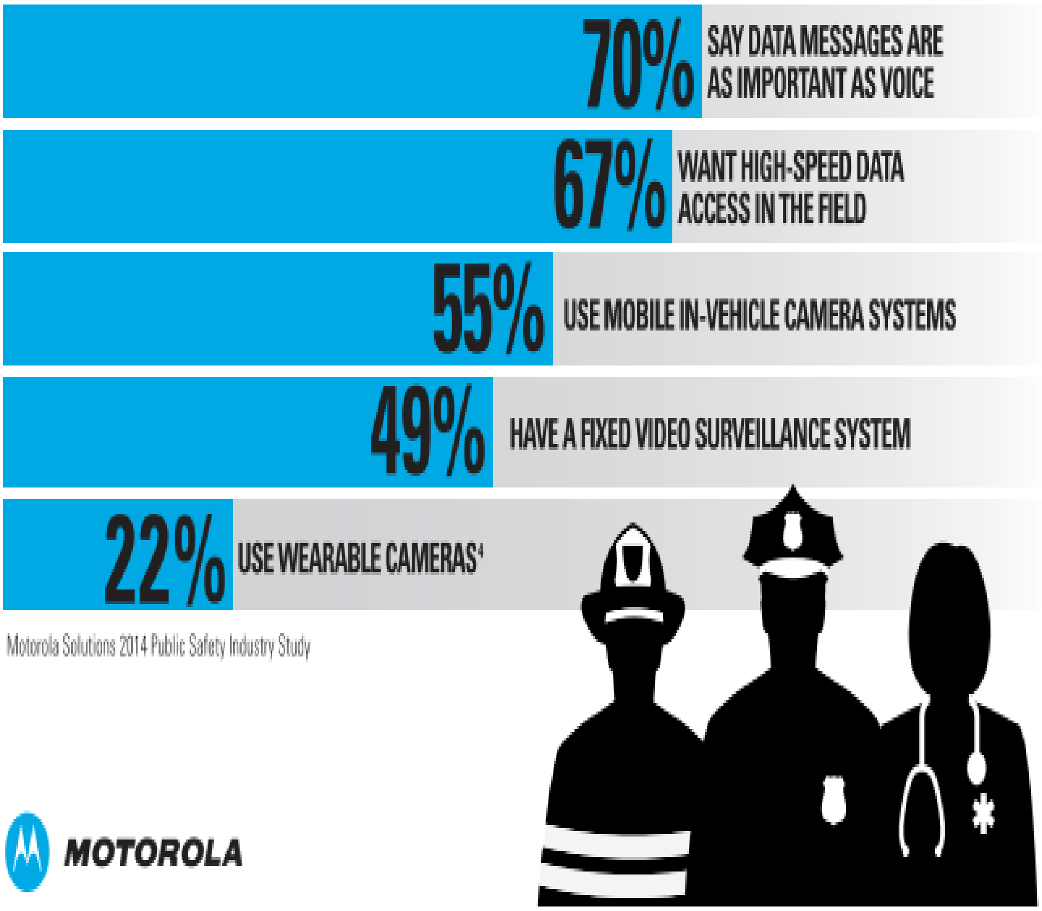

Figure 8 Data is the critical choice beyond voice (https//www.motorolasolutions.com/content/damn/msi/MOT_LTE_WP_A4_EN_102414.pdf).

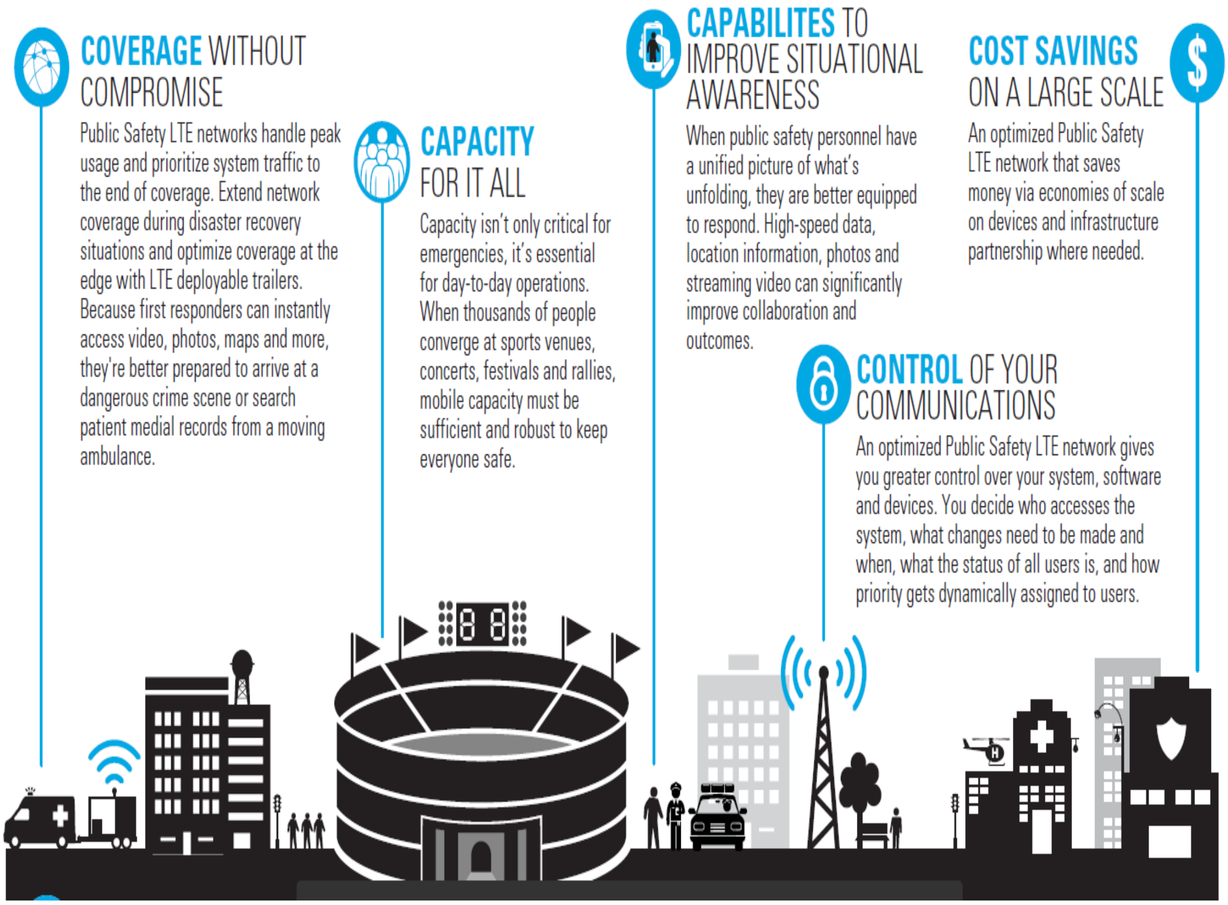

Figure 9 **Private LTE delivers a high degree of 5 C's (https//www.motorolasolutions.com/cotent/damn/msi/MOT_LTE_WP_A4_EN_102414.pdf).**

2.4.2 Spectrum

Spectrum is one of the essential parts in LTE networking usage in the public safety and Public Protection & Disaster Relief (PPDR) community. On many high bandwidth applications like real-time video/CCTV and biometric data analysis, narrowband data networks cannot deliver high operational performance as broadband networks (https://technology.ihs.com/580532/whitepaper-lte-in-public-safety). Private LTE is simply the ability to operate a standards-based Long-Term Evolution (LTE) network in a licensed or unlicensed spectrum. As a private network with local control that serves specific users or devices, as opposed to commercial networks which typically serve both consumer and enterprise users (Delaney & Efimova 2018). This means that network operator holds a license to operate the unlicensed spectrum that is issued by the national telecoms authority that provides the exclusive access to the certain amount of spectrum in a certain frequency brand (Delaney & Efimova 2018).

Harmonization of spectrum allocation are also vital to ensure the end users have the most effective capability. It ensures interoperability as the ability to utilize the latest applications such as video-based technology in a cost-effective and value-driven environment (https://technology.ihs.com/580532/whitepaper-lte-in-public-safety). To effectively run the mission-critical broadband demand, there will also need to be a strong collaborative ecosystem of vendors across multiple tiers offering network, device and application services. This helps to deliver best practice operational solutions but more significantly affirm that public safety end users have the right applications (broadband capability), in the right place at the right time (https://technology.ihs.com/580532/whitepaper-lte-in-public-safety).

The data that need to transmit has filled with spectrum through which have access, additional capacity can be achieved by accessing a new waveform that encodes data into a given amount of spectrum more efficiently (Delaney & Efimova 2018).

2.5 The requirements, challenges and issues on the operation of drones and private LTE network in the disaster area

2.5.1 The requirements on the operation of drones and private LTE network in the disaster area

The requirements for the operation of technical solution in the disaster area have been examined and outlined by several national and international bodies, including the US Department of Homeland Security (DHS), the European Telecommunication Standard Institute (ETSI), and the GSM Association (GSMA) (Ghafoor et. al. 2014).

The DHS program, SAFECOM, has emphasized on communications services and their operational/functional requirements for the emergency domain. SAFECOM explains technical requirements for voice/video performance, Quality of Service (QoS), coverage, energy consumption, robustness and recovery (Ghafoor et al. 2014). ETSI has established a broad range of work programs for Emergency Telecommunications (EMTEL) to assure the interoperability and interfacing of services and systems in emergency situations (Ghafoor et al. 2014). The Mobile Broadband for Emergency and Safety Applications (MESA) project was an international partnership between ETSI and the Telecommunications Industry Association (TIA), which formed technical specifications for mobile broadband technology for PPDR (Ghafoor et al. 2014).

The GSMA Disaster Response Program delivers different resources for mobile operators, including an overview of technical challenges and requirements related to preparing for and responding to disasters. The key factors and requirements for the operation of the technical solution in the disaster area are outlined in **Table 2.**

Table 2 Requirements on the operation of drones and private LTE network in the disaster area (Ghafoor et al. 2014).

Requirements	Description
QoS	QoS includes parameters such as availability, throughput, latency, jitter and error rate. DRNs frequently carry mission-critical communications services for emergency first responders and so availability and performance consistency is essential. Depending on the capabilities of the deployed network, these services may include live audio and video streams with strict limits on acceptable performance metrics. For example, VoIP calls may require a guaranteed low bit rate with maximum packet delay of 100 ms, jitter of less than 30 ms and packet loss of less than 1% [2]. When a DRN is deployed, service level guarantees must be put in place based on the available resources and achievable QoS.
Robustness and reliability	In a disaster scenario, the radio environment may be changing unpredictably, as the communications infrastructure fails or is repaired, as interferers or high priority critical services occupy the medium, and as physical changes block signals. Any DRN should be robust to such changes, and should aim to provide continual coverage. In addition, many of the services being supported may impose extra reliability requirements, including for example, strict latency guarantees on video for remote medical guidance.
Coverage and mobility	Disasters such as earthquakes, tsunamis and floods frequently affect wide geographical areas. Hurricane Katrina affected an area of 230,000 km^2 in the US in 2005. In these situations, disaster response and management personnel require wide-area connectivity to coordinate relief efforts. Handover between adjacent cells and differing wireless technologies may be needed to ensure seamless coverage of the affected area.
Rapid deployment	Any delay in the response to a disaster may result in further loss of life, injury and damage. DRNs need to be deployed and operational as soon as possible and certainly within first 24 hours following the event to support emergency first responders, permit the affected area to be inspected and assessed and to facilitate the coordination of multiple agencies and authorities.
Interoperability	A DRN may need to link together incompatible communications networks, for example between different groups of emergency responders. Standalone systems can guarantee service availability without relying on the presence of any existing infrastructure in the affected area. However, the capabilities of the DRN and the types of services which it can support may be greatly enhanced by linking into any operational infrastructure which may be available on the ground.
Spectrum agility	A disaster can occur in any location. In order to be deployable across a wide range of locations and environments, a DRN needs to be capable of operating in a wide range of different frequency bands. With sufficient spectrum agility, a DRN can be deployed without prior knowledge and agreement about what spectrum is in use and by whom. Spectrum agility means a DRN can be adapted to local variations in spectrum use and regulation, making it easier to avoid the creation of harmful interference.
Self-organization	A self-organizing DRN can reduce the need for time-consuming initial configuration. As the operating environment of a disaster area can change unpredictably, the ability of a DRN to self-organize also reduces the need for manual reconfiguration in the event of changes in spectrum availability, network topology, user demand etc.
Cost effectiveness	More cost effective DRN systems can be made more readily available and deployed more widely. In considering cost, we must look at the cost of establishing and maintaining the DRN system in readiness for use as well as the actual cost of deploying and running that system. In order to provide services rapidly after a disaster, expensive standalone resources can be put in place. However, in the weeks following the event, these expensive solutions must be transitioned to less expensive, more sustainable configurations.

2.5.2 The challenges and issues on the operation of drones and private LTE network in the disaster area

Many of the technological capabilities are already enabled and have significant potential for use in Disaster Response Networks (DRN). Dynamic Spectrum Access (DSA) is often regarded as the key application of LTE; however, there are other potential ways in which LTE can be applied for DRN systems. A disaster management scenario is visible where HA or first responders establish their initial setup of technical solution in an operation centre. LTE network can be used to provide the extended data, with backend connectivity to the operation center with UAVs (Ghafoor et. al. 2014). Some of the potential benefits of technical solution in the context of the requirements for the operation of technical solution in disaster area are examined below in **Table 3** which is outlined previously with remaining challenges.

Table 3 The challenges and issues on the operation of drones and private LTE network in the disaster area (Ghafoor et al. 2014).

DRN requirements	potential	Issues and challenges
QoS	• Adaptability to maintain QoS levels in dynamic environments • Policy management based on QoS requirements	• Sensing time optimization to minimize packet transmission delay • Efficient QoS level switching according to resource availability and application demands • Maintenance of end-to-end path reliability
Robustness and reliability	• Repeated sensing, parameter selection and reconfiguration • Learning from experiences • Reliable frequency and robust transmission technique selection	• Minimized frequency switching delay in case of failure • Algorithms for shorter decision time with accuracy/reliability • Spectrum aware routing algorithms for high spectrum variation • Collaborative and distributed sensing algorithms • Reliable channel assignment and robust transmission strategies
Coverage and mobility	• Repair and extend the partially damaged cellular network • Support heterogeneous wireless systems and spectrum • Wide area coverage using heterogeneous frequencies • User mobility support with delay tolerance	• Efficient DSA techniques • Multihop communication for high bandwidth and wide area coverage • Efficient spectrum selection/sharing/mobility mechanisms • Efficient coordination among neighbors • Optimal relay node selection • Maintaining dynamic topology and end-to-end paths due to frequent mobility • Coverage extension techniques for last mile connectivity • Alternate solutions for backhaul connectivity • Delay tolerant mechanisms for sensitive data services (voice, video)
Rapid deployment	• Reduced delay associated with device pre configuration and spectrum planning • Plug-and-play networks	• Ready to use, lightweight CR systems • Policy management for operation in critical environments • Optimal spectrum utilization with low interference • Algorithms for dynamic network topologies (ad-hoc/multihop/mesh) • Minimized network/neighbor discovery time • Reliability prior to core network replacement/repair
Interoperability	• Serve as single gateway between different communication systems • Flexible resource sharing among heterogeneous networks and spectrum • Dynamic bandwidth access/waveform selection • Reconfigurability and adaptability of operating parameters • Provision of multiple standards and services using a common radio interface	• Linking heterogeneous systems while ensuring service accessibility • Seamless communication and coordination among different operators and systems • PHY/MAC cross-layer design of efficient DSA functions for heterogeneous networks • Robust gateway platforms with optimized protocols • Network identification for coexistence management
Spectrum agility	• Wide spectrum range support • Efficient DSA functions for topology management • Spectrum utilization based on previous experience • Adaptation to region-specific regulations	• Spectrum detection techniques for interference avoidance • Optimized spectrum sharing techniques • Spectrum mobility techniques to maintain QoS levels • Disruption tolerance mechanisms • Interference minimization and congestion avoidance mechanisms for low packet drop rate • Sensing time optimization • Advanced interference management techniques
Self-organization	• Real time system configuration and decision making • Reduced manual configuration to minimize the number of technicians on the ground • Automatic neighbor/network discovery • Reconfiguration and DSA Management to adapt operating parameters	• Machine learning algorithms to avoid manual configuration/maintenance • Distributed communication techniques with local negotiation • Efficient spectrum hand-off mechanisms • Optimal route selection in ad-hoc/mesh CRNs • Location aware radios, networks and applications for emergency responders
Cost effective-ness	• Lower deployment/maintenance costs • Multi-standard basestations/gateways • Fewer specialists and technicians on ground • Less expensive backhaul connectivity	• Robust and flexible gateway for multiple services and platforms • Mesh networking for low-cost backhaul • Low cost inter-/intra-network communication • Low cost SDR/CR devices • Energy efficient algorithms • Protocol optimization to minimize backhaul traffic

3 RESEARCH DESIGN AND METHODOLOGY

According to Creswell (2009), there are three types of research approaches: qualitative, quantitative and mixed methods. This case study research is done by using a mixed approach (both qualitative and quantitative). The main reason for choosing a mixed research approach is by the nature of research objective and the research problem. The objective of this research is to find out how innovative technology (LTE connected drone and portable LTE network) is useful and support the crisis management. Further, the research explores live disaster management demo phenomena, and it attempts to describe the expectations and experiences of people towards the innovative technical solution. In qualitative research, it explains live disaster management demo scenario and the subject as holism as possible. The broad-spectrum result of individual research is the goal of qualitative research (Hirsjärvi et al. 1997, p.161). The data that are organized into tabulated form then converted into the statistical form and made assumptions based on statistical analysis is quantitative research (Remes & Sajavaara 1997, p.137).

There are three generally used research approaches in case studies; exploratory, descriptive and explanatory (Yin 2003). This case study research uses both exploratory and descriptive approaches. According to Saunders et al. (2009, p.139) there are three ways of directing exploratory research. The first step is searching literature, second is interviewing professionals and third is performing interviews in groups. This case study research uses literature searching and professionals interviewing.

Descriptive research is called to describe specific events, situations or persons (Saunders et al. 2009, p.139). This research tries to describe the Nokia Saving Lives (NSL) case and the use case of NSL innovative technical solution. This chapter covers the case study design, case study components, limitations, criteria to judge the quality design and summary of research design.

3.1 Case study design

A case study research permits the researcher to use varieties of data, sources and variety of methods (Denscombe 2010, p.30-31). Type I case study emphasises on single case design and assesses the worldwide nature of a given case (Yin 2014). A type I case study is reasonable for this research, as Nokia Saving Lives case is unique. Till date, there is no end-to-end solution for the crisis management of which this NSL innovative technical solution has. Therefore, the scope of this research is especially on the use case of innovative NSL technical solution and it’s benefits for the emergency management. Hence, this study contributes to the overall body of knowledge on how innovative technical solution and different parties cooperate with each other and deploy innovative technical solutions in disaster management.

3.2 Case study modules

This case study design includes five modules: the study questions, the study propositions, data collection, timing and the data analysis.

Study questions: This case study focuses on the four research questions:

1. How different organisations collaborate to save the lives from disaster?
2. Are LTE connected drones being beneficial to manage the crisis management?
3. Is portable LTE network being beneficial to support crisis management?
4. What are the challenges faced by NSL technical solution and how to overcome them?

This type of research questions will help to classify the role of innovative technology in disaster management and to save the lives from disaster. Additionally, it will also help to identify the challenges and its solutions of the implementation of NSL technical solution in disaster management process.

Study propositions: The scope of study should be examined through propositions (Yin 2014, p.30). The below-mentioned propositions will fix the research domain while examining the research question:

- Three party's collaboration with their own expertise to manage the disaster.
- The video scanned from drones is effective by itself for disaster management.
- The need for centralized decision-making is effectively addressed by the use of private LTE.
- The provided connectivity among different applications fulfils the need for disaster management.
- The challenges and solutions of the NSL technical solution.

Data collection: This study uses three data collection methods and they are: documentation, interviews and participants observation. Documentation includes the Nokia internal documents, company´s marketing material (datasheets, websites). The interview type is flexible, and the data will be collected from the email through interviewee. The interview questions have sent before and after the live Philippines demo to know about their expectations and experiences toward the NSL technical solution. NSL technical solution is implemented in collaboration with the Philippines Red Cross (PRC), Smart Communications and Nokia in the Philippines, for the disaster management and to rescue the people. I would like to report the interviewee's experiences and expectations gap and their opinions and ratings toward the NSL technical solution. As well three parties' collaborations, challenges and solutions on the implementation of technical solution to manage the disaster.

Table 4 describes the overview of the data collection from the interviews.

Table 4 Overview of the interviews

Particulars	**Interview (1 before the live demo and 1 after the live demo)**
Nokia volunteers	12
NSL technical solution trainers	7
Philippine Red Cross	1

Timing: Data was collected before and after the NSL Philippines Live Demo that happened on November 23rd, 2018. The email was sent to interviewees with attached questions 1 week before the NSL Philippines Live demo. That helped me to collect the expectations of interviewee towards the performance of NSL technical solution. Again, the interview questions were sent to interviewees after the live demo in between November

24th to 26th to collect the responses about their experiences on the performance of the NSL technical solution. During that time, they had a fresh memory about the NSL Philippines Live Demo and their experiences and opinions toward the NSL technical solution. That helped to collect accurate information about the NSL technical solution.

Data analysis: This research has been directed by using the mixed approach (both qualitative and quantitative). The data from quantitative was analysed by using the IBM SPSS software and qualitative data was analysed by using the NVIVO software. The interviews response was both in numeric and subjective. Hence, these two software NVIVO and IBM SPSS software made easier to analyse them. **Figure 10** describes the data analysis process.

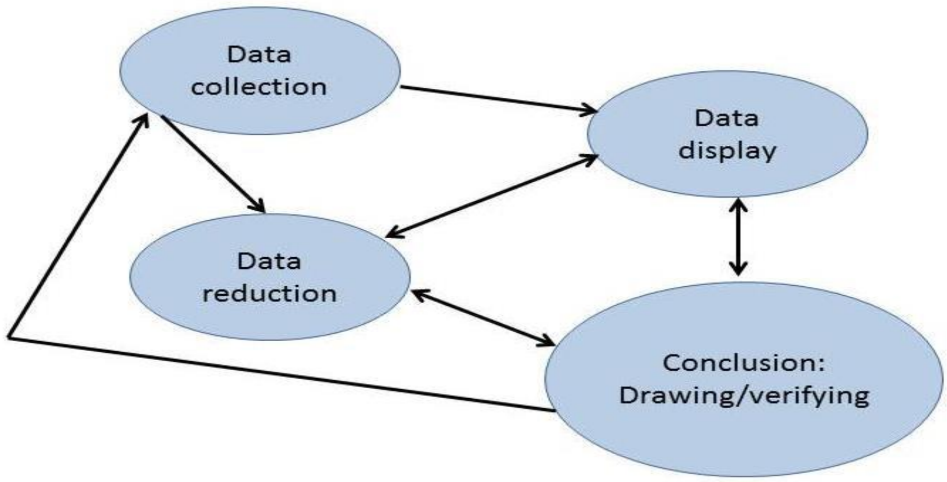

Figure 10 Component of data analysis: interactive model (Miles & Huberman 1994, p.10).

Data are analysed by the data reduction, data display, rating scale and conclusion; drawing/verification. All the components for data analysis continue before, during and after the NSL live Philippines demo. Data reduction includes the process of selecting, describing, concentrating and converting the information. It is an iterative process throughout the research. Data reduction consists analytic selections (Miles & Huberman 1994). Data display is the assembly of data that helps to draw conclusion and to take action. The last is the conclusion, drawing/verification. The rating scale is used to evaluate the perceptions of interviewee on the performance of the NSL technical solution (LTE connected drones and portable LTE network).

3.2.1 Criteria for judging the quality of research design

The quality of the research design has been judged by the construct validity, internal validity, external validity and reliability. Their explanations are as follows:

Construct validity: Construct validity is conducted by identifying correct operational measures for the concepts being studied (Yin 2014, p.46). In considering this, the researcher has used different sources to have the construct validity of this case study research. Along with it, the research report was submitted to the supervisor regularly and the findings and importance of the collected data were discussed between the NSL program head and the supervisor. An interview pilot was developed to get the systematic process in the interviews.

Internal validity: The researcher pursuing to establish a fundamental relationship whereby certain conditions are believed to direct to other conditions as prominent from unauthentic relationships (Yin 2014, p.46).

Accordingly, the researcher linked the analysis and implications to the theory which are identified in a literature review. The articles have been used from authorised publishers.

External validity: The findings of the study is general or define the area in which the findings are generalizable (Yin 2014, pp. 47-48). This is exactly the same case in this research. The research produces the primary information for the case company. Conversely, other technology companies and humanitarian actor can benefit the results of the study when they want to manage the disaster management.

Reliability: The drive of reliability is to minimize biases and errors (Yin 2003, p.37). In this NSL case study research, the researcher planned the guidelines and steps on how to conduct the research. The researcher documented each step carefully so that afterwards another researcher can repeat the same research process and get the same findings and results.

3.2.2 Limitations

The limitations of this research are that the researchers do not have any practice in disaster management operations and could not participate on the Philippines live demo. The data from interviewee and documents of the NSL program have been considered for the analysis parts of this thesis.

3.3 Summary of research design and methodology

The **Figure 11** shows the methodological choices of this research. The theme of the figure is to clarify and present methodological choices in a rational order. The choices are explained more precisely in the figure below.

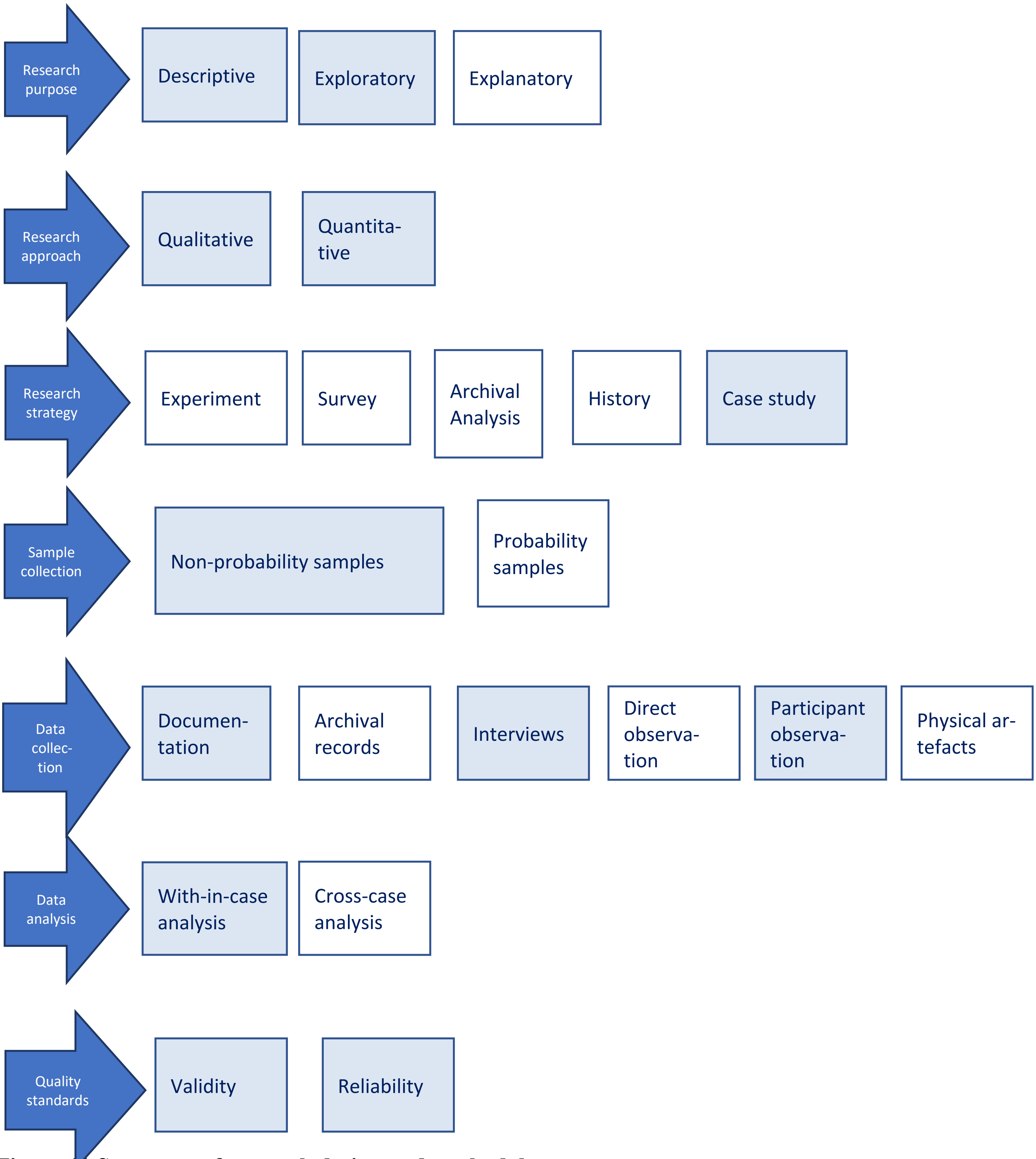

Figure 11 Summary of research design and methodology

Figure 11 Summary of research design and methodology.

The study was directed by using mixed approach (both qualitative and quantitative). The main reasons for choosing a mixed research approach were the nature of the objectives and the study problems. The objective of the study was to find out how innovative NSL technical is beneficial to save the lives from the disaster. Further, the research explores the live demo of the use of drone and LTE network to save the lives from the disaster. It attempts to describe the use case of drone and LTE network, the process of disaster management in collaboration with two parties (Smart Communication and PRC) and technical experts who operate the solution.

The study used a single case study as an appropriate research method. The research used both exploratory and descriptive approaches. The data was gathered from documentation, interviews and observations. The interviews were semi-structured interviews, which were structured to collect comprehensive information about research subject. The study uses within case analysis since the findings are compared to existing theories. Research reliability, internal validity, constructs validity and external validity factors were also debated in the methodology chapter.

4 ANALYSIS OF THE NSL CASE STUDY

In the following chapters, the results from the 20 interviews, observations and NSL documents are presented and discussed. The discussion follows a structure based on the use case framework that was developed in the literature review.

4.1 NSL technical solution live demo in the Philippines

Nokia selected the Philippines as the first implementation of NSL technical solution to save the lives from the disaster. The reason to select the Philippines was that it is the third highly disaster-affected country in the world. The geographic circumstances of the Philippines are highly prone to natural crisis, like earthquakes, volcanic eruption, tropical cyclones and floods. The country is also situated along a highly seismic area lying along the Pacific Ring of Fire where two major tectonic plates (Philippine sea and Eurasian) meet and is highly prone to earthquakes and volcanic eruptions. This clarifies the existence of more or less 300 volcanoes of which 22 are classified as active and the several occurrences of earthquakes and tsunamis all year round (UNISDR 2015).

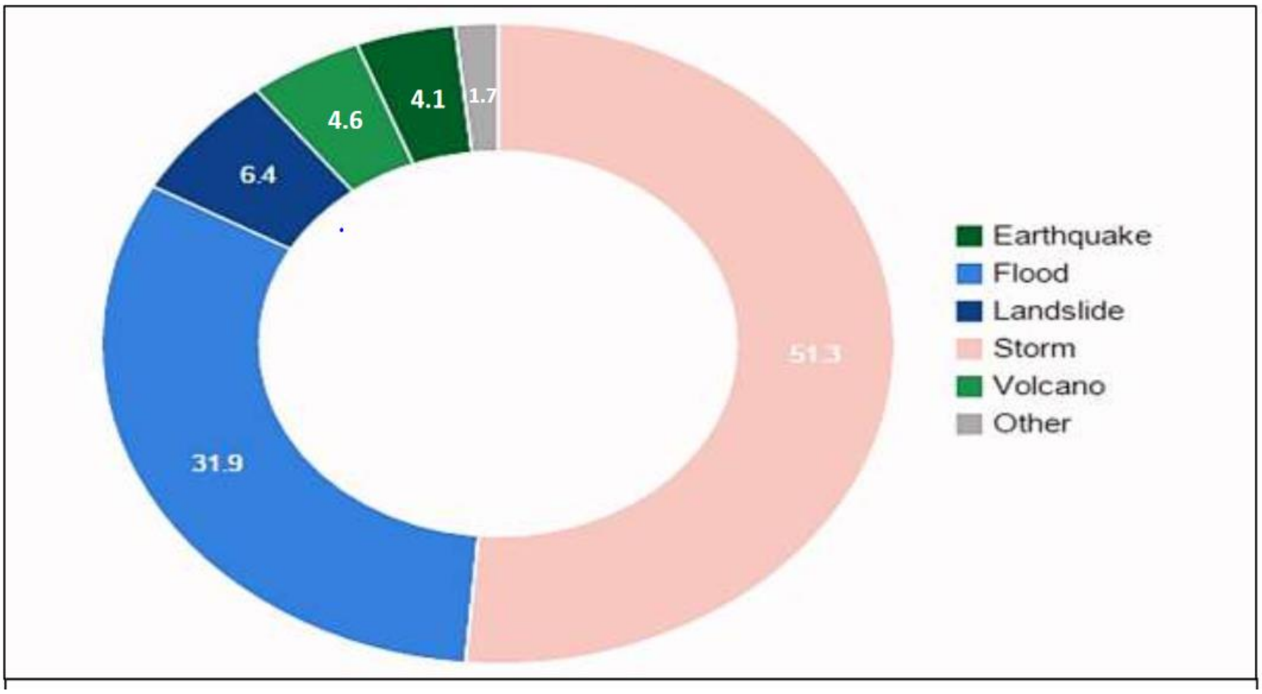

Figure 12 The frequency of natural disasters occurrence from the year 1990-2014 (CRED EM-DAT Feb 2015).

Figure 12 demonstrates the natural disasters for the last 24 years (1990-2014) of which 51.3% of all recorded disasters are due to tropical storms/typhoons. This is followed by 31.9% of flooding, 6.4% landslides, 4.6% volcanic eruptions, and 4.1% earthquakes.

Natural disasters seem 4 times more likely to affect Asia and Pacific than in Africa and 25 times more likely to affect in Europe or North America. Hotspots in Asia include Bangladesh, the Philippines and Vietnam. Per historical assessment, they possessed the highest risk of human losses and economic damages (UNISDR 2015).

Disaster relief operations are a critical thing and it would be better if there are proper systems and organizations to manage the disaster. In considering this, Nokia looked for partners to establish the appropriate organisation and legal setting for use of the NSL technical solution in the Philippines. Then, Nokia collaborated with Philippine Red Cross (PRC) and Smart Communications on this search and rescue operations. PRC became the responsible partner for any search and rescue activities, SMART for the frequency provisioning, and Nokia for the technical aspects, maintenance, training and evolution of the solution. So, Nokia developed the innovative technical solution (LTE connected drones, private LTE network and portable data center for data storage and analysis) and trained technical experts to operate this solution. This allows set up of innovative technology faster in the devastated area, where otherwise lack of understanding of operational processes and technology might delay the use of technology in the emergency area. Then, Nokia provided this innovative technical solution and technical experts to PRC in search and rescue operations who worked under the regulations of PRC to save the people lives and manage the disaster.

The disaster management live demo happened in the Philippines in collaboration with Nokia, PRC and Smart communications on 23rd Nov 2018. In the Philippines live demo, there were two incidents i.e. landslides and the pregnant women in a car accident. The portable LTE network was set up on the disaster area. The LTE connected drone streamed the live video of landslides area and car accident area which helped PRC to understand the real scenario of the incident. Further, it helped the rescuers to take the faster decision to find the best ways to reach the landslides area and car accident area. LTE connected Drone with thermal camera with its infrared signal helps to locate the affected people which helped to rescue the lives faster and HD camera helps to Zoom 30 times of the affected area to find out how the real situation was around the crisis area. The portable LTE network supports transfer of data that were captured by drones including HD and the thermal camera to the portable data centre on real-time safely and securely. Nokia concerns about the privacy of people. The data that are streamed through drones with the support of LTE networking about injured people are safe and secure in the portable data center. The data analyst analyses those videos and forwards that information to PRC instantly to save the people lives from a car accident and landslides and also to manage the disaster.

In this way, NSL technical solution promises to distribute and access information in a timely manner which helps PRC to take the decision on real time to save the lives from a car accident and landslides. However, the interrelations between PRC and smart communications have an impact on the management of disaster and saving lives.

4.2 Phases of NSL for disaster management

According to the researchers there are four phases of disaster management: mitigation, preparedness, response and recovery. Among them NSL is active on preparedness and response phase.

- **Preparedness:** on this phase, NSL works on plans and preparations to save lives and helping on response and rescue operations (UNESCAP, 2010). The right equipment deployment and technical training skills is essential to maintain the coordination among different partners by exchanging the information on real time which make the disaster management effective. In this regard, Nokia developed the NSL technical solution and trained the technical expert to operate the NSL solution. Nokia invested more than 1000-man-hours to train experts on Red Cross disaster preparedness education and NSL solution (theoretical and hands-on training) to make them expert to operate the NSL solution in an emergency area. These technical experts were doing this volunteering job as PRC volunteers. During the volunteering time, they are freed from job duty, while salary continues. The approval from their line managers was essential to take these training and to deploy on the search and rescue mission. The innovative technical solution drones equipped with thermal and HD camera helps to map the crisis area and portable LTE network supports the network connectivity to tranfer the data from drones to PRC on real time to save the lives faster and smoothly.

- **Response:** The preparedness plan put into action is called as response which is visible phase of the disaster management (Haddow et. al. 2011). PRC is the first responders of disasters and they request technical help from NSL and frequency help from SMART to manage the disaster. Then Nokia provided the NSL technical solution to the PRC free of charge. The trained technical experts worked as PRC volunteers and they are doing volunteering free of charge. Smart communication provides the spectrum to operate the NSL technical solution effectively. The three different partners had collaborated with their individual responsibilities to manage the disaster and save the lives by providing the technical solution and trained technical experts to PRC to manage the disaster.

The preparedness and response phase of disaster management in collaboration with PRC, SMART and NOKIA is clearly explained in **Figure 13**.

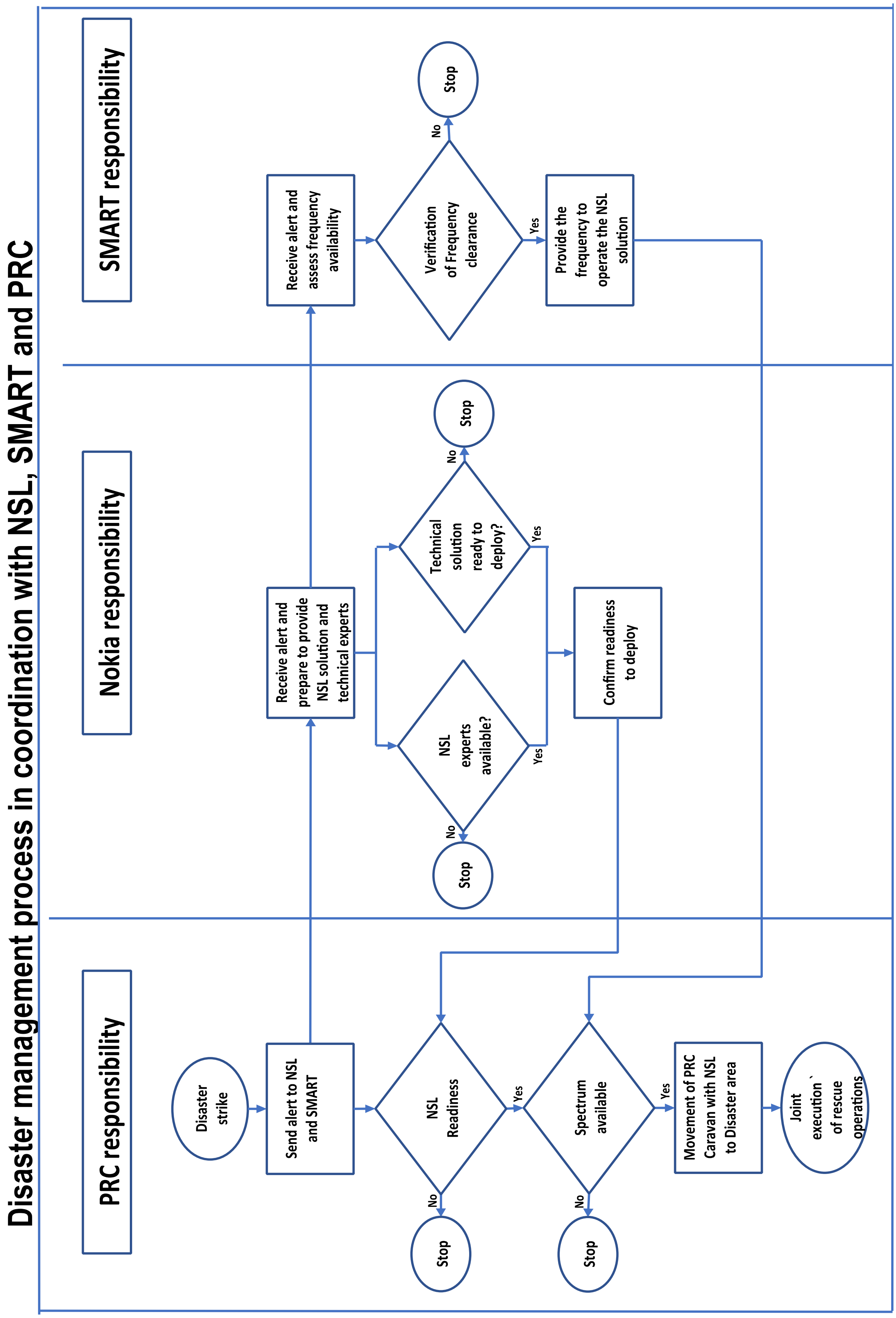

Figure 13 **Disaster management process in collaboration with Nokia, PRC and Smart.**

The process begins with an unexpected disaster strike. When the natural disaster strikes, PRC is the first responders to send alert to Nokia, Smart and technical experts; and ask if they are ready to take their individual responsibilities. Nokia responsibility is to provide the NSL technical solution and respond to the alert of PRC by confirming the availability of NSL solution. Technical experts also need to respond to their availability to PRC to operate the NSL solution. Basically, to implement the NSL solution, the technical experts with skills of drone pilot, networking and data analysis are needed. If anyone of this technical expert misses it would be impossible to operate the NSL technical solution. The confirmation of the technical volunteers and the readiness of the NSL solution helps to proceed with the disaster management process. In parallel, the frequency is asked from Smart communication to implement the NSL technical solution. Smart would check the frequency clearance around the disaster area and confirm the availability of frequency. If the frequency clearance is not possible around the disaster area, then the disaster management process would stop. Subsequently, confirmation from the Nokia, Smart and technical experts, the disaster management process would proceed further. The NSL technical solution and technical experts were moved to the disaster area in the PRC caravan van. Then NSL solution was set up and deployed to rescue the people and manage the disaster. This way joint rescue operations were carried out in the Philippines lives demo. It showed how the collaboration of different organisations can help to manage the disaster by putting their effort from their own field of expertise.

4.3 The drone use case in NSL

LTE connected drones including HD and thermal camera payloads automatedly fly over the emergency area with the help of GPS (Global Positioning Systems) and publicly available relief maps of the region, which help drones to automatedly live stream the videos of the devastated area. Nokia drone is a high-end proficient multi-role platform for natural disaster management. It intended to be used in a wide range of conditions, including harsh outdoor environments. It has a multi-sector lidar system that helps on the anti-collision system and smooth landing system. Drone is equipped with a set of sensors, applications and integrated on-board processing capabilities. The data captured by drone is securely and confidentially processed on a multi-tier platform: onboard the drone itself, and in the portable data center for data analysis. The drones can be scheduled to perform automated flights for inspection and monitoring for crisis management.

The analysis of the response of interviewee from the Philippines live demo on the use case of the drone is presented below.

Figure 14 shows the analysis of the rating on the experience and perception of people on drone handling and operations on the basis of Philippines live demo.

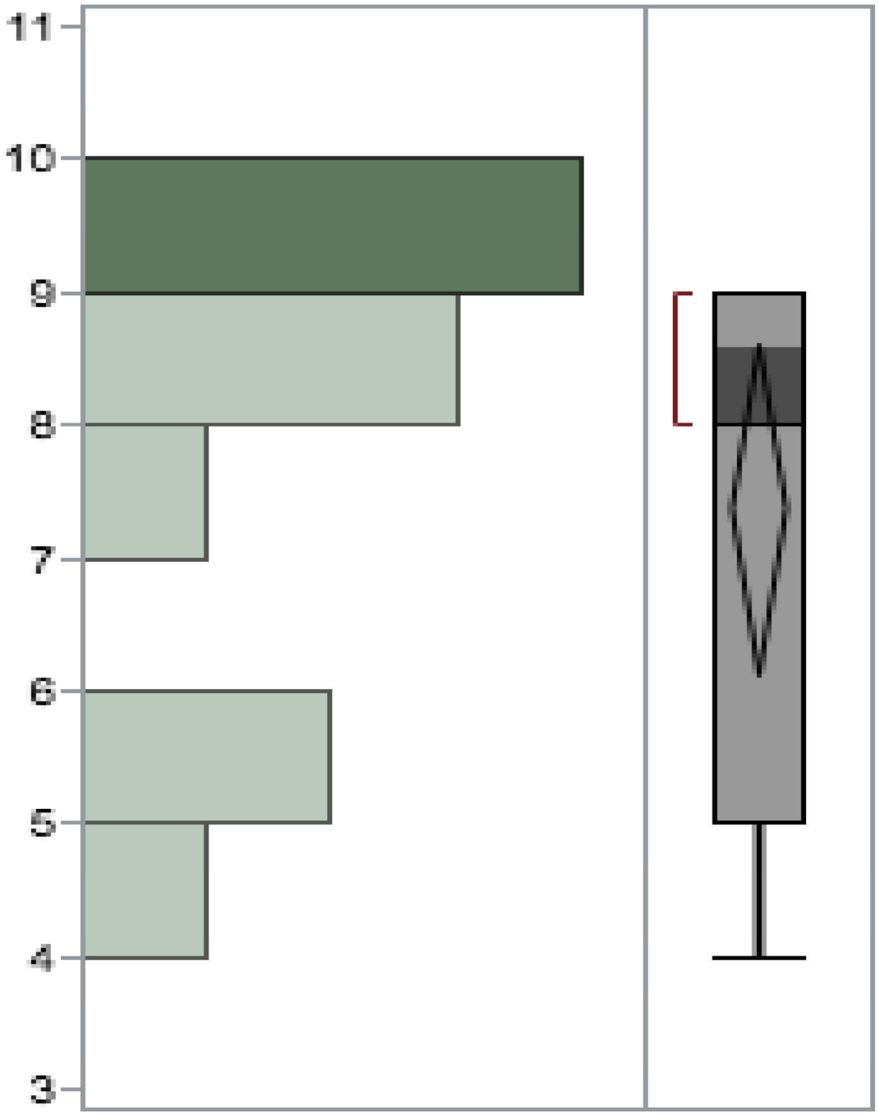

Figure 14 Rating on drone handling and operations.

This figure clearly illustrated that it has more rating on scale 10 meaning maximum people rated 10 on drone handling and operations and after that on scale 9. Further, people rated on scale 6 higher after 9 and 10. However, rating for scale 8 and 5 are the same. On the overall response of 11 people, it showed that drone has a good rating on the operations and handling of it as maximum people rated on scale 10 in comparison to others.

Table 5 Summary statistics on drone handling and operations

Summary Statistics	
Mean	7,3636364
Std Dev	1,8586408
Std Err Mean	0,5604013
Upper 95% Mean	8,6122882
Lower 95% Mean	6,1149845
N	11

Table 5 shows the summary statistics of the rating of drone handling and operations. It includes the mean 7.36, standard deviation 1.86 and standard error mean 0.56. It has less standard deviation value that means its closer to the value and less spread. Hence, it was considered that the rating of drone handling and operations was good. It was useful on the implementation for disaster management process and considered as an innovative approach to handle the uncontrolled situations from disaster.

NSL drone is responsible for data analysis and monitoring of different sensory data. Basically, it enables a data analyst to view a consolidated situational overview of mission status. This includes the drones, live video footage, payload usage, insight based on video analytics, and different sensory observations on the Philippines live demo. The NSL drone is equipped with state-of-the-art video streaming functionality that facilitates low latency video viewing for the data analyst that empowers them to initiate actions in real time. NSL drone which is used to identify and track different objects from car accidents and landslides from Philippine live demo like vehicles, people, with the help of received HD-video feeds and using advanced video analytics. This enables various types of value-added use cases for many disaster management.

The Figure 15 shows the response of interviewee analysis based on; *rate on data analysis and management Vs data delivered from NSL solution satisfying the requirements.*

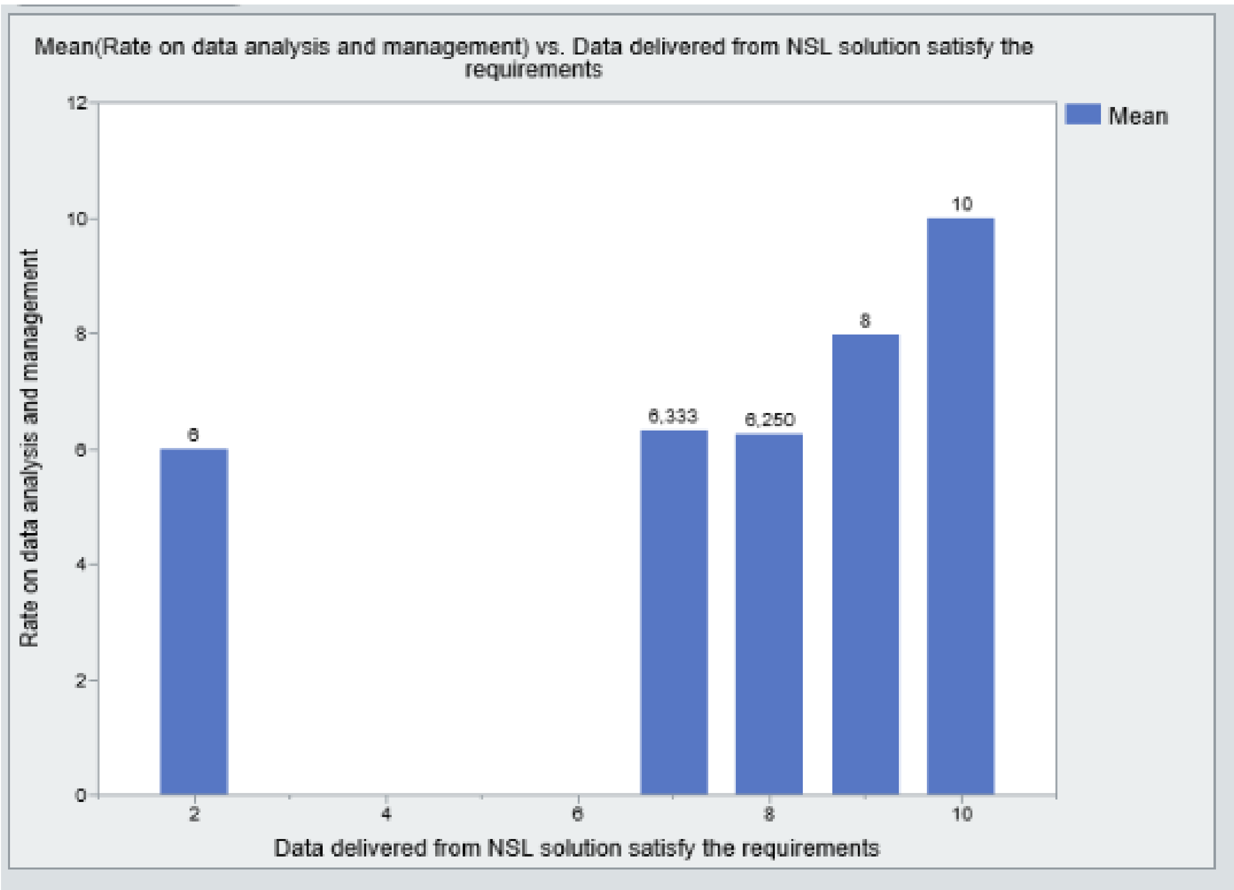

Figure 15 Mean rate on data analysis management vs. data delivered from NSL solution satisfy the requirements.

The above figure shows the relationship between the mean rate on data analysis management vs. data delivered from the NSL solution satisfying the requirements. The X-axis represents the data delivered from the NSL solution satisfying the requirements and Y-axis represents the rate on data analysis and management. The figure clearly shows that it has a high rating on scale 10 on the relationship of the mean rate on data analysis management vs. data delivered from the NSL solution satisfy the requirements. Subsequently, it has higher rating scale on 9. The rating scale on 7 and 8 has a close rating around 6 and half. The lowest rating is on scale 2.

Completely, it denotes that data delivered from NSL solution satisfy the requirements in a verdict of the rate on data analysis and management.

4.3.1 Regulation and legal aspects

The NSL technical solution has been developed in Germany and Finland research center and the advancement process will keep on going. After the development of NSL technical solution, it was exported to the Philippines to provide to PRC and to train the technical experts to operate the NSL technical solution. While exporting the NSL technical solution, there were lots of customs issues that made delay to export to the Philippines. The reasons for customs issues are goods for dual use: local telecom regulations and logistics regarding battery transport and organisational set up, which was new to the three involved parties. Hence, there are the issues of export and import of the technical solution. The technical experts need to have a license to fly the drones. The permission from the Civil

Aviation Authority of the Philippines (CAAP) allows the technical experts to fly the drones on a certain area and altitude of the sky. These legal aspects were taken care by Nokia to operate the search and rescue mission in the Philippines.

4.4 Portable LTE network use case in NSL

Disaster in another way means lack of information and situational awareness. In disaster time, there is a high probability that the network system gets broken and though it's available; the traffic is in hype to contact their beloved ones. Hence, it becomes difficult to communicate among the rescuers to take the right decision to save the people lives. Private LTE network is portable, and it can move in any desired place and set it up wherever the network doesn't exist. Portable LTE network helps to connect the drones and other applications which helps to map the disaster area and provide the real-time information to the rescuers to provide the right information at the right time to the right people to make the right decision which makes the difference on the life and death of injured people. In such a devastating time, every second count where time lost means lives lost (Cisco 2012). Nokia portable LTE network helps to save this crucial second to save the lives of injured people from disaster.

NSL portable LTE network is used to connect the drones in the sky as they provide wide area coverage, thus minimizing additional resources. NSL portable LTE network is designed and optimized according to the need for terrestrial users and proliferation in the sky. Broadcast in the sky is different than the ground as signals typically broader in the sky compared to the ground level. Cell sites in LTE network must be closer together to ensure complete coverage. This improves capacity. Smaller and more numerous cell areas allow higher volumes of user traffic without the need to increase the amount of spectrum. This 'densification' is vital to supply the capacity needed as users adopt more capacity-hungry applications such as video and augmented reality (Source: Nokia Documents).

The drone running an application requires a high throughput, like streaming from an onboard camera towards the base station. Those drone applications that connect to portable LTE helps to update the drones' traffic management with status messages, including the drone location. Further, information from the sensors help flight control function and can utilize to make the decisions. It also allows the flight plan to avoid potential collisions, enable dynamics geofencing, or to command a range of sensor/actuator functions on board of the drone. The beneficial means to provide these applications is to utilize existing cellular networks, the portable LTE based systems, as the infrastructure is in place. Nokia portable LTE supports the swarm of drones for automatic operations, for example, automatic safety surveillance monitoring and inspections for the disaster management. In the Philippines live demo; two drones were used for the monitoring of landslides and car accident area and to rescue the injured people. The number of drones can be used according to the nature of disaster for safety monitoring and surveillance (Source: Nokia Documents). The analyses of the response of interviewee does the LTE network supports drones effectively on disaster management are presented below.

Figure 16 shows the analysis of the Rate on drone handling operations vs. rate on communication capabilities through the LTE network.

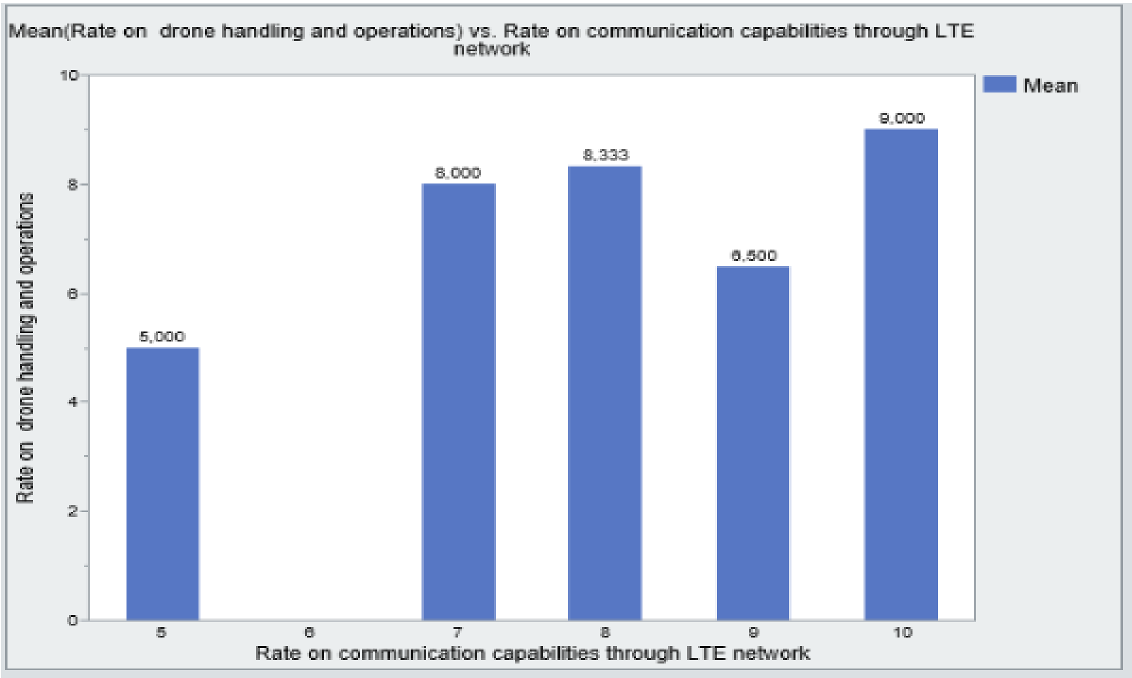

Figure 16 Rate on drone handling operations vs. rate on communication capabilities through LTE.

The above figure explains the relationship between drone handling and operations and communication capabilities through the LTE network. If there is a good LTE connection, LTE connected drone enables the transfer of information promptly captured by its payloads embedded with HD and thermal camera. The figure shows there is a good relationship between drone handling and communication capabilities through the LTE network. On the rating scale from 1 to 10, it shows there is a high rating on scale 10 on the relation of drone handling and operations and LTE network communication capabilities. After that, there is a high rating on scale 8, 7 and then 9 continuously.

However, on the overall relationship of the drone handling and operations and the communication capabilities through the LTE network, we can consider there is a good relationship between drone handling and operations vs. communication capabilities through the LTE network.

4.4.1 LTE network setup and configuration

The NSL solution needs to be set up properly before the deployment of the disaster management process. The whole NSL solution includes the LTE connected drone, portable LTE network and portable data centre for data analysis. The faster the set-up of the solution; the quicker is the disaster management process (Source: Nokia Documents). The NSL solution set up will be analysed below based on the interviewee responses from the Philippines live demo.

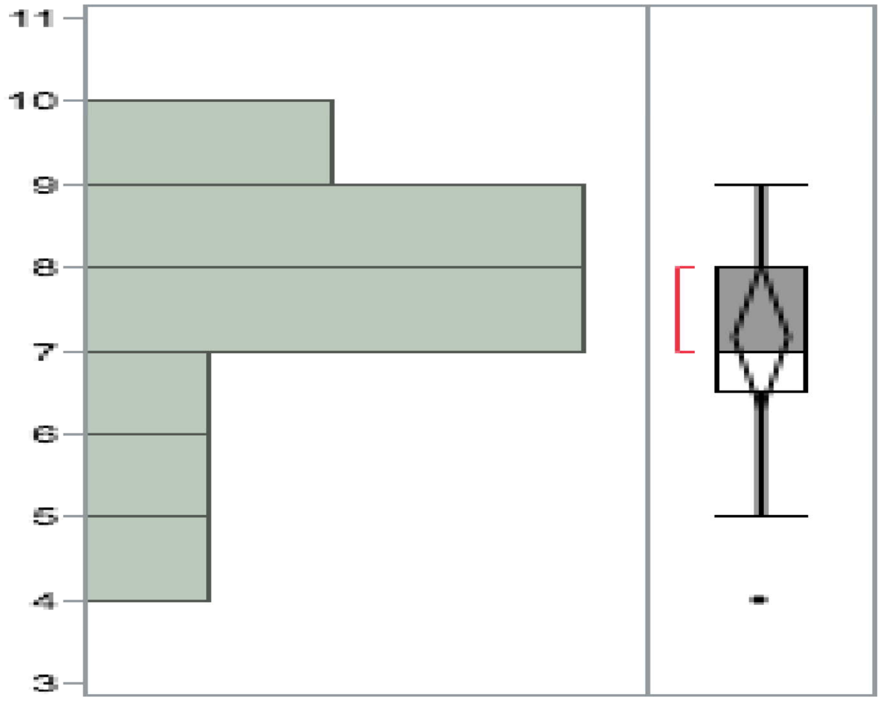

Figure 17 The rating on LTE network set up and configuration.

This figure shows the rating on the LTE network set up and configuration. Most of the interviewee rated it on 9 and 8 scales on the total scale of 10. After this, the higher rate is on scale 10. Maximum number of people rated the same for scale 7, 6 and 5. However, on the scale of 10, most of the interviewee rated on 9 and 8 scale which showed that network set up and configuration is good.

Table 6 Summary statistics on LTE network set up and configuration

Summary Statistics	
Mean	7,1538462
Std Dev	1,4632244
Std Err Mean	0,4058254
Upper 95% Mean	8,0380638
Lower 95% Mean	6,2696285
N	13

Table 6 shows the summary statistics of the LTE network set up and configuration. It has a mean of 7,15, the standard deviation of 1,46 and standard error mean of 0,40. The value of standard deviation is less than mean. It means that it has less spread and closer to the value of network set up and configuration. Hence, it indicates that network set up and configuration is reliable and beneficial for crisis management.

The diagram below shows the expectations and experiences of the interviewed people to set up the innovative NSL technical solution.

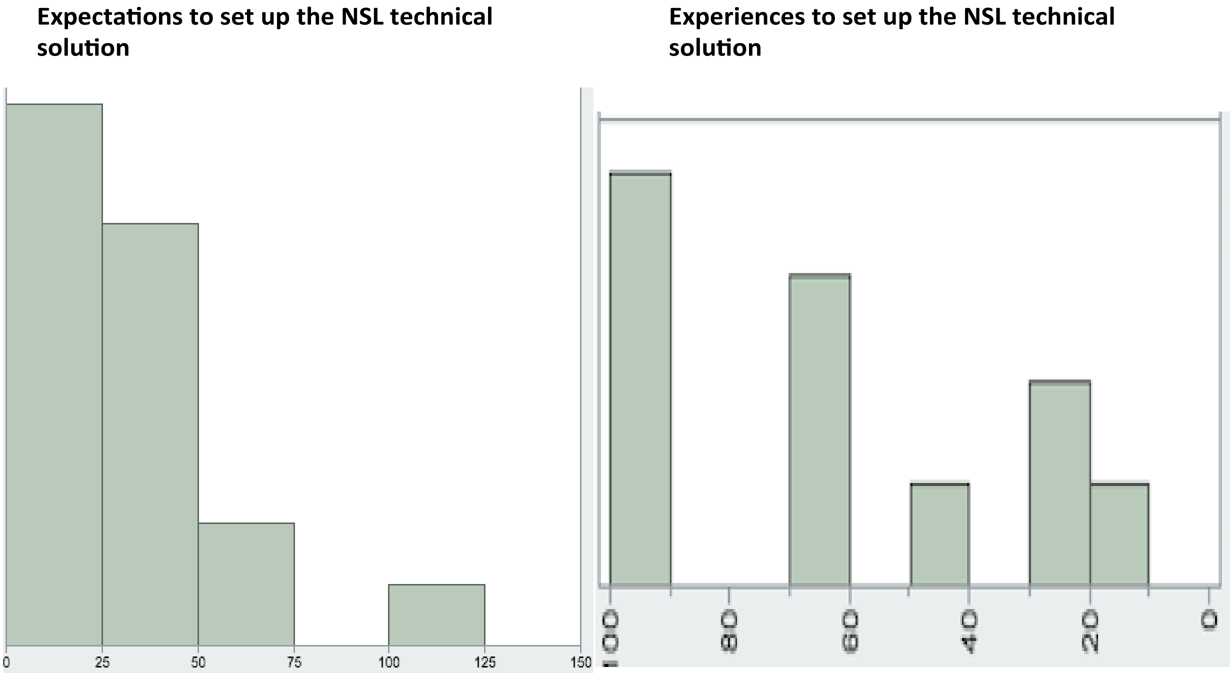

Figure 18 Experiences and expectations of the interviewee to set up the NSL technical solution.

Figure 18 above illustrates the expectations and experiences of the interviewee to set up the whole NSL technical solution in minutes before the implementation of the NSL technical solution in order to manage the crisis. The expectations of interviewee response were collected before the Philippines live demo and experiences response were collected after the Philippines live demo to know the difference between their experiences and expectations on the set up of the whole NSL technical solution. In expectations section of NSL technical solution set up, a maximum number of interviewees responded that it would take 25 mins to set up the whole NSL technical solution. Similarly, it follows with the 50 mins, 75 mins and 125 mins to set up the NSL technical solution. However, in the experiences section of NSL solution set up, responses were higher for 100 mins to set up NSL technical solution and after that for 70 mins and then for 30 mins. Hence, it is concluded that it took a long time to set up the whole NSL technical solution than it was expected in the Philippines live demo.

4.4.2 Summary of innovative NSL technical solution

NSL innovative technical solution is an end-to-end solution connected and operated under a portable LTE network. LTE network supports reliable data analysis from airborne drones, which is one of the requirements for Beyond Visual Line of sight (BVLOS) operations. Airborne drone views wider coverage of an area than a terrestrial user leads on the fair assumption that a drone can cause significant uplink interference (Source: Nokia Documents).

Portable LTE can help humanitarian actors to take advantage of broadband and mission-critical services delivered over their LTE networks. Mission-critical LTE technology enables mechanisms for Quality of Service (QoS) and access policy. The diagram below shows the overall use case of NSL technical solution.

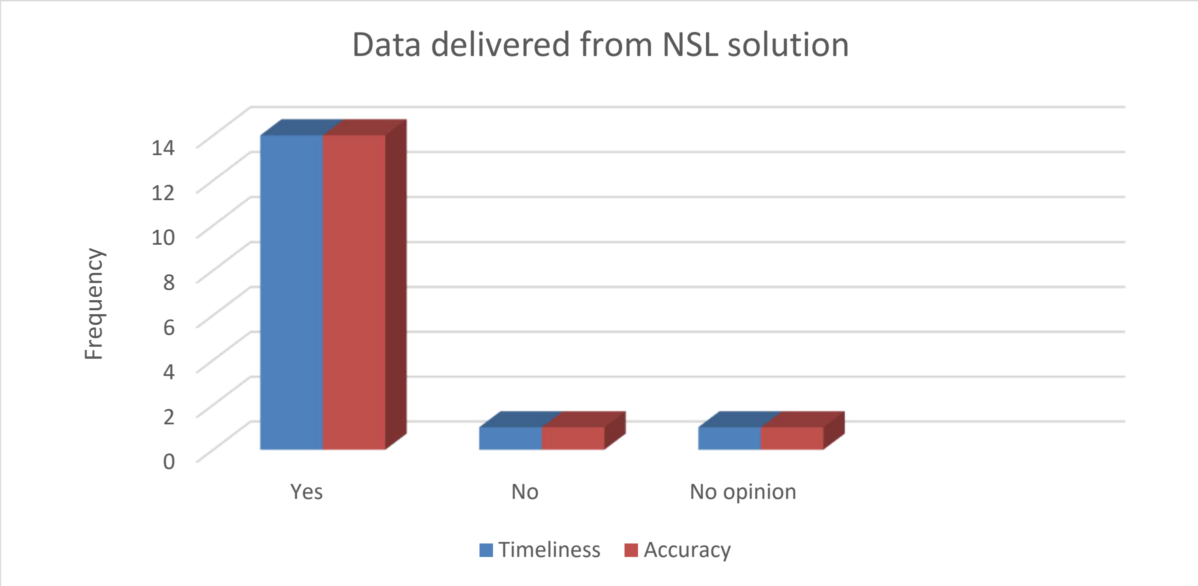

Figure 19 Data delivered from NSL solution in terms of timeliness and accuracy.

Figure 19 explains whether the data delivered from the NSL solution were timeliness and accurate or not. The X-axis denotes the people opinion of Yes, No, and No opinion. Y-axis denotes the frequency of the people responding on the timeliness and accuracy in terms of yes, no and no opinion. The blue colour represents the timeliness and the red colour represents accuracy. Hence, the figure shows that most of the people responded that the data delivered from the NSL solution is both timely and accurate to take the right decision at the right time to rescue the people from disaster. Hence, we can consider that the NSL solution is effective for disaster management.

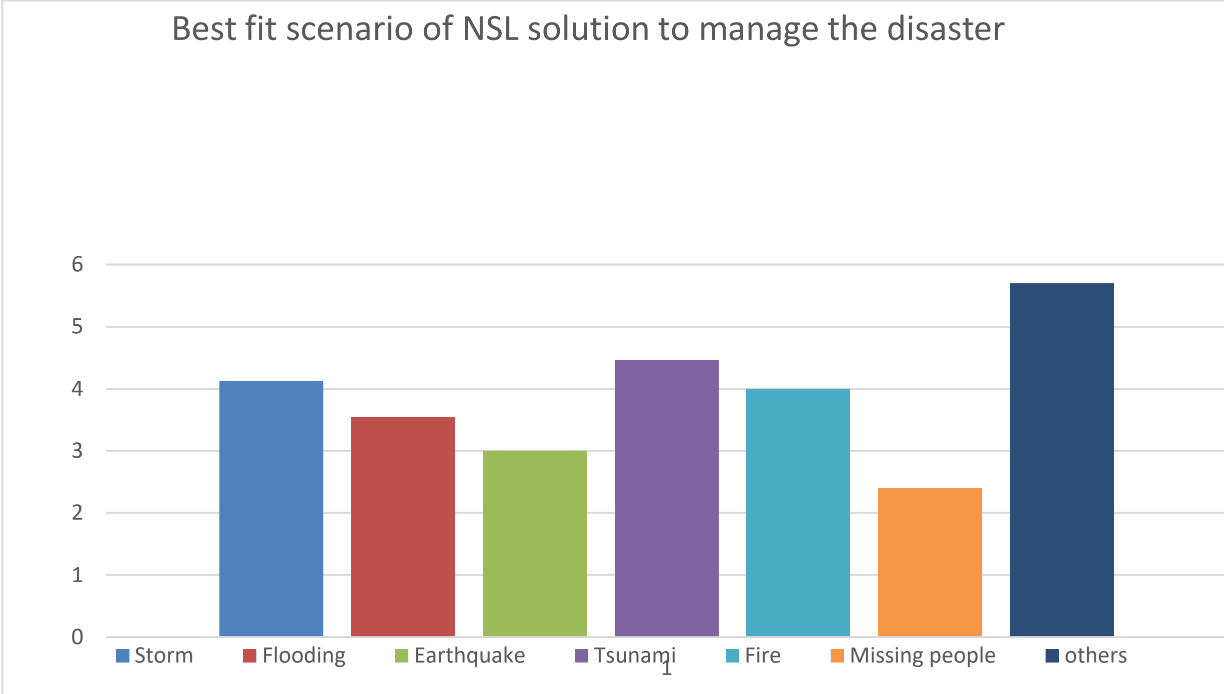

Figure 20 The best-fit scenario of NSL solution to manage the disaster

Figure 20 explains the best-fit scenario of NSL technical solution to manage the disaster according to the interviewee opinions. It has illustrated some of the different disasters' scenario in different colours, such as storm in light blue, flooding in a red, earthquake in green, the tsunami in purple, fire in turquoise, orange in missing people and others in dark blue. Most of the interviewee responded that NSL solution is the best fit in the tsunami, which has 4.5 rating. Subsequently on storm, fire, flooding, earthquake and missing people. People rated on others bit high than another disaster scenario. However, they didn't mention in others on which disaster scenario NSL solution will best fit. Based on this response, we can assume that interviewee has a strong belief that innovative NSL solution has the potential to manage any type of disasters and to rescue the people from a crisis scenario.

In general, a portable LTE network provides good network coverage and supports other applications like drones for mapping and safety surveillance to rescue the people from the disaster area. NSL end-to-end approach and standard-based solutions combined with a comprehensive service portfolio help to safely implement mission-critical LTE with the right level of reliability, security and performance.

4.5 Synthesis findings

This chapter presents a synthesis of findings. It also answers the 4th research questions of this research study and i.e. what challenges are faced by the NSL technical solution and how to overcome it.

It was visible from the Philippines live demo that not only partners need to have good collaboration, whole NSL solution also needs to cooperate with each other to function properly in order to save the lives from the crisis scenario. The NSL technical solution, which is the combination of LTE connected drone, portable LTE network and portable data centre has good cooperation among each other. The portable LTE network provides good support to the drone, which enables the effective safety surveillance and mapping of the landslides and car accident area and pass this information promptly to the portable data centre. Further, data analyst analyses the data achieved from a drone and pass the information immediately to PRC to rescue the lives from those two incidents: landslides and car accident. The three partners PRC, Smart and Nokia also handled their responsibilities properly to make the live demo smooth and effective.

Nokia developed innovative NSL technical solution and trained people to make them experts to operate the technical solution and provided them to the PRC. PRC trained the volunteers for the disaster preparedness and used the information from NSL technical solution to save the lives from disaster. Smart provides the spectrum to operate the NSL solution. If anyone of these parties had failed to fulfil their responsibilities, then it would have been difficult on the deployment of the NSL solution to save the lives from the disaster. The innovative feature of NSL technical solution and the proper collaboration of three partners had made search and rescue operation smooth in the live demo in the Philippines.

Here are the findings which were identified from the analysis of the response of the interviewee, observations and documents of NSL solutions from the NSL live demo in the Philippines.

4.5.1 The strength of NSL solution

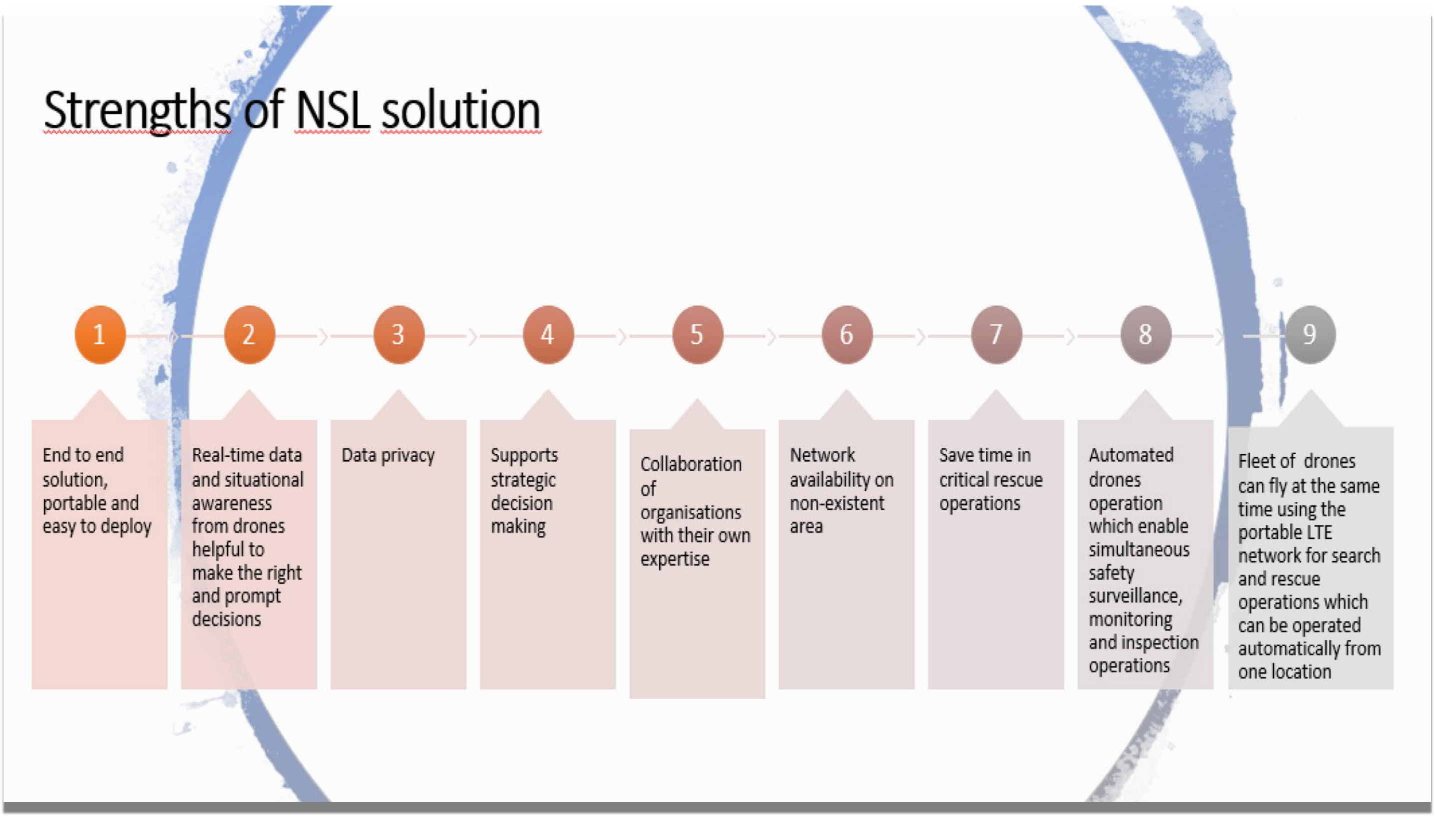

Figure 21 Strengths of NSL solution

The analysis from the responses of the interviewee, observations and from the documents of the NSL technical solution, the above 9 strengths of NSL technical solution were identified which are mentioned in **Figure 21** above.

- **End to end solution, portable and easy to deploy**
  NSL technical solution is an end-to-end solution that has all the technical components for the disaster management i.e. portable LTE network, LTE connected drones and portable data centre. The NSL technical solution is portable and can be deployed anywhere even where the network doesn't exist.
- **Real time data and situational awareness**
  According to the analysis of the response of interviewee, the data from LTE connected drones were on real time which were transferred to the portable data center for data analysis and was rated on 10. In parallel the information is also sent to PRC which helped to made them prompt decisions to save the lives from landslides and car accident from the Philippines live demo.
- **Data privacy**
  Nokia concerns about the privacy of people. The data which are collected from LTE connected drones are stored on the portable data center which is on the private cloud of Nokia. The approval from Nokia is needed to access those data. As well the concern from injured people also needed to share the data to outsiders.
- **Supports on strategic decision making**
  The aerial sight from drones gives the overall view of disaster area which supports on strategic decision making to save the lives from crisis area. The data from drones are timeliness and accuracy which is more reliable for the planning purpose according to the analysis of interviewee response. Further, the analysis from the mean rate on data analysis management Vs data delivered from NSL solution satisfy the requirements which was rated on scale 10 also verifies that data from drones meet the needs of PRC for strategic decision making for search and rescue operations.
- **Collaborations of organisations with their own expertise**
  The management of disaster by using this innovative technical solution, different organisations are needed with individual expertise who can provide the spectrum to operate the technical solutions and who can use the data from innovative solution. In considering this, Nokia has collaborated with PRC who use the data from technical solution for search and rescue operations and Smart who provides spectrum to operate the innovative solution effectively. The three parties also agreed on the specific process which was discussed before on 4.2 heading to manage the disaster smoothly and effectively.
- **Network availability on non-existent area**
  Portable LTE network can be moved and set up anywhere even where there is no existence of network. During the disaster time, commercial network also gets on hype to contact their beloved ones (CISCO 2012). In this scenario, portable LTE network helps to connect among the rescue team and also maintain the connectivity on drones and portable data centre for data analysis. According to analysis of interviewee response, it declared that there was a good relation on drone handling operations Vs communication capabilities through portable LTE network which was rated on scale 10 among the rescue team of PRC.
- **Save time in critical rescue operations**
  During the disaster time, every second counts which make the difference on life and death of injured people (CISCO 2012). NSL innovative technical solution has end to end solution for the disaster management along with coop-

eration of two parties with their own expertise. The analysis from the interviewee response also claims that the data delivered from drones are on real time which is reliable to make the prompt decision by PRC and helps to save time on the critical rescue operations. Along with it, the interviewee also responded that drone is suitable on every type of natural disasters like storm, flooding, earthquake, tsunami, fire, missing people and other types of disaster. So, the innovative solution can be used in any scenario of disaster.

- **Automated drones' operation**

  The fleet of drones are automated, and which empower simultaneous safety surveillance, monitoring and inspection operations. This can be operated automatically from one location. The analysis from the interviewee response also claims that drone handling and operations is effective to manage the disaster as it had highest rating on scale 10.

4.5.2 Factors to focus on the smooth operation of the disaster management

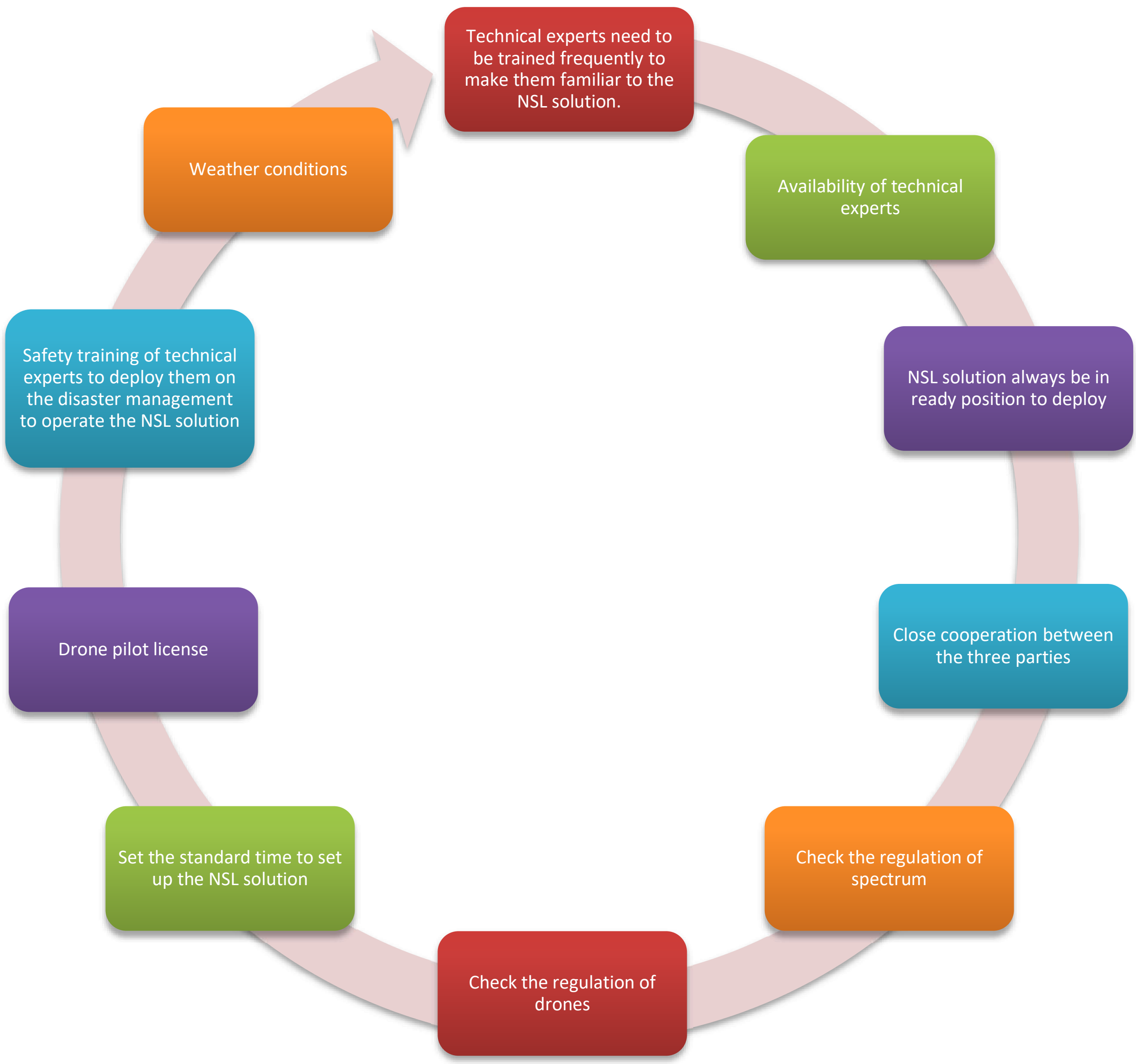

Figure 22 Factors to focus on the smooth operation of the disaster management.

Figure 22 explains up the factors to focus on the smooth operation of the disaster management in order to save the lives that are identified from the analysis of the response of interviewee, observations and documents of NSL solution.

The technical experts are the one who operates the technical solution on disaster area to make the information available on real time to save the lives. I believe, the more they are trained with the technical solution; more they get familiar with it and make faster decision to deploy the solution in a critical time that ultimately helps to save time. The analysis from the interviewee response also denotes that set up of NSL solution took longer time more than 100 mins than expected 25 mins. In the absence of any technical experts, it becomes impossible to operate the technical solution. Hence, from the observations that the availability of all technical experts i.e. drone pilot, data analyst and networking and regular training must be required to operate the solution faster and conveniently. **The NSL technical solution** should always be in a ready position to deploy on the critical area. The participants observed that the backup of extra components like battery and drones should be there for any issues raised time being. The standard time for the set-up of the NSL solution can be fixed which helps to save time and human effort as per the analysis of interviewee response. Further, there should be **close cooperation** among the three parties (PRC, Smart and Nokia). Due to the different time zone in Finland, Germany and Philippines, sometimes it was difficult to set up the regular meeting and update the status of their individual work. So, they fixed this issue by arranging the suitable time and day in a week to maintain the regular communication and follow up among the three parties for the smooth operation of disaster management. It is obvious that the absence of any three parties makes the disaster management process hard. **The regulations of drones and spectrum** should be checked before deploying the NSL solution. Without the compliance of regulations of drones and spectrum, the implementation of NSL solution and disaster management is impossible. So, regulations should be followed properly before the operation of NSL solution. It was observed that without the compliance of rules and regulations, it is hard to deploy the NSL solution in disaster area to save the lives. **The drone pilot** must need to have a license to fly the drones. So, the drone pilot needs to be trained and get the license beforehand to fly the drones in a critical time. **The safety training** should be given to all the people before deploying them into the disaster area. Since drones are lightweight and might not bear the worst weather conditions like a heavy hurricane. Hence, it is always good to check **weather conditions** before the implementation of the NSL solution. Further, the worst weather condition might also put the life of rescuers and life of technical experts in danger.

4.5.3 Challenges and solutions for the usability of NSL solution

The **Figures 23 and 24** show the challenges and solutions to overcome the challenges of the usability of the NSL solution. These are the findings that were identified by the analysis of the response of the interviewee, participants observations and the documents from the NSL live demo.

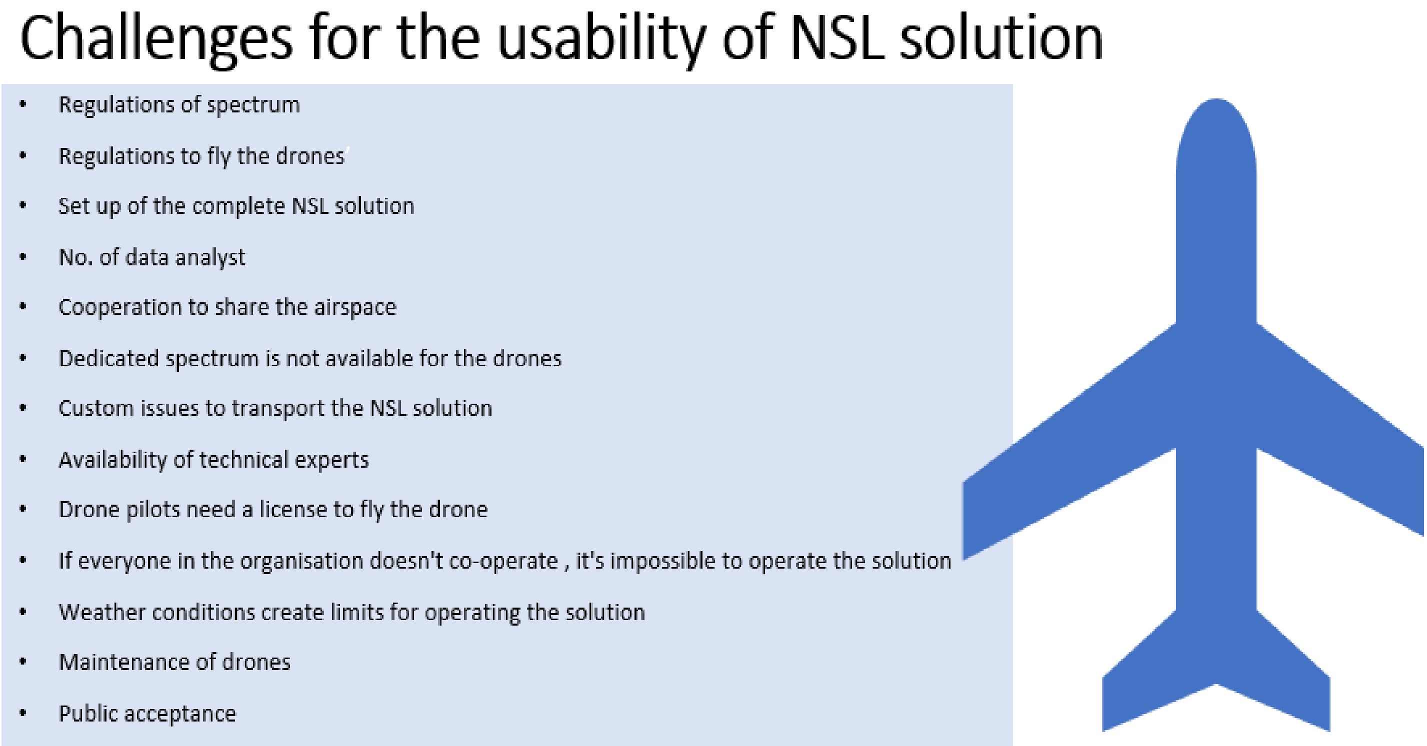

Figure 23 Challenges for the usability of NSL solution

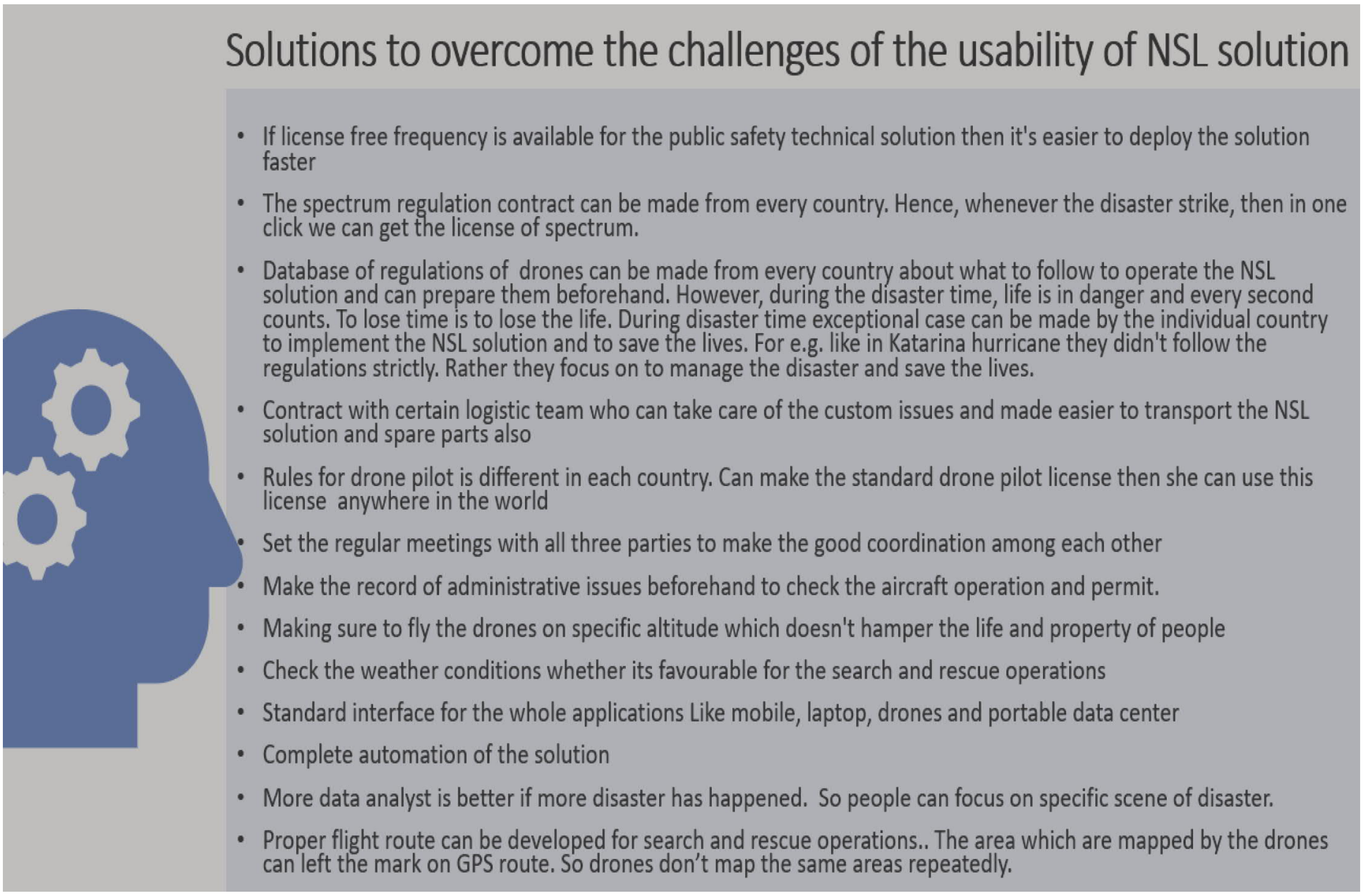

Figure 24 Solutions to overcome the challenges of the usability of NSL solu-ion.

Regulations of the spectrum are one of the biggest challenges on the usability of the NSL solution. Rules and regulations are made to save people and property and are difficult to break. However, during the disaster time, it is difficult to follow all the regulations in a short period of time that makes the delay on the deployment of the NSL solution. Hence, I assume, at least for public safety purpose, the regulations should be flexible to save the lives from the critical scenario. For example, in Katarina hurricane, the regulations were flexible especially on the use of frequency to deploy the solution in order to save the lives.

Further, there can be a license-free frequency for public safety technical solution that makes process easier and faster to deploy the solution to save the lives. The spectrum regulation contract can be done with every country to deploy the NSL solution to manage the disaster. If any change in regulations has happened, then they will be informed about it and can act accordingly. Hence, whenever the disaster strikes, in one click spectrum can be accessed.

Regulations of drones restrict to fly the drones for mapping, safety surveillance and inspection operations. This restriction makes the disaster management process difficult. So, to comply with the regulations of drones, a database of regulations of each and every country can be made and prepare for it beforehand. Conversely, we can have good coordination with legislation to get people familiar with rules and regulations and update on the regular change of rules, which makes easier on the operation of NSL technical solution. The drones should fly on certain altitude, which makes sure that it doesn't affect the lives and property of people. Further, the area, which is mapped by drones, can be marked on GPS route so that drones do not map the same area repeatedly.

Set up of the complete NSL solution took a longer time than it was expected as per the response of interviewee. It took 100 mins to set up the NSL technical solution rather than expected 25 mins. So, it can be researched in this place and can minimise the setup of NSL technical solution which makes faster on the disaster management process.

No. of Data analyst needs to depend on the nature of the disaster. If the disaster scenario is worst and needs to cover the wider area, it is better to have more than one data analyst. This helps data analyst to focus on the specific disaster scenario and collect more information from the wider disaster area. This also helps to locate the injured people from a broad area and rapid up to save the lives from the larger emergency areas.

Cooperation to share the airspace means drones should fly on a certain altitude and it doesn't affect the route of another air vehicle. So, to make the drone fly on free airspace, they need to have a contract with Civil Aviation of Authority (CAA). Then, CAA provides the airspace- the right to fly the drones on the disaster-affected area.

Dedicated spectrum is not available for the drones which makes difficult to fly the drones for search and rescue operations. The need for spectrum is different according to the feature of drones. Hence, it might be difficult to find a dedicated spectrum for the drones. So, maintaining the database of the availability of a different range of spectrum on certain area makes the operation of NSL solution easier and faster.

A customs issue to transport the NSL solution is also one of the challenges in deploying the NSL solution. NSL solution has been developed in Germany and Finland research centre. After the development of NSL solution, it was exported to Philippine to provide to PRC and train the technical expert. However, exporting the NSL solution, Nokia faced multiple challenges. In order to overcome those challenges, Nokia can make a contract with a certain logistic team who will take care of the customs issues and make easier to transport the NSL solution and its parts.

Availability of technical experts is essential to operate the NSL solution. In the absence of technical experts, deployment of NSL solution becomes difficult. Hence, the line manager of technical experts approves the absence from job responsibilities. Even experts are fully responsible to volunteer their expertise as a PRC volunteer in their free time.

Drone pilots need a license to fly the drone. The challenge here is that the license that he/she gets from one country is not valid for another country. This makes difficult to use the knowledge of one people in different countries. So, it would be good, if there were a standard system for drone pilot license so that he/she can use the same license anywhere in the world to save the lives.

Co-operation of three parties is an essential part to manage the disaster collaboratively. Each individual party is responsible to handle their responsibilities like providing a spectrum, using the information from NSL solution to manage the disaster, and developing an innovative solution and training technical experts. If any single party doesn't cooperate, it makes difficult to manage the disaster. So, there should be continuous communication and regular meetings among the three parties to manage the disaster. As well they have to take care of the different time horizon to make the regular meetings smooth.

Weather conditions create a limit to operate the solution. Worst weather conditions make operations of the NSL solution difficult. So, before the deployment of the NSL solution, a technical expert has to check the weather condition that doesn't affect the operation of search and rescue. The lightweight feature of drones makes the operation of the solution difficult on heavy hurricane and dusky weather. Further, it also put the life of volunteers and technical experts in danger.

Maintenance of drones is also one of the challenges on the usability of NSL solution. The spare parts of drones like battery, propellers etc. should be readily available during the search and rescue mission so that if any of the parts get damaged, those parts can be changed immediately, and the mission can be operated smoothly again to save the lives from the disaster.

Public acceptance is also one of the challenges on the usability of the NSL solution. Without the acceptance of the public, it is difficult to deploy the solution to the disaster area. So, to overcome this challenge, make people aware of the use case and benefits of NSL solution. Humanitarian actors should take responsibility to communicate with local authorities and the public about possible impacts and benefits of the solution.

However, the challenges mentioned above are derived from the participant observations and interview response from a live demo and were the initial experiences to operate the NSL solution to save the lives from disaster. The effectiveness of operation of NSL solution depends on the country, circumstances and regulations of the country.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

NSL technical solution is an innovative and non-profit initiative to save the lives by supporting humanitarian actors (HA) for search and rescue operations. Nokia Saving Lives (NSL) technical solution had been implemented in the Philippines in collaboration with PRC and Smart Communications. Nokia developed the innovative NSL technical solution, which consisted of a portable LTE network, LTE connected Drones equipped with HD and thermal camera, and portable data center and trained the technical expert to operate the solution. Nokia provided the complete NSL technical solution and trained technical experts to PRC who worked under the regulations of PRC during the disaster time as volunteers. The spectrum needed for LTE operation was provided by Smart communication to operate the NSL solution.

The NSL technical solution was deployed for the first time in the Philippines on 23rd Nov 2018. There was a live demo on 23rd Nov 2018 on the Philippine to show the use case of the NSL solution and how it could manage the disaster and save the lives in collaboration with PRC and Smart communication. There were two incidents i.e. landslide and car accident demonstrated in close collaboration between PRC volunteering technical experts recruited from Nokia, PRC staff and Smart Communications. The demonstration was started with alerting by PRC, followed by deployment of solution and rescue operations and was effectively managed. All the observers of a live demo and the parties were satisfied with the operation of NSL solution.

5.1.1 Theoretical implications

The aim of this research was to understand the meaning of disaster, the process of disaster management, use case of portable LTE network and drones, and challenges to operate the technical solution in the disaster area. Disasters are unpredictable, and it can happen at any time. It is focused on the technical communications to manage the disaster by providing real-time information to the rescuers to save the lives from the disaster. There are different categories of disaster and they are a natural disaster, technological disaster and manmade disaster. There are four phases for the disaster management i.e. mitigation, preparedness, response and recovery. On the mitigation phase, case company have to collaborate with third parties, which is essential for the successful management of the disaster. For example; Smart communication provides the spectrum to operate the NSL solution and PRC used the real-time information provided by NSL technical solution for mapping the disaster area and rescue the lives. On the preparedness phase, case company trained the technical experts to operate the NSL technical solution. Similarly, Smart had to declare the clearance of spectrum on the disaster area. PRC accessed the real-time information from NSL technical solution to take the right decision and step further to save the lives and rescue the people. On the response phase, the preparedness plans were put into action that was the observable part of the disaster management phases. At last on this phase, it showed the mission was accomplished. However, it was hard to decide the start and end of the recovery phase. The results of the live demo were beneficial to the case company to get valuable data for further crisis analysis and modelling and establishing the warning systems and manage the disaster.

The scientific contribution of the study was crystallized on the use case of LTE connected drones and portable LTE network on the nature of the natural disaster. The specific use case of drones was coordination among rescuers, terrain coverage, and search and rescue operations. The drone's applications management level was divided into 3 groups such as strategic, operational and tactical levels. The real-time data provided by the drones were dependent on the level of management and how they will use it. Swarm of drones' fly and helped on mapping and surveillance on the search and rescue operations. However, there is technical issues such as the automated operation of a swarm of drones have to communicate with each other besides communication with ground control where there require more communication channels. Case company has to understand this issue. The rules and regulations are also one of those factors where case company have to consider seriously. The regulations on the use of drones and spectrum highly restrict the deployment of NSL solution on the disaster area or cause a long time to deploy the solution. The data security is one of the strengths of the case company that preserves the data of injured people who may not like to share with the public. The Nokia drone equipped with HD and thermal camera were the core parts and helped on mapping and surveillance of the disaster area. The thermal camera helps to locate the injured people and the HD camera helps to zoom the crisis area by 30 times that gave a clear vision of the disaster area.

Further, Nokia LTE network is portable and can be set up anywhere with or without a network. Public communication is busy with the volume and velocity of calls that make communications difficult among the rescuers to take the right decision at the right time. The optimized portable LTE network is needed in such a crisis scenario to assure priority communications among the rescuers, which Nokia innovative solution has.

The scientific contribution, of course, would be a more comprehensive, if more use case and process of disaster management would have been used and if the research would have been done on multiple case studies related to the use of the different technical solution in disaster management. However, this study was commissioned by a one innovative NSL technical solution, and that is why used research method was a single case study.

5.1.2 Managerial implications

First, Nokia developed the innovative end-to-end technical solution to save the lives from disaster. Further, it was the cheapest way for mapping and surveillance of the disaster area in comparison to the Helicopters, aeroplanes and even from satellites.

Second, disaster management required a proper strategic plan to take care of every second where every single second matter on the difference between the life and death of people on the crisis time.

Third, the collaboration of three parties i.e. PRC, Nokia and Smart communications with their core competencies was an essential step to bring new and piloted technology into the emergency area. Nokia developed an innovative technical solution and trained the technical expert to operate the solution. Then, Nokia provided this NSL technical solution and technical experts to PRC who worked under the regulations of PRC. Further, PRC used the real-time data provided by NSL solution to make the strategic decisions to manage the disaster. Smart communications provided the spectrum to operate the NSL solution effectively. Hence, effective collaboration of three parties was important for disaster management.

Fourth, the technical solution was a new approach to the disaster management process. It should be possible to train other technical savvy HA staff or volunteers to operate the NSL technical solution for the faster deployment and management of the crisis.

Fifth, a portable LTE network can be moved anywhere and can be set up anywhere with or without a network. This was the core strength of NSL technical solution. The rescuers can move this LTE network anywhere without giving concern on network infrastructure. LTE network supports to connect with drone and command center to make the real-time data available to rescuers and smooth communication among rescuers to manage the disaster promptly, safely and securely.

Sixth, LTE connected drones are efficient among other flying devices that helps to alert the situation of disaster before and after of it. Nokia drones equipped with HD and thermal camera help to provide real-time data. The HD camera with 30 times zooming feature helps to understand the real scenario of the disaster area and the thermal camera helps to detect the injured people, polluted air, gas emission etc. Hence, LTE connected drones can be used in multiple processes.

Seventh, the data delivered from drones were safe and secure. It helped to maintain the privacy of injured people and was the core strength of NSL solution.

Eighth, the regulations of drones and spectrum should be in the databases that can be checked before the deployment of the NSL solution for saving the lives from the disaster. During the disaster time, the compliance of regulations might take longer time and might delay the operation of NSL solution.

5.2 Recommendations for the case company

NSL technical innovation was brought into use at a time where the technology is still new to possible users.

However, with the advancement of technology, there is always a room to make it more advanced and convenient to use. Here is the list of recommendations for the case company:

- The whole NSL technical solution set up seems taking longer time. It would be great if set up is faster. Then, search and rescue operations will also operate faster.
- The operation of the NSL technical solution is dependent on another network frequency. It means Nokia need to have good collaboration with network companies so that they can use the technical solution without any hindrances. Otherwise, the unlicensed spectrum can be used to operate the solution or public authorities owning/controlling spectrum allocation can help.
- The video streaming from drones should be passed in real time to analyse the disaster scenario and rescue the people. More data analytics would be good if the disaster scenarios are worst to analyse the data captured by drones.
- There should be proper coordination among drone pilot, data analysis and networking to implement this solution effectively for the disaster management purpose.
- The portable LTE network is easier to move anywhere; wherever the network doesn’t exist. However, it seems still heavy and difficult to move. It would be convenient if the portable LTE network has 4 wheels than 2 wheels to move it easily. OR still can make the portable LTE network smaller and lighter to make it more convenient to use.
- Wide coverage of LTE network
- Longer flight times and weatherproof capabilities of drones.
- Reduce the sound of drones

- People are losing a life while working with big plants and machines. It's another innovative way to develop an indoor drone that helps to save the lives from an unexpected accident by machines and plants.
- The NSL technical solution hardware can be made in such a way so that it can manage to operate in any harsh weather conditions. Disaster means the worst weather and it should be efficient to operate in such a scenario to save the lives.
- The different sources of information have to be integrated into data analysis including different *in-situ* sensors, such as water gauges or seismometers, and aerial and satellite images. This helps to better analyse the scenario.
- Serve as a single gateway between different communication systems
- Plug-and-play networks

5.3 Topics for further research

The results of this research provided a generic framework on how we can manage the crisis by using the innovative NSL technical solution in collaboration with three parties. In order to validate this framework, other scenarios also need to be examined. Future research could focus on specific organisations following the same approach to manage the disaster and can identify the changes. Besides, other research can be done on the advancement of NSL technical solution or accessing the applicability of current NSL technical solution on another disaster scenario.

Further, this case is bound in one-nation (Philippines) as a live demo to manage the disaster. This can be explored in other disaster-prone countries and realistically manage the disaster to see the efficiency of this solution to disaster management.

In addition, it would be beneficial to investigate the rules and regulations of different countries to implement the innovative NSL technical solution.

Innovative NSL technical solutions are confined to operate on certain weather conditions like not in the heavy wind, cloudy environment and heavy rain. Drone is made of light materials, which do not tolerate the heavy winds and does not have the waterproof system to protect it from the heavy rain. In this area also, there is space for further research.

5.4 Summary

This research explored the use case of Innovative NSL technical solution in disaster management. This gave more emphasis on the interactions between different partners (like Humanitarian Actors (HA) and network operators), processes and innovative technical solution (LTE connected drones, portable data center and portable LTE network). The study was commissioned by the Nokia Saving Lives (NSL) program and was conducted by using both qualitative and quantitative research method by interviewing technical expert volunteers, NSL technical solution trainers and other parties. Interviews were semi-structured, which were designed to collect comprehensive information on the use case of innovative NSL technical solution and collaboration of three parties to manage the disaster. The research problems were explored using these research questions.

1. How different organisations collaborate to save the lives from the disaster?
2. Are LTE connected drones being beneficial to manage crisis management?
3. Is a private LTE network beneficial to support crisis management?

4. What are the challenges faced by NSL technical solution and how to overcome it?

The research used four analysing frameworks; process to manage the disaster, use case of drones, support of LTE network, challenges and solutions to overcome the challenges to operate the NSL solution to manage the disaster and saving the lives. The disaster management process shows how 3 different partners (PRC, Smart communications and NSL) collaborated to manage the disaster. The use of the solution under realistic conditions was demonstrated with partners. Nokia provided its innovative NSL technical solution along with trained technical experts to implement the NSL technical solution to PRC. Those technical experts worked under the terms and conditions of humanitarian actors. Smart communications provided the spectrum to operate the innovative NSL technical solution efficiently and effectively.

The empirical findings revealed that the use case of drones and LTE network were effective to manage the disaster. The portability feature of the NSL solution made it more effective to set up the technical solution anywhere, where the network doesn't exist and rapid up the saving lives from disaster. The end-to-end solution made the operation of disaster management faster without depending on other technical parts. However, it depends upon the network communication to get the spectrum to operate the solution and rescuers who can use the information from the solution to manage the disaster. Considering this, NSL had collaborated with PRC and Smart to make the disaster management process smooth and effective. The parties with their core competencies handle their responsibilities in a proper way that made the live Philippine demo successful. After the live Philippine disaster management demo, NSL solution won the trust of interviewee and convinced the people that NSL solution is an innovative technical solution approach to save the lives and manage the disaster.

There were certain challenges to deploy the NSL technical solution. They were regulations of drones, spectrum and customs issues to operate the NSL technical solution. Nevertheless, these factors need to be taken care beforehand by making records of all the regulations and can check them before deploying the NSL solution. However, disaster is uncertain, and it is impossible to follow all the regulations in a short period of time. During disaster time, every second counts and time lost means lives lost. Considering this, there should be an exception of regulations to deploy the innovative NSL solution that is seriously helpful to save the time and save the lives by helping the rescuers to provide the prompt information of disaster area and status of the injured people.

Since the research explored the disaster management process by using the NSL solution (LTE connected Drone, portable LTE network and portable data storage) and by collaboration of three parties, the results may offer valuable information to other Humanitarian Actors or Public Safety organisations whose purpose is to save the lives from disaster and want to make the positive impact on earth.

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Appendix

Research on the usability of the NSL technical solution

Personal Information

Name:

Role:
(For e.g. Drone pilot)

Organisation:
(For e.g. Nokia)

Interview Questions

1. A) What is your **expectation** that how many minutes are required to set up the NSL technical solution after arrival on the rescue area through flight readiness?

   ___________________minutes.

   B) what is your **experience** that how many minutes are required to set up the NSL technical solution after arrival on the rescue area through flight readiness?

   ___________________minutes.

   C) Which areas would you recommend for improvement?

   ____
   ____

   D) I don’t have any experience.

   ____
   ____

2. A) Please rate your **expectation** that how well the Nokia, Philippines Red Cross (PRC) and Smart Communications will collaborate from the rating 1 to 10? (Please rate 1= poor to 10= excellent and put cross (x) mark on the side of your rating)

1	2	3	4	5	6	7	8	9	10

   B) Please rate your **experience** that how well the Nokia, PRC and Smart communications has collaborated from the rating 1 to 10? (Please rate 1= poor to 10= excellent and put cross (x) mark on the side of your rating)

1	2	3	4	5	6	7	8	9	10

C) Which areas would you recommend for improvement?

____

____

C) I don't have any experience.

____

____

3. If you have any experiences with the operation of the NSL technical solution, how would you rate? OR if you don't have the experience you can leave this question out.

A) a. Drone handling and operations (Please rate 1= poor to 10= excellent and put cross (x) mark on the side of your rating)

1	2	3	4	5	6	7	8	9	10

b. which areas would you recommend for improvement?

____

____

c. I don't have any experience.

____

____

B) a. Network set up and configuration (Please rate 1= poor to 10= excellent and put cross (x) mark on the side of your rating)

1	2	3	4	5	6	7	8	9	10

b. Which area would you recommend for improvement?

____

____

c. I don't have any experience.

____

____

C) a. Data analysis and data management (Please rate 1= poor to 10= excellent and put cross (x) mark on the side of your rating)

1	2	3	4	5	6	7	8	9	10

b. Which area would you recommend for improvement?

____

____

c. I don't have any experience.

____

____

4. A) Would you consider the data delivered from the solution is relevant in terms of timeliness and accuracy to rescue the people and disaster management? (Please put cross (x) marks on the side of your rating)

Timeliness	Yes	No	No opinion
Accuracy	Yes	No	No opinion

B) If no, which areas would you recommend for improvement?

____

____

C) I don't have any experience.

____

____

5. A) Are the data provided by the NSL technical solution are satisfactory for your requirements?
(Please rate 1 = not satisfied to 10= most satisfied and put cross (x) mark on the side of your rating)

1	2	3	4	5	6	7	8	9	10

B) Which areas would you recommend for improvement?

____

____

C) I don't have any experience.

6. A) please rate your satisfaction with the communications capabilities through LTE network on a scale from 1 to 10. (Please rate 1=poor to 10 = excellent and put cross (x) mark on the side of your rating)

1	2	3	4	5	6	7	8	9	10

B) Which areas would you recommend for improvement?

C) I don't have any experience.

7. In which scenarios would you think the NSL technical solution for disaster management fitting best? Please write the scenarios from 1 to 7 on the side of options (1 best fit to 7 least fit)

Storm	
Flooding	
Earthquake	
Tsunami	
Fire	
Missing people	
others	

Feedback and suggestions

1. Would you recommend the NSL technical solution for disaster management purpose? (Please put cross (x) marks on the side of your rating)

Yes
No
Do not know

2. Do you have suggestions and feedback that was not covered before?

____

____