Masters Program in **Geospatial Technologies**

Data Validation and Quality Assessment of Voluntary Geographic Information Road Network of Castellon for Emergency Route Planning

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ABSTRACT

Disasters are unpredictable. Natural disasters such as earthquake, flood, landslide or man-made disaster such as fire, road accident can affect our life anytime. Many casualties occur during the disaster on the absence of preparedness and prevention measure. Lack of evacuation routes and the timely response to the injured people to the nearby emergency services is one of the main sources for a large number of casualties. Proper response operations must be carried out, as a slight delay can risk the lives of citizens. Since disaster cannot be mitigated, preventive measures before and after the disaster are important. Spatial data play a significant role in emergency management: preparedness, response, recovery, and mitigation. A suitable network analysis aids to a smooth network and especially helps during a disaster.

In this paper, Castellon network dataset is developed using validated Voluntary Geographic Information. It is developed to find the fastest route to the emergency services, especially during or after the occurrence of a disaster. Data quality assurance is performed using positional, attribute and network length check to produce efficient results. The fastest and safest route to and from the emergency services are recognized to plan safety measure during the occurrence of a disaster. The evaluation of the network by participants provides insight into the quality and use of the network in a disaster scenario. It also reveals that VGI can be used further in the preparation of a disaster prevention system for various cities.

KEYWORDS

Castellon
Data Validation
Disaster Preparedness
Emergency management
Mapathon
Network Analysis
OpenStreetMap
Quality Evaluation
Volunteer Geographic Information

ACRONYMS

ESRI – Environmental Systems Research Institute

GI – Geographic Information

GIS – Geographic Information System

GPS – Global Positioning System

HOT – Humanitarian OpenStreetMap Team

ISO – International Organization of Standardization

LED – Liquid Crystal Display

NMA – National Mapping Agency

OSM – OpenStreetMap

QGIS – Quantum Geographic Information System

UGC – User Generated Content

VGI – Volunteer Geographic Information

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1 INTRODUCTION

1.1 Background:

Disaster is a sudden and catastrophic event, such as floods, earthquakes, aircraft crashes, chemical leaks, road accidents affecting our normal life causing human casualties and loss of property (Wan, 2003). According to the World Disaster Report (2018), 3751 natural disasters occurred between 2008 and 2018 worldwide, affecting 2 billion people and estimating US$1,658 billion in overall damage (IFRC, 2018). Due to this kind of loss, emergency response performance is critical after a disaster event (Kermanshah & Derrible, 2016) where the right response can save thousands of lives. Hence, response and recovery operations are conducted to minimize the effects after the occurrence of a disaster. In accordance with the scale of the disaster, the vulnerability of the affected area and the site-specific condition, appropriate decisions and actions must be taken. The decision might be taken before or after a disaster such as warning and evacuation, mobilizing search and rescue parties, supporting citizens instantly or evaluating damage and restoration process (NRC, 2007). In these circumstances, the lack of evacuation routes and the timely response to the injured people to nearby emergency services is one of the main sources for a large number of casualties.

Although disasters are unpredictable and cannot be fully mitigated, detail resilience plan can be designed to reduce the impact of the disaster (Poser & Insight, 2015; Wan, 2003) so that it will help decision-makers to react correctly after the occurrence. An effective preparedness plan mitigates the impact and contributes to return to normal condition. The frequency of disaster has made people aware of the effect of the disaster, which has led to changes in relief and response to vulnerability analysis and risk management. In addition, relief operation has changed to preparedness and adaptability where organizations such as International Federation of Red Cross recommends government and donors to ensure the advancement, climate, and humanitarian aid funding structures and facilitate adaptability, local ability, and preparedness (Haworth, 2016; IFRC, 2018). Historically, humanitarian organizations such as International Federation of Red Cross, the United Nations, various non-governmental organizations (NGOs) and government bodies were strongly presented and mobilized for the disaster response and recovery (Haworth, 2016; Wan, 2003).

Now, traditional hierarchal structure of relief and response method has changed to more cross-cutting risk management approach, including community-based disaster risk management initiation, where vulnerable people themselves are involved in planning and implementation of mitigation measures. Volunteer Geographic Information (VGI) considerably interrupts the traditional order of top-down incident management and reflects the cultural shift from authoritative information control (Haworth, 2016).

Data is the key to reduce threats and improve response. Understanding historical patterns of disaster and mapping vulnerable areas are essential elements to cope with disasters (Wan, 2003). Many factors must be taken into account while creating a preparedness plan, whether it is the design of a tsunami alert system, construction of roads for transport or building emergency services in an appropriate area. Spatial data and tools, together with other safety measures, also have the potential to reduce injuries, save lives and reduce coping prices (NRC, 2007).

Given the importance of spatial data in the preparation phase, the World Disaster Report also encourages investments in pre-disaster mapping exercises with local partners in disaster-prone states (IFRC, 2018). Spatial data consist of data and information located on the ground with a geographical location. An updated spatial data provides information about every single change in the ground, locate injured persons or damaged buildings so that responders can act faster after the disaster (NRC, 2007). Different types of risk and evacuation maps are prepared to study the area. Accompanied by maps, a web/mobile application can play a major role in navigating during a disaster, as the advancement in technology has led easy access on mobile, computers and the internet. There are different types of maps to incorporate into the application, such as Google Maps, TomTom, HERE, OpenStreetMap (OSM), and Mapillary.

Although the National Mapping Organization (NMA) has been responsible for creating maps over the years (Neis et al., 2012; Koukoletsos, 2012) with high standard, properly documented quality models and management processes (Poser & Insight, 2015). It is not capable of producing updated maps with every single change in the ground due to high ground survey costs, data maintenance, professionals required to meet the standard and efforts required to share the spatial data (Helbich et al., 2012). Different commercial companies and volunteer communities claim to have updated accurate maps. Although commercial companies claim to have an updated map, they are expensive and are out of reach for people and grass-roots organization (M. Haklay, 2010). (Haworth, 2016) claim that VGI can best fit into preparedness and recovery phases for disaster management. Taking into account the restriction lying in the commercial company spatial data, a voluntary community such as OSM and Mapillary consists of a large amount of data prepared by volunteers from all over the world without restriction. Existing OSM functionality has made OSM popular in the community. The advantages of using VGI such as OSM are the updated maps with cost-effective, easy to use and accessible by everyone (Haworth, 2016). It also gives us the flexibility of authority control of information and disrupts the traditional top-down approach (Haworth, 2016). Due to the easy access and data volume of OSM, OSM is used in the project.

Safe areas vary depending on the varieties of disaster. Every disaster has its own type of effect and vulnerable areas. Considering earthquakes, open areas are considered safe but, in the case of floods or tsunamis, high elevated areas where water cannot reach are safer. Quick mobility to safe locations plays a crucial factor in every disaster. Disaster victims prefer to travel to a safe area to reduce the impact. Transportation systems are very important during extreme events (Kermanshah & Derrible, 2016). In addition, finding the fastest and safest route to travel, emergency services access, and resource distribution are also equally important. Hence, the route information is essential. In critical circumstances, a proper decision should be taken to reach the destination as quickly as possible as there is no chance to take the risk. During a standard day, long time or longer route are often taken which cannot result abundantly, however within the crucial period even second matters. Therefore these issues must be sorted out during a disaster. A proper network must be developed to find the safest and fastest route to reach the emergency facilities.

OSM has been used in different scenario while providing aid to people during disasters whether it would be creating a map during the Haiti earthquake, or used as a base map for different purposes. OSM was used widely in Nepal Earthquake 2015 for resources distribution, rescue operation and damage assessment (Fischer, n.d). OSM is famous for its flexibility in creating new information, but it has issues in terms of authenticity and reliability (M. Haklay, 2010). Research reveals that the OSM quality assessment is important, and several studies have been carried out in the past for OSM data. But the designed route network prepared using OSM has not been reviewed. Since navigation is very important in a disaster, the efficiency of the route network must be studied.

In order to address this knowledge gap, a route network is developed in this project to find the fastest route to the emergency facilities and to solve other routing issues using OSM. Taking into account the risk involved in using OSM data to solve routing problems, an application is configured with the route network and evaluated by volunteers through a questionnaire survey. VGI also challenges the quality of data and data organization, accountability and digital divide issues (Haworth, 2016; Haworth & Bruce, 2015). Hence, three different quality assessments are assessed. Mapathon is organized to update and validate data.

In a nutshell, a web application is developed with four different tools to find the closest facility with the fastest and safest route with the validated OpenStreetMap data on an ArcGIS platform. The application developed is evaluated by volunteers finding the pros and cons of OSM to use it during an emergency condition. The methodology used in this research can be applied in other areas with proper validation through mapathon.

1.2 Research Questions:

i. Does VGI boost for preparedness plan of a city during a disaster and is it trustworthy?
ii. What are the essential steps required to build a city network with VGI?

1.3 Aim & Objectives:

The research primarily aims to find the fastest and safest route by creating a Castellon route network using validated Voluntary Geographic Information, followed by quality assessment consisting of network length comparison, positional, and attribute accuracy during an emergency.

To fulfill the aim, the specific objectives are:

i. To prepare the complete spatial database of Castellon using OpenStreetMap.
ii. To improve the quality of geographic data by creating a mapathon by engaging volunteers.
iii. To undertake spatial data quality assessment of route network by using network length comparison, positional and attribute accuracy.
iv. To create and evaluate the network model to find the fastest and safest route.

1.4 Organization of the thesis

The thesis is divided into 3 segments namely; i) review and selection; ii) study and development; iii) evaluation and analysis. Figure 1 shows the clear structure of the overall methodology.

The first segment consists of the study of the voluntary dataset, data types, various source for spatial data and review of the positive and negative factors associated with it. It also highlights the use and importance of OSM data and discusses the success story of OSM use during a disaster. Additionally, it focuses on various methods used for the quality assessment of spatial data in the literature review section and adopts three kinds of solutions. The research has selected network length comparison, positional and attribute accuracy for this project. Similarly, in this section, the importance of mapathon for validating OSM spatial data is also discussed. Also, four types of network analysis are selected.

The second segment comprises of study and development. During this stage, OSM and its data features are studied, roads features are analyzed, and solely roads accessible by drive are selected, and a network dataset is created. To resolve different kinds of routing problems and meet the research objective, four types of models are created, i.e.; the fastest route to find the closest facility from an incident, fastest route between two or more than two points, location-allocation to locate the features and service area to find the area that a facility can serve in driving time. The models developed are published in the ArcGIS platform. With the tools developed, a web app is configured for evaluation. Additionally, the process of conducting a mapathon is also discussed.

The third segment consists of an evaluation and analysis of the result. It includes a quality evaluation of the OSM data. Three different methods (network length, positional and attribute accuracy) are applied to compare OSM with reference dataset.

The evaluation of the application developed in the project is done through a questionnaire form developed on Google form. The evaluation form consists of visual inspection and technical comparison. The result is driven from the evaluation, then future work and limitation are discussed.

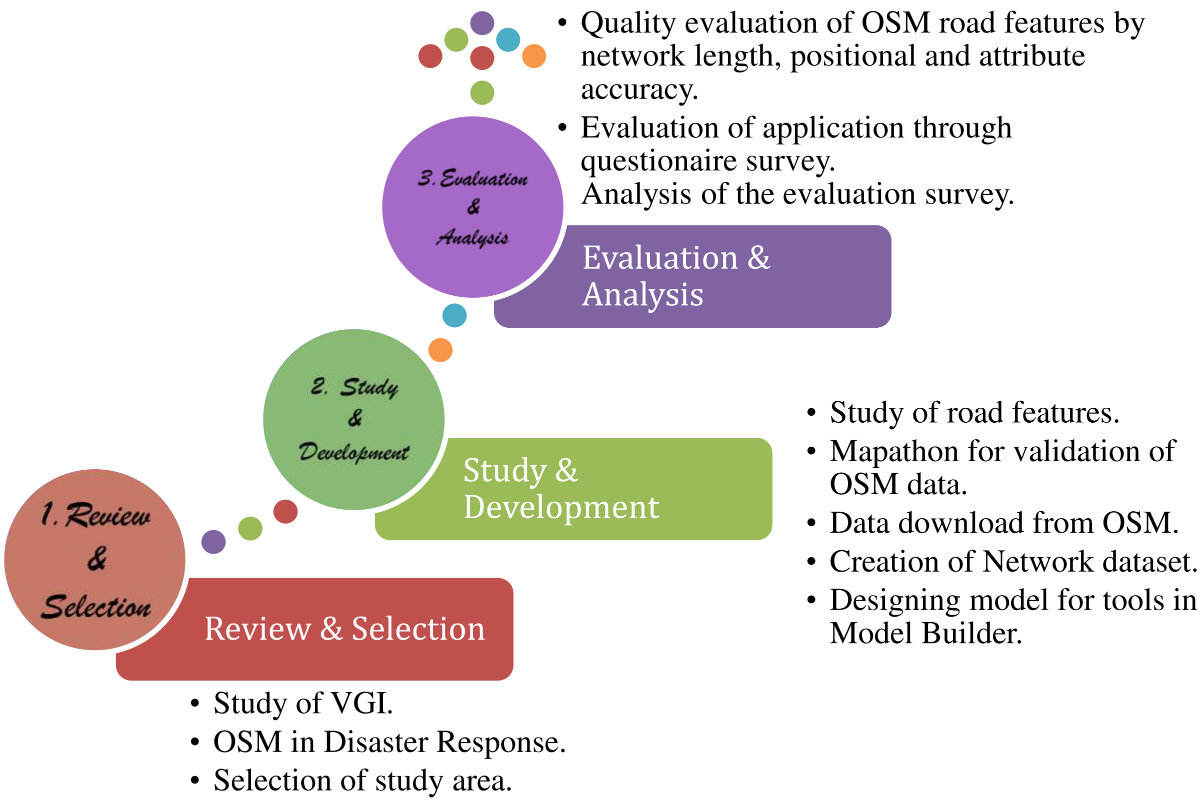

Figure 1: Organization of the thesis

2 LITERATURE REVIEW

This chapter presents the background study about Volunteer Geographic Information and OpenStreetMap and highlighting the importance of disaster response. It also reveals the use of OSM in disaster. Accompanied by a quality comparison of OSM and the importance of data validation through mapathon.

2.1 What is Volunteer Geographic Information?

Since the early days, people have used maps for navigation. National Mapping Authorities (NMA) are the authorized organization to create maps for different purposes. Over the years, NMA is responsible for production, dissemination, and use of the spatial data and are considered as an expert and professionally equipped (Neis et al. 2012; Koukoletsos, 2012). The period of creation of spatial data only by professionals has now changed. The recent technological boom has made spatial data accessible and modifiable by the general public. They can feed information through any GPS devices by identifying locations, verifying other's spatial data etc., technically known as User Generated Content (UGC). The massive use of User Generated Content (UGC) has increased map creation by general people. Easily available location-enabled smartphone has helped to fill up the data in various online web services (Goodchild, 2007).

With the advancement of Web 2.0, people contribution to spatial data has increased (Goodchild, 2007; Haworth, 2016). VGI thus refers to the voluntary creating and sharing of spatial data by the public with a web-supported location-enabled device (Goodchild, 2007). (Antunes et al., 2015) claim that the map produced by volunteer can replace the service provided by professional mapping services (Haworth, 2016; Jiang, 2013). The existing challenges in VGI associated with emergency management are power disruption and inability to efficiently manage the resource and large amounts of instantaneous data (Haworth, 2016).

Several examples exist for various types of VGI projects such as Wikimapia, Mapshare, Google Map Local guides known as Google Mapmaker, OpenStreetMap, and Mapillary. Even if they are voluntary projects, there are several restrictions within these projects, such as restriction for download, data sharing, no global coverage, and compulsion to buy the device or editing service available through the ground. (Haklay et al., 2012) whereas OSM covers the entire world and consists of the global editor where data can be volunteered by people and can be downloaded by anyone irrespective of their previous contribution (Neis et al., 2014; Neis et al., 2010).

2.2 OpenStreetMap

OpenStreetMap (OSM) focus on creating an elaborate representation of earth's surface and is one of the most promising projects for VGI (Helbich et al., 2012) which is updated on an hourly basis by worldwide amateurs, enthusiasts, and professionals (Antunes et al., 2015). Goodchild states" OpenStreetMap is an international effort to create a free source of map data through volunteer effort." With Goodchild, (Koukoletsos et al., 2012) also admit that flexibility of OSM to the users and the advantages of using the data for various purposes has made OSM popular, thus increasing the density of the data, making it more qualitative and vital. OpenStreetMap has been popular especially in developing countries where several map application such as Google Maps are not well equipped and has fewer data. (Coetzee et al., 2018). As well as, it can also be the cheapest option for the creation of geographic data (Goodchild, 2007).

Apart from other VGI platform, contribution in OSM can be done by tracing georeferenced aerial imagery or by actively collecting location of earth feature from GPS-enabled handled device and uploading the information (Budhathoki & Haythornthwaite, 2013; Neis & Zielstra, 2014). OSM has a wide range of aerial images (Bing, ESRI, Digital Globe, and OpenStreetMap) where the spatial data can be traced. Data generated by VGI have been applied on various platforms and projects such as spatial decision-making, navigation applications, participative planning, location-based services, and scientific research (Budhathoki & Haythornthwaite, 2013; Neis et al., 2012). The information exchange system developed with OSM can help to develop an intelligent system to alert people about the precise location and extent of damage, identify escape routes and facilitate the development of mitigation and aid procedures after a disaster (Manfré et al., 2012).

2.3 Disaster and Emergency Management

Disasters are often defined as a dreadful event that devastates the community to act normally. It can be caused by different factors whether it is natural (e.g. flood, drought, landslide, volcano, hurricane, earthquake, winter storm, tsunami) or artificial (e.g. accident, fire), or technological (e.g. chemical spill, computer failure, train derailment, plane crash, power outage, bridge collapse), or social (e.g., riot, terrorism) (Koukoletsos, 2012). Disaster affects our normal life disturbing our whole administrative and operational system leaving a negative impact on our physical, economic and social life by the loss of lives, property, and infrastructure (NRC, 2007). Disaster may vary according to the magnitude, the degree of threat, duration and geographic extent (NRC, 2007). There has been frequent catastrophic disaster terrorizing a larger area at different times (Manfré et al., 2012).

The time immediately after the disaster is called a crucial phase where small efforts can save thousands of lives and property. (NRC, 2007) states that emergency management is the way to organize and manage tasks and resources to cope with all aspects of the disaster. Preparedness, response, recovery, and mitigation are the four phases of emergency management. It may include different institutions, organization or agencies coordinating on some detailed structured plan to respond to the emergency requirements. The availability of well documented geospatial data has a huge impact on the capability and capacity of emergency response and recovery to minimize loss especially in developing countries where the availability of data is limited (Neis et al., 2010; NRC, 2007). Spatial data are important after the occurrence of a disaster to gain the idea about the terrain but are also very important for disaster preparedness and planning. In addition to that, spatial data are equally essential for disaster risk reduction. Proper plan before the occurrence of any disaster is essential every time to fight during a disaster and reduce the loss after the occurrences (Burnham, 2007).

2.4 Related works of VGI in Disaster Response

VGI has also gained popularity for the innovative way to information creating, sharing and application of geospatial data including emergency management (Haworth, 2016). The occurrence of disaster events like typhoons, tsunami, cyclones, flooding, and earthquakes has increased nowadays. These disasters have drawn attention to the importance of spatial data for emergency rescue and response (NRC, 2007).

Goodchild has demonstrated the importance of VGI as an alternate source for wildfire in Santa Barbara, USA. Goodchild emphasized the benefits of VGI in disaster management which includes timely information exchange in the affected areas, real-time data capture without limitation of satellite imagery or weather conditions (Jiang & Thill, 2015). VGI has been applying in different disaster events but, Haiti earthquake 2010 is a prominent example of the use of VGI for emergency management (Neis et al., 2010). Similarly, in Australia, VGI is used to respond to cyclone and floods. In Queensland, 2010/2011 affected citizens and authorities used social media to exchange information and mitigate the misleading information about the event (Jiang & Thill, 2015).

Along with government bodies on the disaster site, several NGOs is helping to recover from the disaster. With that Missing maps and Humanitarian OpenStreetMap Team known as HOT has been assisting for different humanitarian action and community development (https://www.hotosm.org/our-work). It is actively involved in the production and supply of free maps for the provision of humanitarian relief efforts in several parts of the world (Neis & Zielstra, 2014). The working countries of HOT are seen in Figure 2. HOT aims to provide disaster management data and dedicated to sustainable development. The impact areas for HOT include disaster risk reduction, disaster response, poverty eradication, transportation and many more.

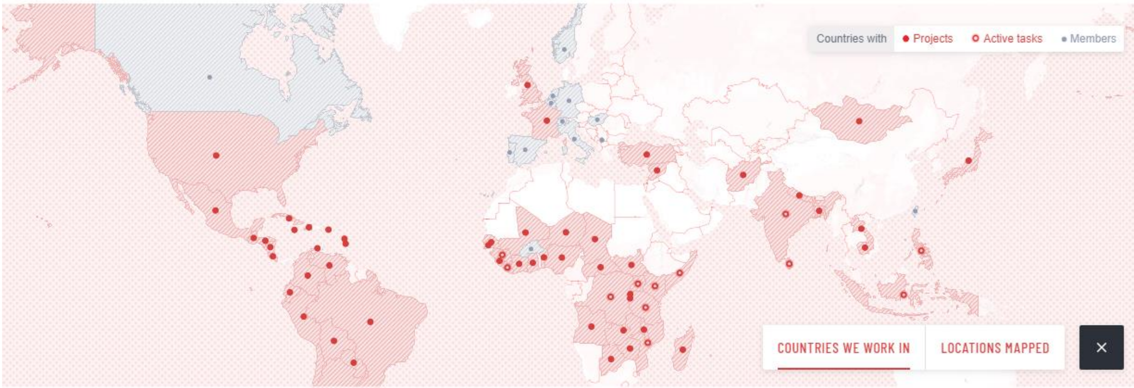

Figure 2: HOT working countries (Source : HOT, n.d.)

(Haworth, 2016) states that VGI is directly beneficial to preparation phase where he highlights the capacity of community member's contribution, data sharing for risk awareness, participation in disaster risk reduction and strengthening connection and providing local contextual knowledge in strategic planning.

2.5 OpenStreetMap in Nepal Earthquake 2015

Although Haiti was a prominent example of OSM popularity, OSM was widely used during the Nepal Earthquake 2015 for resources distribution, rescue operation and damage (Fischer, n.d.). Nepal was hit by a 7.8 magnitude earthquake on 25 April 2015, with another 7.3 magnitude earthquake on 12 May 2015, followed by several aftershocks. The country was shaken and urged for help. There was a huge loss of casualties and damage in infrastructure and people needed help after the earthquake. Spatial data from the affected areas were outdated, and relief distribution was not as easy as expected. There was an information exchange gap between earthquake survivors and volunteers.

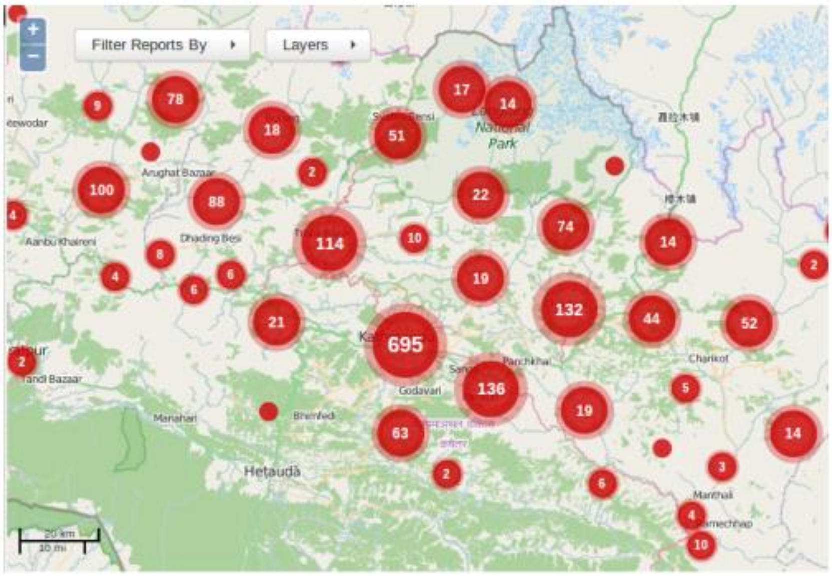

Figure 3: Information gained from various sources about the Nepal earthquake.
(Source: Zielstra & Zipf, 2010)

The local OpenStreetMap community, Kathmandu Living Labs, and HOT brought together people from all over the world and helped to digitize the road network and damaged infrastructure for aid delivery and reconstruction efforts in OSM. Kathmandu Living Labs launched quakemap.org with OSM data for communication between earthquake survivors and volunteers to enable people to report the requirement at their location, verify the requirement and conduct a proper relief operation. Data were collected through crowdsourcing using telecommunications (KLL, n.d.). 5055 mappers made 111,683 edits within the month of the earthquake (Nepal Earthquake,n.d.). The Nepalese Army used OSM as its primary source for search and rescue operations.

Furthermore, the data were used to create an intervention plan and visualization by the United Nations and several individuals (HOT, n.d.). If the emergency route data and facilities were previously mapped during the preparation phase, the process could have saved many injured lives. Figure *3* shows the information collected by various sources during the earthquake.

2.6 Data quality of OSM

Accuracy and precision are the quality measure for the evaluation of spatial data where accuracy is the degree of the content in a map that matches the reference data, but precision is the degree of correctness and measurement of correctness in a geodatabase (Helbich et al., 2013). (Arsanjani et al., 2013) mentions in his paper that the data quality should be characterized according to the data production standard and specification. Features are created in OSM using GPS enabled location device and satellite images. The accuracy of the GPS and satellite images varies according to different types of GPS used the strength of the GPS signal and the location of the GPS. The accuracy of the satellite image varies on the quality of the image.

OSM project does not count into any qualification of users before creating or editing features as it is available to the general public. OSM might claim that it contains up-to-date data, but on another hand, they are built by non-expert volunteers (Antunes et al., 2015). The data created by all users may not be accurate as some volunteer lack spatial ideas for map creation and surveying (Goodchild, 2007; Neis et al., 2012). The combination of this kind of error may lead to unknown quality (Koukoletsos, 2012). Therefore, before using OSM for any purpose, OSM data reliability and credibility need to be studied. Incomplete, wrong and unclear data can result in an incorrect result raising a question for the consequences of the geospatial application. It can directly affect while applying for practical use (Arsanjani et al., 2013). Therefore, the standard of data is extremely important (Haworth & Bruce, 2015).

2.7 Relevant work carried out to compare the accuracy of OSM

Many studies have been carried out to come up with different elements to measure the quality of VGI data. Research has been based on the accuracy between OSM and commercial data providers and national mapping agencies (Haklay et al., 2010). Positional accuracy of OSM was compared with United Kingdom commercial data where (Haklay, 2010) claimed that the accuracy of OSM data is equivalent to the commercial data providers and NMA (Haklay et al., 2010). Similarly, completeness accuracy has been carried out by (Zielstra & Zipf, 2010) for the dataset of Germany. Both results concluded that the data are similar to professional data providers (Helbich et al., 2012). It also resulted that the OSM coverage is higher in urban areas compared to rural areas (Neis et al., 2012). But a study performed in San Francisco, US 2011 shows that the rural area has a high density of data than in urban areas (Neis et al., 2012). Similarly, routing activities were carried out where all the routing request could not be completed due to the topological errors presented in OSM (Neis et al., 2012). Additionally, researchers focused on the quality comparison with machine learning techniques, integration of elevation data which resulted that the accuracy is higher according to the volume of the data.

In 2011, OSM was compared in Germany with TomTom a navigation service provider, where OSM did not contain 9 percent of data for driving whereas, for general roads, OSM consisted of 27 percent additional data than TomTom. Preliminary studies show that the data are not adequate, but now it appears that OSM is comparable in terms of other data sources according to the location and availability (Neis et al., 2012). According to OSM's trend, it also shows that the addition of data is rapid, but the error also increases with the volume of data. However, proper actions can be taken to minimize errors.

2.8 OSM Data Comparison

Quality comparison factors include lineage, positional accuracy, attribute accuracy, logical consistency, completeness, temporal quality, usage limitations, variation in quality and resolution. However, ISO 19157 (ISO, 2013) has introduced a new standard to measure for VGI (Antoniou & Skopeliti, 2015). ISO has defined six elements for quality elements: i) completeness; ii) logical consistency; iii) positional accuracy; iv) temporal quality; v) thematic accuracy; vi) usability. A reference data is required to compare OSM data according to the standard developed by ISO. Although spatial data are not hundred percent accurate, the comparison is made considering that the reference data have accepted quality and prepared with high standards. Among OSM data features, the road network is one of the most important features. In terms of quality measure, positional and completeness accuracy is the most popular (Arsanjani et al., 2013). The components described below mentions issues for assuring data quality.

2.8.1 Completeness

In relation to the reference data, different research has been conducted out to compare the completeness of the data by measuring the number of features, feature-length, feature area, completeness measurement, and completeness index. Commission and omission are measured where omission refers to the missing data in the VGI, whereas the commission refers to the additional data. (Koukoletsos, 2012). Founder of OSM Steve Coast states that completeness is an important factor to be considered to measure the usability of OSM (M. Haklay, 2010). In order to measure the usability of OSM in our research, network length comparison is applied similarly to the study done by (Graser et al., 2014).

2.8.2 Logical consistency

Logical consistency is measured by the consistency of the database with other databases, whether they belong to the same theme or another theme. Hierarchy and outliers are identified in the database as well as identification of classification and topological relationship and consistency is examined by different spatial similarity and mathematical techniques (Antoniou & Skopeliti, 2015). (Koukoletsos, 2012) emphasizes that logical consistency consists of topological, temporal and thematic consistency. However, (Coote & Rackham, 2008) disagrees that the measurement can only be carried out conceptually but is pretty hard for implementing in VGI due to lack of information regarding the specification and standard (Arsanjani et al., 2013; Koukoletsos, 2012). (Koukoletsos, 2012) also states that topology consists of a set of rules and has spatial relations with the objects in the dataset. It holds diverse elements like geometry, data integrity rules, spatial analysis, refined editing and more. As the limitation to measuring logical consistency the same condition applies to topology. Thus, it is not feasible to consider for quality assurance of VGI.

2.8.3 Positional Accuracy

Positional accuracy is one of the renowned accuracy assessment. Data quality can be measured using a higher quality reference dataset where the position of reference data is assumed to be precise (Fonte et al., 2017). The purpose of testing the usability of VGI for various purposes is to assess the positional accuracy of the data (Helbich et al., 2012). As described in 2.6 about the accuracy dependence of VGI with GPS and satellite image, the recent technological changes have increased the positional accuracy of VGI (Fonte et al., 2017). Several studies have been conducted to compare the positional accuracy (Antunes et al., 2015) of OSM with authorities dataset. However, (Antunes et al., 2015) have compared OSM data with authoritative dataset and vice versa reasoning that OSM may contain up-to-date data than authoritative data. Therefore, in this research, both OSM and reference dataset positional accuracy is carried out.

2.8.4 Temporal Accuracy

Temporary accuracy takes into account the evolution of the VGI data at a different time. Although changes in OSM can be observed at a different interval, (Coote & Rackham, 2008) claim that this method is not very useful for the quality assessment of VGI. Therefore, temporal accuracy is not measured in this research.

2.8.5 Thematic Accuracy

The thematic accuracy is measured by the percentage of specific tags correctly classified i.e.; attribute information. Users are fascinated to collect roads and buildings features as it is visually seen in the map, whereas collecting attribute information may not be as satisfactory (Neis & Zielstra, 2014). Completeness can provide an answer about the feature's existence, but information about the attribute may be lacking (Koukoletsos, 2012). Since road information is important while navigating during a disaster, attribute accuracy assessment of road name is carried out in this research

2.8.6 Usability

Usability is the most appropriate quality measure for VGI as it is based on user requirements and it evaluated by all quality elements mentioned before. Generally, VGI data does not focus on any specific purpose during creation. So, usability can be a good measure to compare the usability of VGI data for a specific purpose.(Antoniou & Skopeliti, 2015). Whereas (Coetzee et al., 2018) claims that among all quality elements, usability is one of the toughest to validate automatically due to a specific user requirement. Additionally, (Antoniou & Skopeliti, 2015) also mention that usability is similar to VGI theme fit for use.

Though ISO has defined its data quality elements, all of the factors are not needed for the quality comparison but are being used according to the need (Arsanjani et al., 2013). Therefore, network-length, attribute accuracy of road names and positional accuracy is selected and assessed in this research.

2.9 Data Editing and Validation/ Mapathon

Mapathon can be used as one of the measures for data addition and data validation while questioning the quality of VGI data. Generally, mapathon (literally "map marathon") takes place in a specific location where users meet in the community, interact with each other, share their experiences and utilize their time mapping and exploring the area fulfilling community needs (Budhathoki & Haythornthwaite, 2013; Coetzee et al., 2018). The purpose of a mapathon is diverse for different purposes and processes. Mapathon was popularly known as mapping party mostly to add missing data, aids to create new users and contributors to the community to encourage mapping and serving for the project. With the positive impact of the mapathon, several questions arise about its productivity, quality, and impact on open map data and influence on the mapathon participants (Coetzee et al., 2018). (López, et al., 2014) claims that local users add local content and verify existing data, which plays as an important part in the validation process. They also suggest that local citizen's enthusiasm can be used to address the local problem which is costly or cannot be done alone by the government especially during a disaster. As well as (Haklay et al., 2010) suggests that VGI needs to be approached as heterogeneous datasets that must be evaluated locally and not globally.

2.10 Road and Network

Right, and quick information plays a vital role in an emergency. Rescuers rely on the information for rescue and evacuation after a disaster (Hu & Janowicz, 2015). Roads are an important navigational factor and can be observed visually and used to design rescue routes (Fiedrich et al., 2018). The actual up-to-date condition of the road with hindrance and danger areas is very helpful while planning humanitarian operation (Neis et al., 2010). Up-to-date road information would lead to the right resources at the right time rather than trial and error at a crucial stage (NRC, 2007). Moreover, roads are also used for resource distribution and accessing emergency facilities

According to the rapid changes going in the ground and the amount of speed and volume of the data being updated, planning rescue operation by manual and visual interpretation of data is quite challenging. Therefore to solve the network problems according to the data available, a network dataset is needed with proper tools developed.

2.11 Spatial Network

A spatial network is defined as a network of spatial elements made by interconnecting curves, polylines appearing in the geographic application. The network is used in our daily lives whether it is a transport network such as roads, railways, the supply of resources and energy, the distribution of goods and services (Martí, 2013).

Geodatabase consists of two types of models: network data for undirected, and geometric for directed. Transport networks fall into the undirected flow, while utility networks and river networks fall into a directed flow (geometric dataset). Network dataset comprised of the transportation network. The transport network is created by lines and points that take into account important features such as a junction, turns, and barriers. Here, a network dataset is created to solve network problems during a disaster.

3 RESEARCH METHODOLOGY

This chapter presents the method carried out in the research. This chapter is divided into sub-parts where it discusses the selection of the study area and resources used, Starting from OSM data preparation till creating network dataset and designing the tools to configure in the web application is described. Similarly, it also includes the detail of the mapathon event organized for data validation.

3.1 Overview

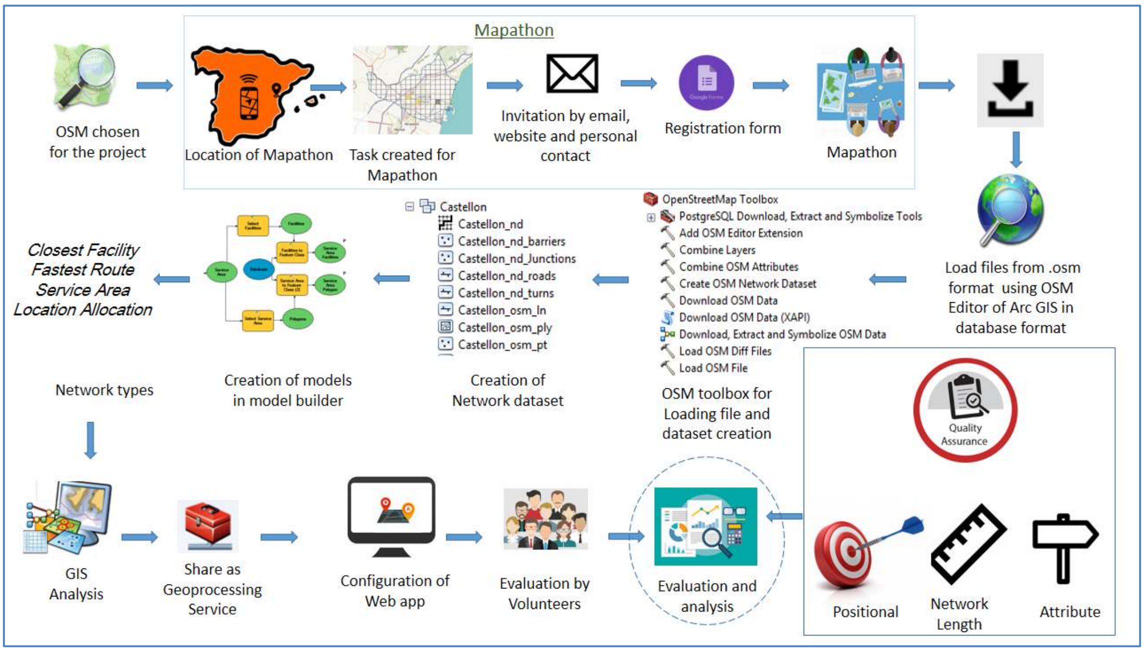

Figure 4: Methodology of the thesis

Maps have been popular from the early days for navigation purpose. In the present condition, there are numerous sources for map creation. This study focuses on VGI especially OSM for solving network problems. The study area for the project is Castellon municipality where emergency facilities are highlighted to locate the safest and fastest route during a disaster. The preliminary idea of this study is to create a web application to acquire a smooth network in Castellon, using OSM data. Spatial data is retrieved from OSM. Adding and evaluating the OSM data is done by organizing a mapathon. Participants of the mapathon are international masters and exchange students from UJI. Afterward, with validated OSM data from mapathon, network dataset is formed followed by the creation of network tools for navigation. Web application 'Castellon - A step towards Preparedness' is developed.

Three types of quality evaluation of the OSM are carried out in comparison to reference dataset for assurance of the data during an emergency condition. An approach is defined to evaluate the application developed from the project through a questionnaire survey and the result obtained from the survey is used for the assessment. The evaluation response is carried out with the residents and non-residents of Castellon. Through the evaluation response and the quality assessment of the OSM with reference data, results are retrieved.

3.2 Study Area

Figure 5: Study Area

The study area of the research is Castellon municipality, the capital of the province of Castellon in the Valencian Community, Spain, located on the Mediterranean coast, 65km north of Valencia and 150km south of Barcelona. The Desert de las Palmas mountain range rises lies in the north. Also, Prime meridian crosses through Castellon. The total area covered by Castellon is 108.78 km^2 (42.00 sq. mi) and the elevation range from 0 to 609m. Castellon is a quite small city with a population of 171,669 and density of 1600/km^2. The inhabitants depend upon tourism and industries.

3.2.1 Transportation in Castellon

According to the Ajuntament de Castellon, there are 12 urban bus lines and eco-friendly trams, as well as a bike rental facility called "bicicas". Although Castellon is a small town, taxi services are readily available for city travel or long distances from the area. Surrounding municipalities can be reached using intercity buses which are easily accessible. Trains are also available to the surrounding municipalities.

3.2.2 Available emergency services

There are more than six hospitals located in the study area. There are hospitals with 24-hour emergency service, whereas some hospital has dedicated service time. Hospital la Magdalena, Hospital General University de Castellon, Hospital Provincial Centre de Castellon, Hospital Rey Don Jaime are the four biggest hospitals which are open 24 hours and have emergency facilities. Hospital Unión Mutuas Castellon, Mental Health Center, and Institute of Traumatology - Union of Mutual Societies are the one with dedicated service time. Similarly, there are two police station Policía Local de Castellón and Comisaría de Policía. Castellon also has fire service for rescue and salvage in case of fire. Additionally, Castellon has a Civil Protection Bureau provides emergency planning and management services, citizen and corporate self - protection supervision and the promotion of voluntary civil protection (Castellon, n.d.).

3.2.3 History of disaster in Castellon

According to the disaster documented in Desinventar website (https://www.desinventar.net/) 14, natural disaster incident has occurred in Castellon till date, consisting of 13 events of flood and one storm. According to the records, in 1994, 234 houses were damaged, and during the flood of 2000, 10 people were evacuated. Four deaths and four injuries were registered in those 14 events. Table 1 shows the statistics for catastrophe events. Although the occurrence of a disaster in Castellon is rare, Castellon is selected for the study as a proxy indicator to other disaster-prone areas.

With these incidents registered in the Desinventar website, Castellon activated its first territorial emergency plan on October 2018 to address the warning of the risk of intense rain. Ajuntament de Castellon brought together the municipal operative coordination center, the political and technical coordination committee for an emergency. More than 140 local police and firefighters were mobilized to ensure citizens security. Following the prediction of heavy rain and storm, preparedness plan was developed where essential equipment such as pumping stations, generators, bomber equipment as well as irrigation channels, floodgates, etc. was checked. The signaling and marking elements needed to signal and mark the conflicting points or roads, underground passages and some roads in the city were made ready.

Event	Location	Date (YMD)	Data Cards	Houses Damaged	Evacuated	Death	Injured	With Houses Affected
Flood	Castellón	1581/08/29	1					
Flood	Castellón	1581/09/16	1					1
Flood	Castellón	1597/00/00	1					1
Flood	Castellón	1700/00/00	1					1
Flood	Castellón	1783/11/24	1			1	1	
Flood	Castellón	1787/10/08	1			1	1	1
Flood	Castellón	1790/00/00	1			1	1	
Flood	Castellón	1801/11/17	1					1
Flood	Castellón	1883/10/09	1			1	1	1
Flood	Castellón	1994/10/09	1	234				1
Flood	Castellón	2000/10/20	1		10			
Flood	Castellón	2005/11/14	1					
Flood	Castellón	2009/09/25	1					1
Storm	Castellón	2004/09/01	1					
Total			14	234	10	4	4	8

Table 1: Disaster registered in Desinventar website. (Source: Desinventar)

Although natural disasters are less likely to occur in Castellon, there are always chances for human-made disasters. Ajuntament de Castellon is quite aware and prepared for the risk that can happen. It recently launched a road safety campaign called **Al Volant, zero alcohol** during Christmas where citizens were made alert to leave their car in the parking to avoid serious consequences. In addition to that, for road safety, it has started a pilot test for intelligent lightning for pedestrians to improve safety. When there is the presence of pedestrians and cyclist, this technology, combines LEDs with motion detectors and permits to intensify the lighting in such a way that it improves its visibility as well as anticipating its presence to the drivers.

3.3 Resources and Technologies

3.3.1 Data

The data used in this project is OpenStreetMap. According to the advancement of VGI in the community and the data volume of OSM, OSM data is used for the route network (Budhathoki & Haythornthwaite, 2013; Goodchild, 2007). Detail description of the OSM structure is explained in section 3.4.1. Data were retrieved from Planet.osm using BBike (https://extract.bbbike.org/). As reference data for OSM quality comparison, the TomTom data shared by ESRI is used.

3.3.2 Software

All the data is processed in ArcGIS 10.6 desktop version with the extension of network analyst and a special extension of OSM, specially dedicated for the access, edition, and analysis of OSM data. This extension is used for accessing the OSM data in a geodatabase format and further geoprocessing analysis is done such as creating network dataset. Other tools such as spatial analyst, data management are also used in the project.

3.3.3 Web application

With the standard license of ArcGIS Online account, Web application 'Castellon - A step towards Preparedness' is built using Web App builder configuring the template with custom settings and displays. The detailed procedure applied to develop the app is described in 3.9.

3.4 Data Preparation

3.4.1 OpenStreetMap feature

OpenStreetMap represents features in the ground using nodes, ways, and relation. OSM describes the OSM feature in different tags, where tags give us all the information about the specific nodes or ways. For example one of the tags for the line is a highway where a highway can be tertiary or pedestrian. Generally, highways can come up with a secondary tag specifying type or attribute of the road like name, number of lanes, access, service, and one way. Whenever a feature is created in OSM, it is described with a tag. There are several inbuilt tags in OSM to categorize the data. The tag knows as primary feature includes aerialway, aeroway, amenity, barrier, boundary, building, emergency, highway etc. while secondary tag values are included inside these tags. OSM also has an option to create a new tag which can be verified later.

Although OSM has an enormous amount of spatial data, there are no specific strict rules or quality control to keep a feature on a specific tag or feature dataset. Due to the flexible nature, classification of OSM data can be quite challenging while applying in a project (Ramm, 2015). Taking this into consideration, (Ramm, 2015) came up with a specific format where OSM data classification can be applied. The classification of the road will further be discussed in the following section and used for quality evaluation at the end of the project.

In this project, a special extension of OSM in ArcGIS named as OpenStreetMap toolbox is used. This toolbox lets OSM data download into three types of feature i.e.; point, lines, and polygons. The main target of this research is to create a route network. Therefore, special observation is carried out for the line feature. The important attributes in the line feature are highway, natural, waterway, amenity, railway, power, barriers, osmid, osmuser, max speed, max speed forward, and name.

3.4.2 Road classification of OSM highway used for this study

Major roads		
1	Motorway	Motorway
2	Trunk	Significant roads, usually divided
3	Primary	Primary roads, usually national
4	Secondary	Secondary roads, usually regional
5	Tertiary	One of the important road in the country which links smaller town and villages, tertiary roads, usually local
Minor Road		
6	Unclassified	Smaller local roads
7	Residential	Roads in residential areas
8	Living_street	Streets with priority for pedestrians over cars
Highway Links		
9	Motorway_link	Roads that connect one route to the same or lesser route
10	Trunk_link	
11	Primary_link	
12	Secondary_link	
13	Tertiary_link	

Table 2: Road Classification (Source: Ramm, 2015)

As mentioned earlier, the road feature is OSM are tagged as a highway. According to the nature of road features, roads are classified above with reference to (Ramm, 2015). Several types of roads exist in the real ground but the roads used for the study are only displayed in Table 2.

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3.5 Mapathon

OSM has collected an enormous amount of data and its growing every day. OSM consists of flexibility in data editing which has made OSM data richer (Ramm, 2015). As the feature on the ground continues to change and OSM data is created by volunteers, there is no guarantee that OSM is complete. After visually interpreting the data of Castellon and regarding the importance of data validation by local people in OSM, a mapping party named 'Make Castellon Data Better' was organized on the special day of World GIS Day, 2018 at University Jaume I. Generally, mapathon is an event where volunteers come to a fixed place and map the area around. There is not any standard way to conduct mapathon. The mapathon depends entirely on the purpose, the experience of attendees and time conducted (Coetzee et al., 2018). Our mapathon was planned so that volunteers can contribute to the betterment of OSM data in Castellon. The aim of the mapathon was to validate OpenStreetMap road features of Castellon municipality and mark important features needed during or after a disaster. The steps followed in the mapathon are described below:

3.5.1 Mapathon Preparation

The preparation of mapathon was done with the help of missing maps (Missing Maps, n.d.) guidelines. A checklist was prepared, and the preparation of mapathon was divided into four main tasks. Firstly, to locate the venue and time for the mapathon. Secondly, to invite students to mapathon, thirdly, to create a task of Castellon in tasking manager to map efficiently. Lastly, to plan for successful execution of the mapathon to populate and validate OSM data and encourage participants to contribute to OSM in the future.

After several discussion, the venue for the mapathon was fixed on Information and Mathematics building first-floor room no TI1021SM, University Jaume I on 14th November 2018. The time for mapathon was fixed from 10:00 -11:30 with a short introduction and mapping session. Students were invited to join the mapathon in several ways. Volunteers were invited by email, personal contact, and open call through Geotech website (http://geotec.uji.es/Castellon-mapathon-2018/). Mapathon was planned considering the participation of students from UJI especially Masters in Geospatial Technologies.

Task named ‘UJI Castellon Mapathon GIS day 2018’ was generated with the tasking manager for the smooth functioning of the mapathon which can be found in https://tasks.klldev.org/project/43. A task was developed to coordinate the joint mapping by participants so that many volunteers can contribute to the same area at the same time. The study area i.e. Castellon municipality was divided into grids to skip redundant editing issues.

Volunteers were requested to register themselves in the registration form attached to the invitation email. The registration form was designed to estimate the number of volunteers during the mapping campaign. As well as additional information regarding the volunteer knowledge on OSM, OSM contribution experience, and their preferred area in Castellon were acquired. The registration form is provided in Annex I. One day before the event, one more email with general information about the event was sent to registered volunteers as a little reminder. In addition, brief introductory videos such as the significance of maps during a disaster, ways to add and validate maps to familiarize participants with the mapathon were provided. Volunteers were also requested to create an OSM account before the mapathon. Since the mapathon was located in a university lecture room without computers, all the participants were requested to bring their own laptop.

3.5.2 Mapathon Day

On 14th November, mapathon was conducted with a total number of 20 enthusiastic volunteers. A quick introductory presentation was given regarding OSM, event procedure and steps to follow during the mapathon. The presentation was focused on the ways to edit and validate the OSM data in the task created in the tasking manager using the ID editor. It mostly focused on creating and validating features needed during a disaster, for example, emergency services i.e. hospitals, important road features turn, one way etc. Afterward, participants were invited to map and ask for assistance, if needed.

Volunteers were suggested to choose their own specific grid created in task manager and work on their specific grid. After mapping the selected grid, volunteers were requested to signify the grid they worked on as mapped and leave for validation. All the changeset was marked with a unique id called #CastellonMapping whenever some edits were completed. Volunteers contributed to OSM of Castellon for one hour. Volunteers were encouraged to contribute and the real-time result was displayed using Show me the way (https://osmlab.github.io/show-me-the-way/), an application to see the real-time contribution in OSM. The changes done during the mapathon were seen through OSMCha (https://osmcha.mapbox.com/), an application to view the changes by any specific users applying various filters such as date, time, location etc. and OSM Kartoza (http://osm.kartoza.com/) using filters like mapping date and categories. Throughout the mapathon, volunteers had a comparison of their contribution using OSMfight (http://osmfight.neis-one.org/) tool which made the mapathon more entertaining and competitive. Figure *6* shows the activity of the mapathon using the tool mentioned above.

Figure 6: A: OSM fight between two volunteers. B: Screenshot of the changes during the mapathon. C: Building contributors in Castellon area. D: The area for the mapathon with highway contributor’s chart.

Mapathon was completed by acknowledging all the participants and encouraging to contribute in OSM in upcoming days as well as stressing the importance of maps during a disaster. All the participants were delighted to contribute to the mapathon. The mapathon was ended by taking a group picture and with some cookies. The mapathon event was published in Master Geotech website of Masters of Science in Geospatial Technologies and Geotec website of UJI which can be found in Annex II and Annex III respectively.

Figure 7: Pictures captured during and after the completion of mapathon.

3.5.3 Outcomes of the Mapathon

Most of the volunteers participated in the mapathon were students of Erasmus Mundus Master in Geospatial Technologies and all of them had experience of using maps. Volunteers consisted of twenty individuals from thirteen different countries who stayed in Castellon from two months to one-year contribution and experience with GI from less than one year to eight years. Out of 20 participants, everyone had an idea of OSM and four of them had experience in OSM. The information about the volunteer's nationality and OSM contribution are shown in Figure 8.

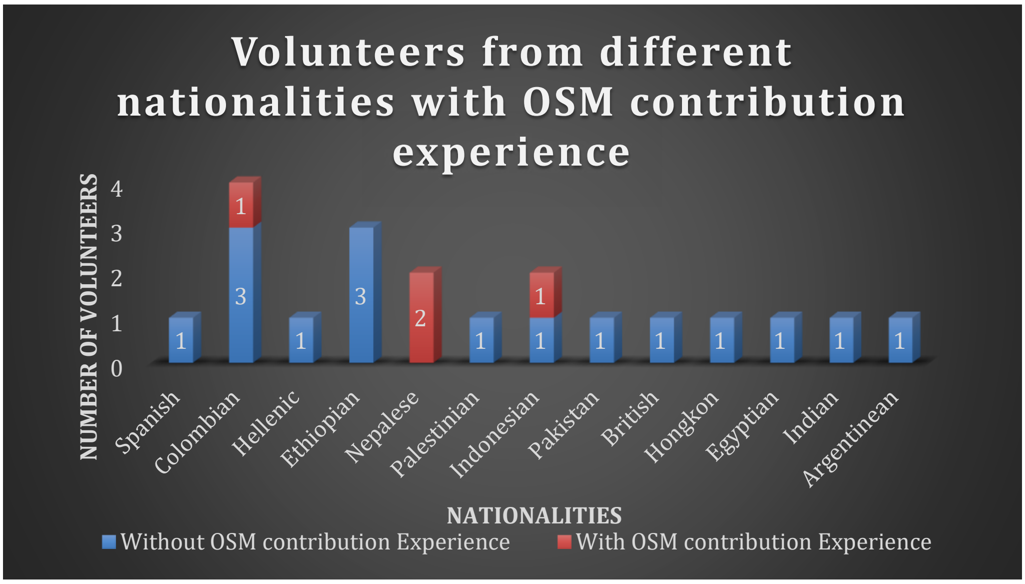


Figure 8: Volunteers from different nationalities with OSM contribution experience.

Similarly, Figure *9* shows the experience of the volunteers in the GI field. Among the volunteers, the number of female participants was 25 percent. Castellon's OpenStreetMap consists of a large amount of data, but it consists of several missing features and errors, so validating the data was an important step. Therefore, mapathon was organized so that the volunteers can use their local knowledge and validate the area around them.

Figure 9: Number of volunteers with GI Experience.

Out of twenty volunteers, most of them were new to the city. Although being new to the city, there was a significant contribution to mapping bicycles tracks and university areas. Volunteers also mapped the area around their residence and famous areas of Castellon such as Park Ribalta, Grau and the city center. As the task was to validate line features especially road, there were some significant results in road turn and one-way restrictions resulting in an increase in OSM accuracy.

During the mapathon, volunteers made two hundred three edits in that defined period where it consisted of forty-three new buildings, point features, and line features. Although all of the volunteers were from the geospatial background, 73 percent of volunteers were new contributors to OSM. The data generated by the volunteers consisted of some errors, while the data created and validated by the experienced volunteers were more qualitative and reliable. It shows that experienced contributors produce qualitative results. Through the result obtained, it depicts that the data produced during the mapathon has a healthy balance on efficiency and quality while more emphasis should be given to volunteer engagement, enthusiasm, and attitude to contribute to making the society secure. Additionally, volunteers also had the opportunity to experience open source data capture tools.

Several questions appear after conducting mapathon such as the impact of mapathon on the volume of the data, area, quality and feature mapped (Coetzee et al., 2018). There are a handful of positive results drawn from the mapathon. Firstly, the results generated by the contribution of the volunteers while validating the data for productivity and quality. Secondly, the huge impact of mapathon on the volunteers making them aware of the impact of a qualitative map for a humanitarian purpose. Finally, the mapathon also highlighted the importance of mapathon institutionally and plan to conduct mapathon in the upcoming days.

3.6 Data download and its features

The data feature of OSM and the attributes related to the road are described above in 3.4.2. As mentioned above, OSM toolbox of ArcGIS was used to create a Network dataset. *Download extract and Symbolize OSM Data* in OSM toolbox were restricted to the number of nodes to download, so the data was downloaded from BBBike.org in ".osm" format and loaded using *Load OSM Files* tool. The *Load OSM Files* tool generates three layers i.e.; point, line, and polygon translated from the node and ways of the OSM notation. It also generates two tables for relation and revision with an osm_ prefix.

Due to the flexible nature of OSM data with its key value as an attribute table, it is quite challenging to present in the normalized way of a relational database (Github, n.d.). OSM stores all features as a point, line, and polygon. The research aims to create a network dataset from OSM data, therefore line features are taken into consideration. After downloading and creating a database, the dataset is projected into WGS 1984 UTM zone 32N.

3.7 Creating OSM Network Dataset

Network dataset is created with the tool *Create Network Dataset* extension from OSM Editor with the network configuration files for driving. Considering a disaster scenario, only drive access roads are selected. The tool generates 4 feature classes named as **barriers, junction, roads, turns,** and a **network dataset** as shown in Figure 10**.** Line features downloaded from OSM are filtered and the feature class named Castellon is formed. Unnecessary data required to create network dataset are neglected. Line like power, railway, manmade, waterway, barrier, amenity, natural, administrative boundary are eliminated and hence network dataset is created.

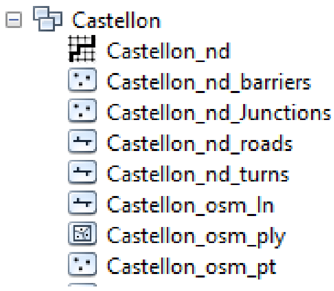


Figure 10: Network Data created using "Create Network Dataset" in ArcMap.

Castellon municipality road features for driving consists of motorway, trunk, primary, secondary, tertiary, unclassified, residential, living_street, motorway_link, primary_link, secondary_link, tertiary_link, and trunk_link. Whereas secondary tag like one way, number of lanes, name, access, service, max speed are included to give more detail about the road during network analysis. Turn developed in the network dataset consists of no, no left turn, no right turn, no straight on, and no u-turn.

3.7.1 Special features of the Network dataset

The information obtained after creating a network dataset from open street toolbox is used to create the following feature class schema:

Field Name	Alias	Type	Description
Object id		ObjectId	It is the unique id that identifies the row.
Shape		Polyline	It defines the geometry of the feature.
Road class	Road Class	String	It clarifies the type of road. e.g. primary, secondary, trunk etc.
Road name	Full street name	String	The full street name, such as “Calle Vall d' Alba”. It is used for driving direction and used for attribute analysis in the project as well.
Road status	Road status	String	It gives us information about the status of the road. E.g. normal, under construction or damaged.
Oneway	One way indicator	String	It defines whether the street is one-way or both way. This feature is used to define the behavior of the one-way restriction attribute in the network dataset.
Lanes	No of lanes	Short	It gives us information about the number of lanes on the road.
Max speed	Maximum speed	String	It gives us information about the max speed assigned to the road. E.g. any positive integer 20, 50, 200 etc.
Turn	Turn restrictions	String	It states if any restriction exists in the road like no-left-turn, no right turn etc.
Service		String	It gives us the information about the information or restriction on the road like parking aisle, driveway etc.

Table 3: Necessary tags for roads.

3.8 Design of the model for Network Analysis

After the creation of network dataset, it is further used for network analysis to find the fastest route to the facility, fastest route or to locate service area. Network analysis is done with the help of network analyst tools available in ArcMap. Different kind of analysis is built using a model builder in ArcMap. Model builder supports editing, generating and handling tools in ArcMap and is also called as visual language programming for the construction of workflows (Schröder, n.d.).

Models are workflows that feed the tool's output of one tool as an input to another tool to make a sequence of geoprocessing tools (Martí, 2013). Model is created for each type to automate the process so that it can be further used to create a geoprocessing service. It can be used to build the workflow of a scheduled task to be performed. It helps to automatize the work and aid for sharing the workflow with others as a geoprocessing package. The aim of the project is to create a spatial network of Castellon for preparedness plan during a disaster and deploy as a web application. Therefore, network analyst tools from the ArcToolbox are used for the development of the models. Four different models are created to solve problems in a different environment for further analysis.

i. The fastest route to find the closest emergency services.
ii. The fastest path to find the fastest path between two or more than two points.
iii. Service area to discover the service area around the location in the network.
iv. Location-allocation to find a new location for a campsite during an emergency.

3.8.1 Fastest route for the emergency services

The aim of the model is based on the closest facility, where users can find their closest emergency services such as hospital, police, doctors, fire station, clinic, town hall, shelter, pharmacy, dentist within Castellon, from any specified location of Castellon. It also allows users to select their own location for an incident where they can search for the specified emergency facility, number of facilities to find and the direction towards or from a facility. Special parameters have been configured in this model such as drive time as impedance cost attribute.

The selection of facility type by users is achieved by following the next step. A new variable as a string, featured as an amenity, *Merge, Make feature Layer*, *and Select*

Layer by Attribute tools are required for this operation. Since features in the ground are represented by points, lines, and polygons in OSM. Some facilities are represented as polygons. Therefore, polygons are converted into point features using *Feature to Point* tool and merged with the point features using the *merge* tool. Then, the string variable called 'Amenity' is created and a standard emergency facility type is listed on it as 'hospital, police, fire-station. Then for the string variable amenity, the parameter is configured as a value list where emergency facilities are listed. The result leads to a dropdown facility to be selected by the users. Then the layer is converted into a feature layer to execute *Select Layer by Attribute* tool. This tool uses the parameter list in amenity and returns a SQL expression. It runs a spatial query where the service that users want can be chosen. The facility is selected in the SQL expression and the facility layer is added to the model using the *Add Location* tool. Example. If a user wants to find the nearest hospital then, the user can select a hospital from the drop-down list and the location of the hospital is added.

One of the important tool in this model is the *Add Location tool*. Users can add the incident location using the Add location tool. This tool enables the users to add a location by clicking anywhere on the map. It also allows users to search for different kinds of emergency services. Assuming emergency during a disaster, several barriers may arise in a different location. This model also permits to add barriers to the network if there are any. Users can add barriers to the network using the *Add location tool*. Hence, the model is ready to find the fastest route to the facilities skipping the barrier along the route. Different factors are considered in the roads such as turns, one way and the speed limit of the road to execute the model to find the shortest route. A solve tool is executed where it generates the fastest route, emergency facilities, and location of the incident with direction information to the services. The workflow of the closest facility model is presented in Annex IV.

3.8.2 Fastest Route

The main aim of the model is to determine the fastest path between two or more points. Here the users can select the location he/she wants to go whether passing by the hospital or any parks or any location within Castellon which is named as stops in the model.

In this model, users can select stops for the route and barriers that exist as parameters. A feature set is created allowing users to add points as input for the incidents entered by the tool *Add Location*. This tool enables the users to add stops in a subsequent route which can be done by clicking anywhere on the map. Barriers are also created similar to stops. i.e.; creating a feature set where polygons can be drawn in the map by users and loaded as input in the network. After adding stops and barriers, solve tool is used to resolve the network which results in the final route layer, the stops, and direction. The final route displays the fastest route to the stops passing by, considering U-turn, direction on the road, the speed of the road. It also avoids the barrier located on the road. The direction tool is also executed which gives the direction in an XML file with the route direction information and saved in a directory. It is helpful to navigate in the route especially to apply in web and mobile to give directions. The workflow of the fastest path model is presented in Annex V.

3.8.3 Service Area

Service area is the area that incorporates all available roads from any specified location that is within a specified distance in the network (Kermanshah & Derrible, 2016). This main objective of this model is to calculate the area covered by an emergency facility with accessible streets within a specified impedance (time or length) around Castellon. It can be used to identify the number of facilities, population, area or any information within the region calculated (Martí, 2013). In the model developed for this project, users can select the service area from different emergency facilities with different impedance.

In this model, users can select facilities to define the service area and drive time as the impedance attribute as parameters. One-way is selected and U-Turns restriction is allowed on the restriction section. While hierarchy is not used. Similar to the model generated for the closest facility, a string value named as Amenity is developed and the model parameter is created where the emergency facility hospital, police, fire station, clinic, town hall, shelter, dentist, and pharmacy are listed as value. *Selection by Attributes* tool is executed where users can select the facilities from the drop-down menu. The model is developed by keeping in break values as parameter. Hence, users can select one or more default break values to obtain corresponding polygons from the selected facility. E.g. 5, 10, 15 drive time. The workflow of the service area model is presented in Annex VI.

3.8.4 Location-Allocation

The main motive of the model is to analyze the best facility to be chosen from the demand points input given by users. This model helps us to discover the facility which serves the best to the given demand point. It can also be used in a scenario where some services or facilities are shut down during disaster or emergency and helps to find out which facility can serve those demand points. Users can input demand points, facility type, a number of facilities and direction as parameters to execute the model.

Similarly, as other models described above, two feature sets are created to input the demand points and barriers respectively where the users can click anywhere on the map as the input for demand points and barrier. In addition, a string value is created with specified facilities (police, hospital, doctor, pharmacy, clinic, fire station) where the facilities can be chosen by *Select by Attributes* tool. Users can select the number of facilities and the direction they want. The workflow of the location-allocation is presented in Annex VII.

3.9 Publishing Geoprocessing Services

The main target of the project is to develop a web application to solve network problems. Therefore models are created in the model builder and shared as a geoprocessing service. Geoprocessing service is the way to represent powerful analytic abilities of ArcGIS to world-wide-web (ESRI, n.d.-b). Geoprocessing service consists of a geoprocessing task. Task are characterized as web-based API or tools which runs on a server and returns results which are processed by a server (ESRI, n.d.-b). In order to publish the model as a geoprocessing service and to create a task for each model, administrative access to ArcGIS was provided from a UJI server. All four models, i.e. closest facility, fastest route, service area, location allocation, were performed separately and the properties and task of the service were determined to share the results as a geoprocessing service. (ESRI, n.d.-b).

All geoprocessing services are published as a tool on the ArcGIS web portal. A Web map is created, followed by the creation of Web App 'Castellon - A step towards preparedness' by configuring Web App builder in ArcGIS Online. All the tools are embedded in the web app and configured with the input and output symbology for easy user interpretation. The overview of the Web App is shown in Figure *11*.

Figure 11: View of the Web App Castellon - A step towards preparedness

3.10 Quality Analysis

OSM has not only given access to free spatial data like roads, buildings but also has given the opportunity to contribute to society. Special concern needs to be given on these types of maps (Antunes et al., 2015). Despite the advantages of VGI, it possesses numerous challenges. It can be the data availability, impact of the event, localization, data quality and data collection (Poser & Insight, 2015). Out of these challenges, only data quality is discussed in this research.

The comparison is based on the difference between the road network available from OSM and reference dataset. Data from TomTom are taken as reference data. Three kinds of method are considered to assess the quality of OSM data.

3.10.1 Network Length Comparison

Network length comparison is widely used completeness check for road network (Graser et al., 2014; Haklay, 2010). Comparison of the length of the road is carried out by summing up the length of the road of OSM and TomTom respectively. According to the statistics gained from the process shown in *Table 4*, it shows that there is huge difference between the number of segments between OSM and TomTom (TomTom: 7844, OSM: 4510) whereas the difference between the total road length of OSM and TomTom is less (TomTom: 865.521 km, OSM: 843.395 km) in compared to the difference of the number of segments. It clearly illustrates that TomTom has more number of segments compared to TomTom and the length of TomTom is also greater than OSM. OSM only consists of 4510 segments having 3334 segments less than TomTom. On the other hand, the difference between the total lengths of the road is only 22.13km as seen in Table 5. This shows that the length of the segment in OSM is longer than TomTom.

Category	Length of Segment (km)	Number of Segment
TomTom	865.521	7844
OSM	843.395	4510

Table 4: Network length comparison between OSM and TomTom

Difference between total length (km)	22.13
Difference between the number of segments	3334

Table 5: Difference between the number of segments and the total length of OSM and TomTom

3.10.2 Positional Accuracy

Positional accuracy signifies the coordinate variation of any spatial object with reference to its true location (Haklay, 2010). This assessment is conducted by computing the distance between the road features used for the network analysis extracted from OSM and the reference data (TomTom). While Goodchild and Hunter (1997) have proposed buffer method, where reference dataset and a test dataset are overlapped to estimate the accuracy (Haklay et al., 2010). Whereas (Frizzelle et al., 2009) acclaim that there is not any proven method to access positional accuracy for roads. Therefore he believes that according to the method and source of the spatial data proper methods need to be decided.

Buffer and the near tool are applied to calculate the positional accuracy of the OSM road features. Both OSM and TomTom data are converted into points using the *Feature to Point* tool. Later the distance between points derived from OSM and the line features of TomTom is calculated. Similarly, point feature extracted from TomTom and OSM line features distance is computed with the *Near* tool. This helps to calculate the distance from every point in one feature class to the nearest line features in another feature class (ESRI, n.d-a.).

Considering the OSM data acquisition techniques through mobile devices and digitization in satellite images, 10m and 15m distance search distance are applied. Points which lie outer than the search distance are eliminated and the result is summarized according to the highway class for OSM and generally summarized for TomTom due to unavailability of TomTom data classification.

Table 6 describes the distance of the OSM and TomTom in 10m and 15m search distance respectively.

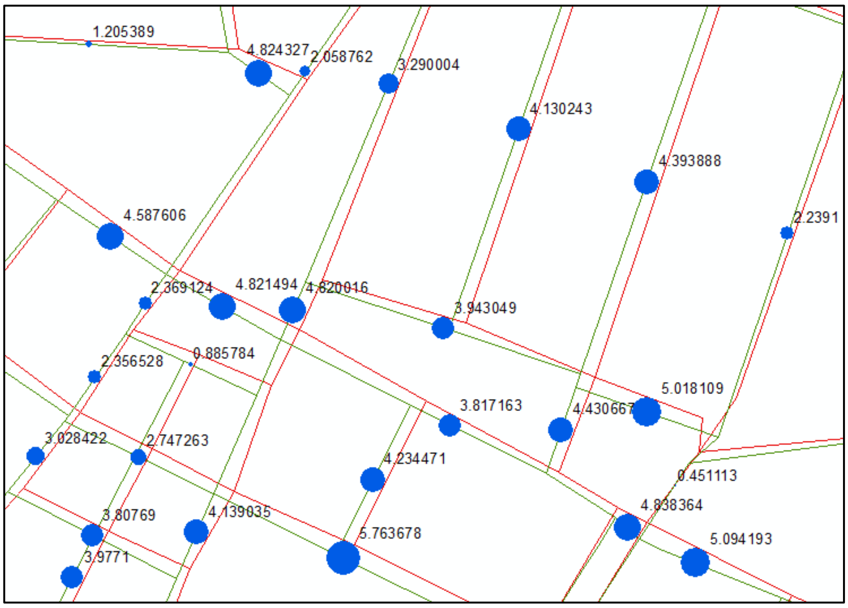


Figure 12: Distance between OSM points and TomTom road.

The difference between both approaches (OSM and TomTom) is quite satisfactory. In Table 6, the row of OSM refers to the distance between point OSM road points and TomTom line features whereas a row of TomTom refers to the distance between TomTom points to OSM line features.

Category		Mean	Min		Max	Standard Deviation
TomTom	10m	3.083	0.00099		9.99	2.31
	15m	3.48	0.00097		14.99	2.94
OSM	10m	2.79	0.000384		9.98	2.04
	15m	3.10	0.000384		14.99	2.62

Table 6: Distance-based statistics for OSM and TomTom

As well as the row with 10m and 15m refers to a search area of 10m and 15m respectively. It clearly shows that the results are quite evident as the mean distance is below 3.5 for both approaches on 10 and 15m search distance. And the standard deviation lies below 3. A lower value near to zero between OSM and TomTom clearly shows the existence of road intersect at some places. Whereas the maximum value is almost to the search area i.e. 9.99 for 10m and 14.99 for 15m.

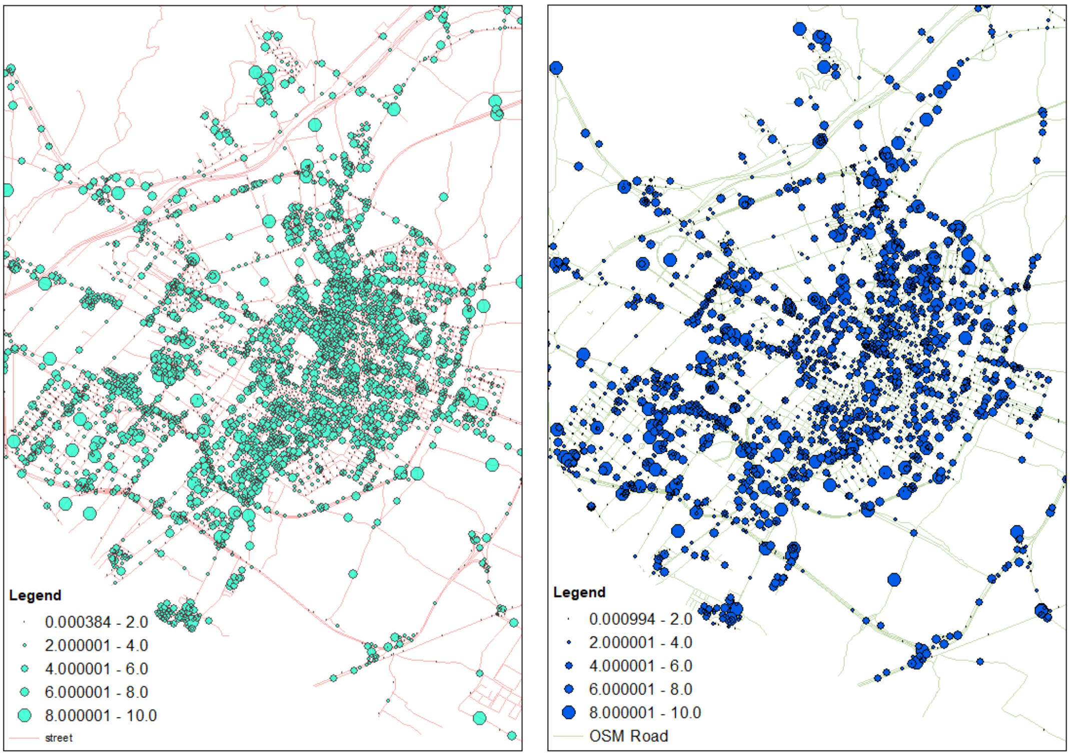


Figure 13: Deviation between OSM points and TomTom lines (left) and TomTom points and OSM lines (right)

(Antunes et al., 2015) claim the different result between OSM points and TomTom lines and TomTom points to OSM lines are due to the conversion of lines to points. The result may not be accurate but it signifies that there is the existence of a feature in the buffer region applied. The distance between OSM (green) points and TomTom (red) is shown in Figure 12 with the proportional symbols in blue where it signifies the distance between OSM and TomTom in meters. Small circles depict that distance is less whereas bigger circles display that the distance between OSM and TomTom is higher. The distance between the two roads is labeled in meters. According to Figure 13, it shows that the accuracy of the OSM point reference to TomTom data is diverse according to different locations. The positional error distribution shows spatial heterogeneity where it has high and low positional accuracy (Helbich et al., 2012).

In addition to the statistical result for TomTom and OSM data, distance-based statistics according to categories of roads on OSM is also calculated. According to the classification of roads described before in

Table 2. Only major roads are considered for the accuracy assessment. As seen in

Table 7, it illustrates that trunk roads have the highest accuracy than other roads being the mean distance at 1.7 while primary roads have the highest mean distance being 4.25. It also displays that some roads are intersected with each other as the minimum distance is zero and the maximum distance states that some roads are near the search area.

Road	Number of Segments	Mean Distance	Minimum Distance	Maximum Distance	Standard Deviation
Motorway	96	2.23	0.01	9.09	1.94
Trunk	108	1.70	0.0109	9.79	1.93
Primary	97	4.25	0.009	9.79	2.50
Secondary	231	3.54	0.007	9.56	2.39
Tertiary	652	2.94	0.006	9.99	2.09

Table 7: Statistical Distance comparison of OSM with road classification

3.10.3 Attribute Accuracy Assessment

Computing accuracy assessment is not an easy job as it requires efforts and consistency, comparability in data attributes which may lack among road datasets (Frizzelle et al., 2009). To measure the accuracy of the OSM with reference to TomTom data, attribute accuracy is carried out. The road names are considered as the attribute check where the result shows that 23.64 percent of OSM road features do not contain road name whereas TomTom considered as reference dataset also does not contain 17.32 percent of road name. Detail statistical information about the road name of two datasets is explained in

Table *8*.

While detecting the attribute of the road, spatial information is also taken into consideration.10 meters of spatial distance is used for *feature compare* and the features are compared. TomTom data are taken as base data and OSM data are taken as updated data for the check. The comparison result can be seen in Table 9.

Object ID	Road with Name Information	Number of Segments	Length (km)	Length (%)
1	OSM_Null	1056	199.42	23.64
2	OSM with name	3454	643.98	76.36
3	**OSM Total**	**4510**	**843.40**	**100**
4	TomTom_Null	1763	149.88	17.32
5	TomTom with Name	6081	715.64	82.68
6	**TomTom Total**	**7844**	**865.52**	**100**

Table 8: Statistics of the attribute information (road names) of OSM and TomTom.

Change	Number of Segments	Length (km)
Delete	1687	193.222
New	1093	140.651
No Change	1366	163.174
Spatial	2052	539.760

Table 9: Result of Attribute Accuracy

According to the comparison of the attribute accuracy done by matching the number of lengths of attributes. Deleted features and new features are neglected as it only considers spatial information changes. Only the features with the same attribute i.e. road name are considered for the accuracy.

Accuracy is evaluated by (Length of the Matching attribute /Total Length)*100 %

Hence, the result reveals that 67.8 percent of OSM attribute matches with TomTom data.

4 PERFORMANCE SURVEY

This chapter presents the questionnaire survey conducted with participants regarding the web application developed in the research. It reviews the design of the response form, the involvement of participants and the evaluation of the response after using the application.

4.1 Study Design

As the study was carried out on VGI, the project was designed to engage volunteers on different phases of the study. Hence an evaluation is carried out with some participants to measure the effectiveness of the application built during the project and to study the participants thought on the use of OSM, its effectiveness, and quality. This evaluation does not entirely focus on the usability of the application but rather concentrates on the outcome of the results after executing the tool developed during the project. It gathers views about OSM reliability to use for disaster preparedness on other areas.

In the first part of the evaluation, participant's knowledge and experience on maps used for navigation and the familiarity with OSM and its uses is determined by questionnaires. Later, the result of the tool developed in the web application 'Castellon - A step towards preparedness' is obtained by means of a questionnaire developed after using each tool and comparing the result with Google Maps. Finally, the overall view of the participants is taken by summarizing the results obtained after the application experience.

4.2 User Sampling

A convenient sampling method was implemented for the response study. 17 participants from different nationalities, ranging from 23 to 42 years, participated in the study. The users were divided into three categories:

- Participants who volunteered in mapathon organized on 14th November 2018.
- Participants who did not volunteer in mapathon but have visited Castellon.
- Participants who did not volunteer in mapathon and never visited Castellon.

In addition, many participants had experience with OSM and were Masters in Geospatial Technology students. The demographics of the participants are shown in

Table 10.

Category	Value	Total	Percentage (%)
Gender	Male	12	70.58
	Female	5	29.42
Age	20-30	14	82.35
	30+	3	17.64
Participation	Participants who volunteered in mapathon	9	52.94
	Participants who did not volunteer in mapathon but visited Castellon	4	23.52
	Participants who did not volunteer in mapathon also never visited Castellon	4	23.52

Table 10: Demographics of Participants.

4.3 Procedure

A response form was created and forwarded via email to participants with the link of the application 'Castellon - A step towards preparedness' (http://geotec.init.uji.es/portal/apps/webappviewer/index.html?id=e8c55d5f03434ca18756b7248b66dc6f). All the participants could use the application via their laptop with an internet connection. The response form was prepared with a Google form and presented to the participants. Questionnaire generally consisted of particular question regarding the use of the tool, as well as some general and important question concerning the quality of OSM that they found out after using the tool and their view on applying OSM in the future. The questions were divided into four main categories.

- General questions about mapathon participation.
- Questions regarding the experience of using maps for navigation and experience regarding OSM and the quality of navigation application.
- Questions regarding the use of the tool and the results obtained from it.
- Analysis of the results derived from the use of the tools. The overall reaction of users on the use of OSM in navigation especially for disaster mapping.

In the task section, in order to use the application for each tool, questions were designed for a better understanding of research and easement in responding to the questionnaires. The response form is included in Annex VIII. Some tasks were made to compare the result of the application with a professional map service app (Google Maps). Task designed for each tool is shown below:

Categories	Description
Closest Facility	Suppose, there is an accident in the train station of Castellon. Locate yourself in Castellon train station with the incident tool. Then, try to find the closest hospital by choosing "hospital" from the drop-down menu of the facility. Select the number of facilities as 1 and direction as "Travel to". What is the total number of hospital shown in Castellon area? And compare the route with Google Maps and compare the result with and without barriers.
Fastest route	If you want to navigate from hospital provincial to Parque Rafalafena and find the fastest route. Select the fastest facility tool and locate points in Hospital Provincial and Parque Rafalafena and run the tool. Take the same points as input and check in Google Maps. Does the result shown by the application matches with the result shown by Google Maps?
Service Area	Try to find the area covered by the hospital in 3 minutes' drive time. Select the hospital as "Facility" with break values 3. What is the result?
Location-Allocation	Try to find out the police station that can be readily available if any incidents happen. Select UJI, Parque Rafalafena, and Parque Ribalta as "Demand points", points where an incident might happen" And try to find out which police station can be chosen. Therefore, select police as "Facility" with 2 as "Number of Facilities". What is the result show?

Table 11: Task and Description of the task for each tool

4.4 Result

After the development of the tools for network analysis and creating a web app, the web app was presented to the participants. Since the tool was developed using OSM data, the outcome of the result of the tools represented the quality of the OSM data. All the participants in the survey tested the application and the response was well received. All the responses were derived from the questionnaire developed. From the responses, it reveals that all the participants have used maps before, where 58.8 percent of participants use maps on a daily basis whereas, 41.2 percent of participants use map whenever they travel to new places. Although some of the participants came from a different background other than the geospatial sector, the result presents that map is used as an integral part of life to everyone nowadays, especially for navigation.

Considering the popularity of navigation application, Google Maps is the most popular application where 16 of the participants claimed using Google Maps. The popularity of professional maps such as Google Maps is more efficient especially in urban areas where the data is quite populated and effective with traffic data, encouraging people to use them. After Google Maps, six of the participants informed using OSM, and two of them mentioned using the application called Maps.me, which also uses OSM data. It revealed that eight of the participants used OSM for navigation after Google Maps. Some participants also added that they used TomTom and Waze. Waze is the largest community-based traffic and navigation app supported on GPS enabled smartphones and tablet. Waze gives turn-by-turn navigation information, travel time and details of the route shared by others through the mobile telephone network (Waze, n.d.).

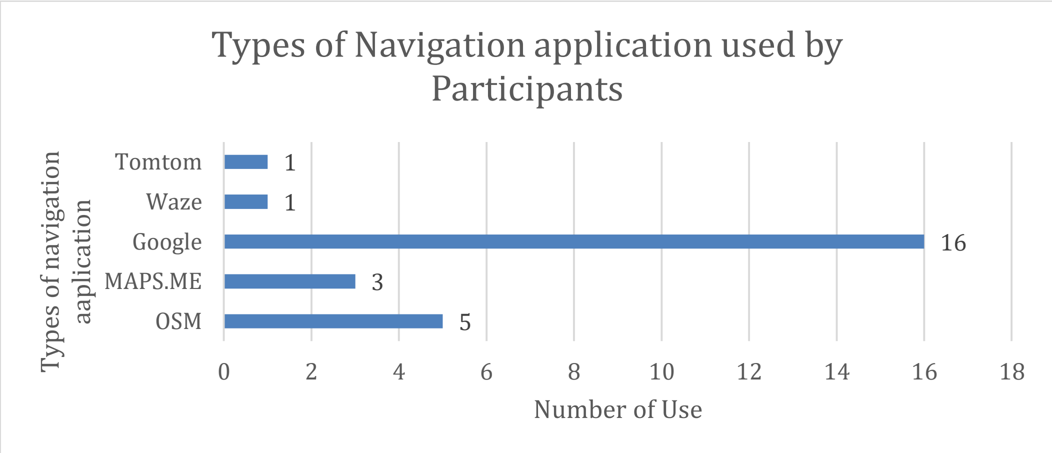
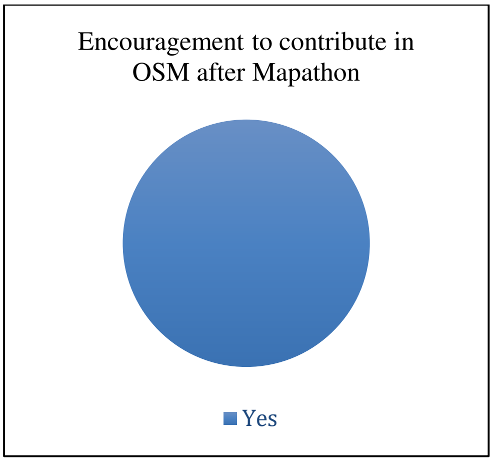


Figure 14: Response from the participants about the types of navigation applications

For the quality/effectiveness of the navigation application they used, participants were inquired if they have always obtained true results. Four participants claimed that it always provides the right information, while thirteen participants pointed out that these applications sometimes failed to provide the right information.

This study also tried to explore the use of OSM in diverse fields. So, participants were asked about the purpose of the use of OSM. One of the participants said that he had never used OSM, however, eight participants claimed that they have used OSM for navigation. Participants disclosed that nine of them have used OSM for other applications being the highest use of OSM in this survey. In addition to that, one of the participants stated that he has used OSM as a base map for another study. However, one of the participants said that he has used OSM during an emergency which advocates the research objective.

The questionnaire survey consisted of mixed participation in terms of mapathon participation held on 14th November. Nine of the questionnaire survey participants volunteered in mapathon and rest of eight participants did not volunteer in mapathon. All nine participants who volunteered in the mapathon highlighted that the mapathon encouraged them to contribute to OSM. Among nine participants, four of them revealed that they have contributed to OSM even after the mapathon while five of them did not contribute after the mapathon. This results strongly conveys that organizing a mapathon can contribute to more responsible citizens for mapping. Figure 15 explains the effect of mapathon on the users who took part in mapathon.



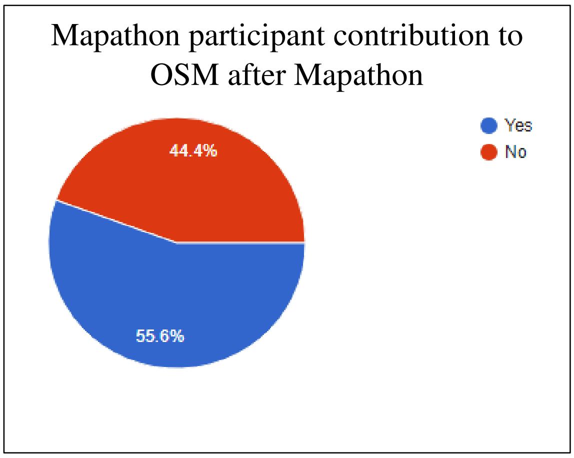


Figure 15 Mapathon effect on the participation to contribute to OSM

Out of the eight participants who did not volunteer in the mapathon, four participants never traveled or visited Castellon, while one of the participants stayed in Castellon for less than six months and three of them stayed in Castellon for more than six months. Also, all the nine participants who contributed to the mapathon are staying here in Castellon. Figure 16 illustrates the participant's categorization and their knowledge of OSM.

Considering all the category of the participants in terms of Castellon stay, limited questionnaires were designed to acquire the result after using the application. All four tools had different questions according to the use. Questions were created, bearing in mind of the participants who have never visited Castellon before can navigate through the application.

After using the closest facility tool, 76.5 percent of the participants were able to find the right answer, whereas the rest of the participants came up with the wrong results. 70

percent of the participants disagreed that the result shown by Google Maps matches with the result shown by the application which is correct. Regardless of the fact that all of the users did not obtain the right result because OSM data contains some errors and missing data. 76.5 percent of participants stated that OSM data can be used during an emergency, depending on the quality and quantity of the data. While 19.6 percent of participants believed that OSM can be used during an emergency and 5.9 percent of the participants denied that OSM cannot be used during an emergency.

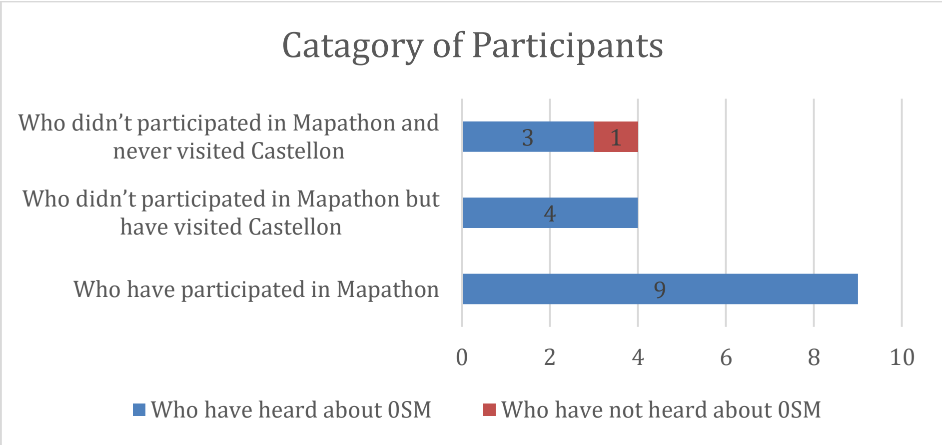


Figure 16: Category of participants in the questionnaire and their knowledge in OSM

After using the fastest facility tool, three participants said that the results shown by OSM and Google Maps are the same, but the rest of them said that the results vary. The period to answer the questionnaire was for one week. Therefore, participants conducted their test in the application at a different time of the day. As Google Maps consist of traffic data and according to traffic data, results varies at a different time. At some particular time of the day, the fastest route shown by Google Maps and the application almost matches with slight differences in some turns. Therefore, the result of the question varied. Information was collected with the participants regarding the difference of the route between Google Maps and the application. Ten participants agreed that the absence of traffic data in the application and their belief that Google Maps are made by professionals which contains fewer errors and are reliable has caused the difference. As well as seven participants also agreed that OSM data is of less quality as it does not contain all one way and turn restriction information. In addition, 58.8 percent of participants believed that after upgrading the quality of OSM and adding traffic data, the results would be more accurate. However, the rest of the 41.2 percent participants were not sure that the quality would be improved even after upgrading the data and including traffic data.

Similarly, participants were asked to follow some steps and compare the results for the Service Area and the location-allocation tool. Three of the participants believed that the result consists of error. Also for the location-allocation tool, one of the participants assumed that the result obtained was wrong. It undoubtedly depicts that even there are the right results, proper interpretation ought to be taken by the users. Wrong interpretation of the map or data may lead to the wrong action which may be harmful especially during an emergency.

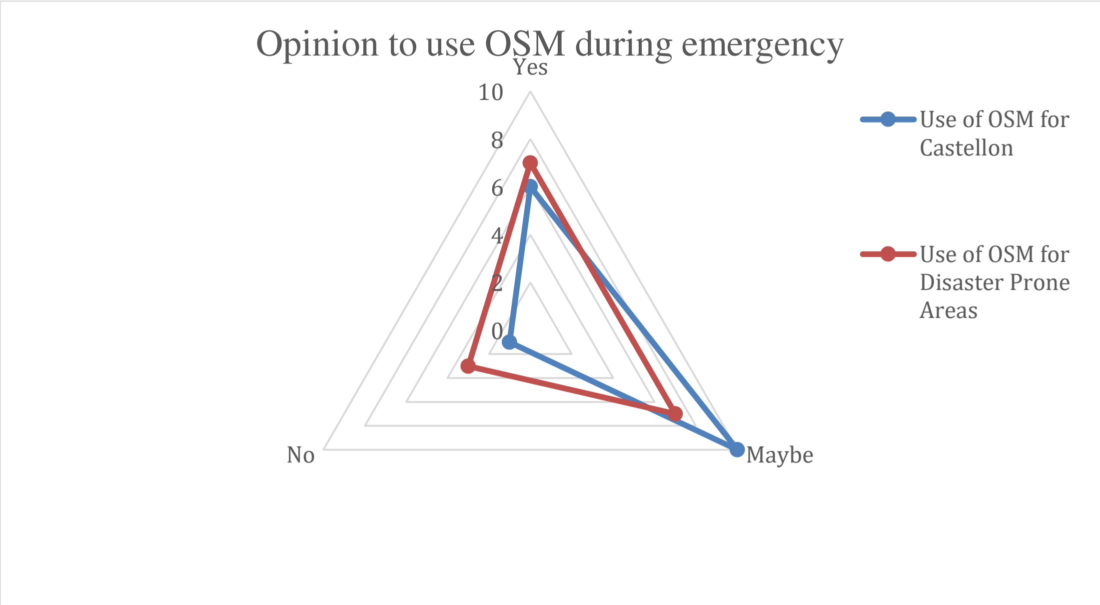


Figure 17: Use of OSM in Castellon and Disaster Prone areas

After all the tools were executed, users were asked about the results they have obtained. The overall reaction of the participants is illustrated in Figure 17. Six participants agreed that OSM could be used for navigation during an emergency in Castellon, although ten of them were not assured that it could be used, while one of the participants disagreed that it was not appropriate to use. Apart from Castellon, seven participants believed that OSM could be used in disaster-prone areas, while seven participants had confusing opinions, whereas three participants denied the fact to use OSM in disaster-prone areas. If there are quality assurance and no missing data, sixteen participants believed that it could be appropriate to use but, one of the participants believed that the accuracy of the OSM is dependent on the software used. As OSM is created by a contribution from people, thirteen of them have ensured that they will contribute to OSM in the future, which is the positive impact of mapathon and the application. Participants also ranked the OSM of Castellon from 1 to 5. Figure 18 illustrates the rank given by the participants.

Participants also focused that OSM gives more accurate result when the data are validated and reliability of OSM data must constantly be borne in mind while using it. Participants also insisted to improve the application with traffic data with minimum and maximum time to reach the destination. Participants also claimed that in urban areas, Google Maps are more effective and populated whereas in the rural areas it's exactly the opposite. Also, the participants were concerned about the ease of use of the application during an emergency.

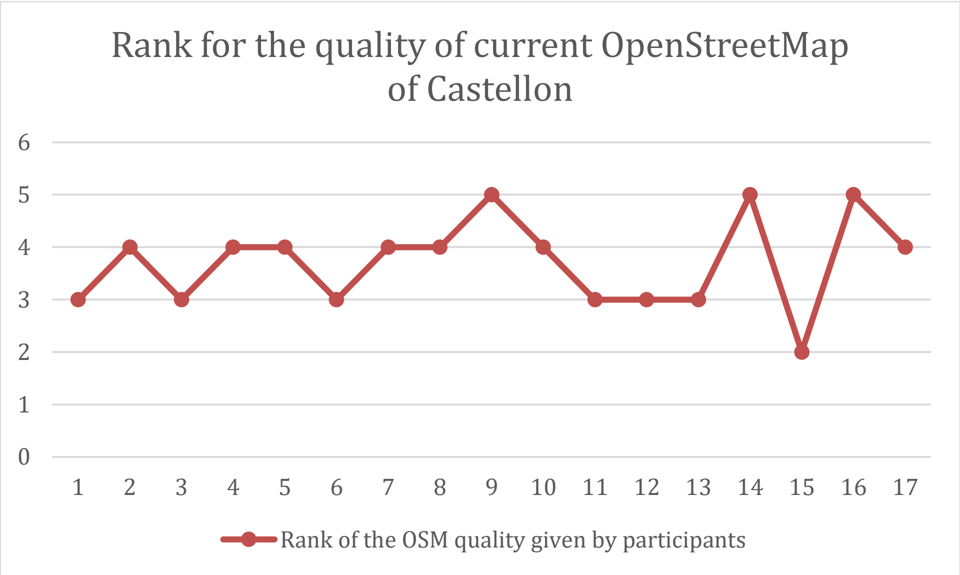


Figure 18: Rank of the OSM in Castellon given by participants.

5 DISCUSSION AND FUTURE WORK

This chapter reports the findings of the research, in particular with the quality analysis and performance survey. Additionally, it presents the limitation and future work of the research.

5.1 Interpretation of results

Results are drawn from the analysis carried out in the research, such as the outcome of the mapathon, quality analysis of the OSM dataset, evaluation of the network tools developed.

Considering the results obtained from mapathon, the contribution of volunteers is satisfactory. The result shows that the contribution of experienced volunteers is qualitative and reliable compared to new contributors. It also shows that the mapathon has a vital impact on the volunteers where five out of nine volunteers claimed that they have contributed to OSM after the mapathon event. Influence on the participants of mapathon to contribute to OSM is one of the satisfactory outcomes for this project. Awareness of the volunteers about OSM and their enthusiasm can help to make OSM more qualitative.

Quality analysis with reference to TomTom data was performed using three methods, where positional accuracy shows that the average distance between OSM and TomTom is three meters. It reveals that the OSM positional quality is satisfactory and also indicates that the accuracy can be improved in the future with the high specification technology. Network length comparison reveals that TomTom data consists of more data than OSM. Missing features in the OSM can be drawn later by organizing a mapathon. Attribute accuracy reveals that the attribute in both datasets is not complete. With the existing attribute, an analysis is performed with road names, which gives 69.7 percent of accuracy. The accuracy obtained shows that within 10m of buffer distance, there is a presence of road with the same name. The road name between TomTom and OSM must be exact for the comparison. If there are any grammatical errors then, the result shows errors. Therefore, proper attention should be given to attribute while creating the features.

Summarizing the quality assessment of the OSM data with TomTom, it recommends that creating precise specification and standardization of OSM while contributing to OSM would increase the quality of the data.
The quality evaluation of the network tools with the use of web applications results that some participants were not able to interpret the data correctly although being used to technology and maps which might result in wrong actions while navigating in the ground. As well as participants had various opinions on using OSM in Castellon and other disaster-prone areas. Participants recommended that OSM can be used for disaster preparedness plan only if the OSM data consists of updated and reliable data with the incorporation of traffic data and right information of the emergency services and turns restriction.

5.2 Limitations

While undergoing the research, some limitation came up with the progress of the work. Firstly, the study area was not an ideal study area for disasters. Although, the historical data observed show that there are subtle occurrences of disaster in Castellon. Proper planning of the city has made Castellon less vulnerable which might be different in other areas when we apply the methodology that we have obtained.

Secondly, some technical errors constricted the scope of the project. Limitation in the extension of OSM Editor, elevation values extracted from DEM could not be incorporated which would have ensured better accurate results. Also, OSM data could not be updated automatically due to technical issues in ArcMap. In addition to that, the widget available in Web App builder of ArcGIS had some restriction, therefore, resulting in a barrier option as required.

Additionally, for any quality assessment, high qualitative reference data is required to compare with OSM data which might not be available everywhere. The accuracy assessment is carried out in this research compared to the TomTom data provided by the ESRI. The data provided by ESRI are five years older and is not complete and outdated. Although there may not be significant changes in roads in a developed area, this might not be the same case in other developing areas. For the accuracy assessment of the attributes, road names were used where the reference data lack 17.32 percent of the names, which resulted in low accuracy in the comparison.

Another limitation of the project was the involvement of the participants in the project. Getting a wide variety of participants was challenging where language was one of the barriers to invite volunteers. Therefore, convenient sampling method was applied to be fast and effective where most of the participants were students and their age ranged from 23 to 42 years, and their duration of stay in Castellon from 2 months to 1 year. The result would have been more effective if it included a variety of users who knew Castellon better. As well as all the volunteers are familiar with digital technology and maps which might not be in the same case in disaster.

Since the network was created especially for the municipality of Castellon, the result near the border may not be effective, as the road feature outside the border, which could be the fastest route, may be lacking.

Lastly, the results were obtained from the self-study report through the response from the questionnaire survey developed after the use of the web app. A more qualitative method to get the response from the participants would have made it superior.

5.3 Future works

In the future, the work done in this project can be improved in various ways in terms of data source, data validation, software used and evaluation process. In this project, the capability of VGI was assessed by using OSM. Apart from OSM, mapillary can also be an alternative where the images in the mapillary can provide additional information than the attributes in OSM.

For the validation process, participation in mapathon can be increased through publicity and local volunteers can be encouraged to contribute to the betterment of the quality in OSM. As well as the duration of mapathon can be made longer with the additional exercise of validating features going outdoor.

ArcGIS was used as the software for analysis and ArcGIS server for creation of a web app. If there is an upgrade to the OSM editor extension, incorporation of elevation values can improvise the results. Similarly, automatic update of the OSM data can be done which would be realistic and efficient during disaster. The application can be made more effective by including all modes of transportation. Creation of widget from scratch would be more efficient rather than using the default consisting of restriction. Rather than using ArcGIS platform, Open Source software like QGIS and free hosting service can be a better alternative which can be effective and also would not require a license and free to use. This application can be extended as a response and validation hub for communication during a disaster. Additionally, the evaluation can be more intense rather than a questionnaire survey. Lastly, the methodology applied during this project can be conducted in other areas especially in disaster-prone areas.

6 CONCLUSIONS

The main aim of the research conducted in this thesis is to solve network problems for Castellon using OSM during a disaster.

The results obtained from the study reveals that VGI can be used for disaster preparedness, depending on the data volume and quality of the data in the specified areas. The quality evaluation of OSM shows that quality can be increased by adding missing features and validating existing data. Roads are important for the creation of network data. Road features such as turn, number of lanes, traffic data are essential for network analysis. Attributes of the features are also equally important. Incorrect features or features without adequate information can be more dangerous than with the absence of features during an emergency.

This research also highlights the importance of disaster preparedness to reduce the after effect of disasters. All administrative bodies must create a Spatial Database Platform to meet the basic needs during a disaster search and rescue.

This study also reveals that the methodology developed in this research can be used in other areas with some modification. The traffic data and automatic update of the OSM data and validation of the features should be given importance while carrying out this methodology in other areas. Adding all modes of transport can lead to effective use and increase credibility.

This study justifies the importance of mapathon, which increases the assurance of data quality and the addition of missing features in OSM. Validating features by going outdoor can increase the efficiency of the mapathon. As well as the OSM data can be made trustworthy by organizing mapathon sessions time and again to make the database complete and updated. This study also has a positive effect on research participants about the idea of the OSM, the working mechanism, the social impact of mappers and the impact of participant's contribution to OSM. Encouraging local people to participate in the mapathon can lead to updated and validated data if there are any changes in the ground. Since volunteers create VGI, the participation of effective volunteers can improve quality and produce better results.

On the long run, rather than using the ArcGIS platform which requires a license to use, Open source software like QGIS for analysis and free hosting platform can be used which is more practical and cost-free.

In a nutshell, VGI has the potential to deal with network problems for navigation and to create a disaster preparedness plan if the data are updated and well validated.

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ANNEX

I. Registration Form for the Mapathon Participation

1/14/2019 General Information

General Information

This form is generated to get the general introduction about the volunteers for the mapping campaign "Make Castellon Data Better" held in 14th Nov 2018 at University Jaume I. We will make sure that your data is purely confidential and will only be used to make the project efficient and valuable

* Required

1. **Email address** *

2. **Name** *

3. **Surname** *

4. **Date of Birth** *

   Example: December 15, 2012

5. **Nationality** *

6. **Profession** *

   Check all that apply.

   - [ ] Student
   - [ ] Professor
   - [ ] Other

7. **Study Level** *

   Check all that apply.

   - [ ] Bachelors
   - [ ] Masters
   - [ ] Phd
   - [ ] Ongoing

https://docs.google.com/forms/d/1Bypoz0MK1uD2lIDsQgu6NJjEsUuVFgY79mFXYm2ZAzc/edit 1/3

8. **How long have you been in the GI Sector?** *

Check all that apply.

- [ ] No idea about GI
- [ ] Less than 1 year
- [ ] 1-3 years
- [ ] 3-7 years
- [ ] 7-10 years
- [ ] More than 10 years

9. **How long have you been in Castellon** *

Check all that apply.

- [ ] Less than 6 months
- [ ] 6-12 months
- [ ] 1-2 Years
- [ ] 2-5 Years
- [ ] More than 5 years

10. **In which part of Castellon do you live?** *

____

11. **Which Part of Castellon do you like?** *

____

12. **Do you know about Open street Map?** *

Check all that apply.

- [ ] Yes
- [ ] No

13. **Do you have experience in contributing to Open Street Map?**

Check all that apply.

- [ ] Yes
- [ ] No

14. **Would you like to know more about the result of this project?** *

Check all that apply.

- [ ] Yes
- [ ] No
- [ ] Maybe

II. Mapathon News hosted in Master Geotec website

CASTELLÓN MAPATHON 2018

Home / Castellón Mapathon 2018

Nov 22

posted by Geoteoh Master | in Sin categoria | 0 Comments

This World GIS Day, 20 volunteers of University Jaume I participated in "Make Castellon Data Better Mapathon" held at University Jaume to increase the quality of OpenStreetMap in Castellon. The aim of the mapathon was to validate OpenStreetMap road features of Castellon Municipality and mark important features needed during or after disaster occurrence which was organized by me and my supervisor Andres Munoz. It was also used as a data validation process for my project entitled "Data validation and Quality Assessment of VGI Road Network of Castellon for Emergency Evacuation Route Planning" for my Master's thesis.

Volunteers were gathered with the help of email and personal contact and were asked to register before the mapathon. Volunteers were also requested to watch the introductory videos on the concepts of the editing in OpenStreetMap using Id Editor. Castellon municipality area was selected for mapathon where the task of the mapathon was created here. The Mapathon was conducted for one and half hour starting from 10:00 am in the morning where I gave a short introductory presentation about the mapathon and the way to validate the roads and add missing features. Afterward, the volunteers were asked to start mapping where volunteers map Castellon for one hour. A unique id called #CastellonMapping was used to locate the edits done during the mapathon.

Most of the volunteers participated in this mapathon were students of Erasmus Mundus Master in Geospatial Technologies and every volunteer had a background of Geoinformatics. Out of 20 participants, everyone had an idea about OSM and 5 of them have already contributed to OSM before. Among the Volunteers, the number of female participants was by 25%. The OpenStreetMap of Castellon is almost completely mapped but there exists some errors and validation of the data was an important step to carry out. Therefore this mapathon was organized so that the volunteers can use their local knowledge and validate the area around them. Out of 20 participants most of them were new to the city and had few experience in the area, however, they produced good results in mapping bicycles tracks and the university area. They also mapped the area around their residence and famous areas of Castellon such as Park Ribalta, Grau and the city center. As the task was to validate line features especially road, there were some significant results in road turn and one-way restrictions.

During the mapathon, volunteers made 203 edits in that time period where it consisted of 43 new buildings, few point features and rest of the edits were line features. Throughout the Mapathon volunteers also had a comparison of their contribution using OSMfight tool which made the mapathon more entertaining and competitive. Volunteers were encouraged to contribute to OSM and the real-time result was shown using Show me the Way. The changes done during the mapathon was seen through OSMCha and OSM Kartoza using various filters like mapping date and area.

Mapathon ended by thanking all the participants and encouraging them to contribute in OSM later in upcoming days as well as highlighting the importance of maps during a disaster. All the participants were delighted to contribute and be a part of the mapathon. The mapathon was ended by taking a group photo and some cookies.

RECENT

FILES

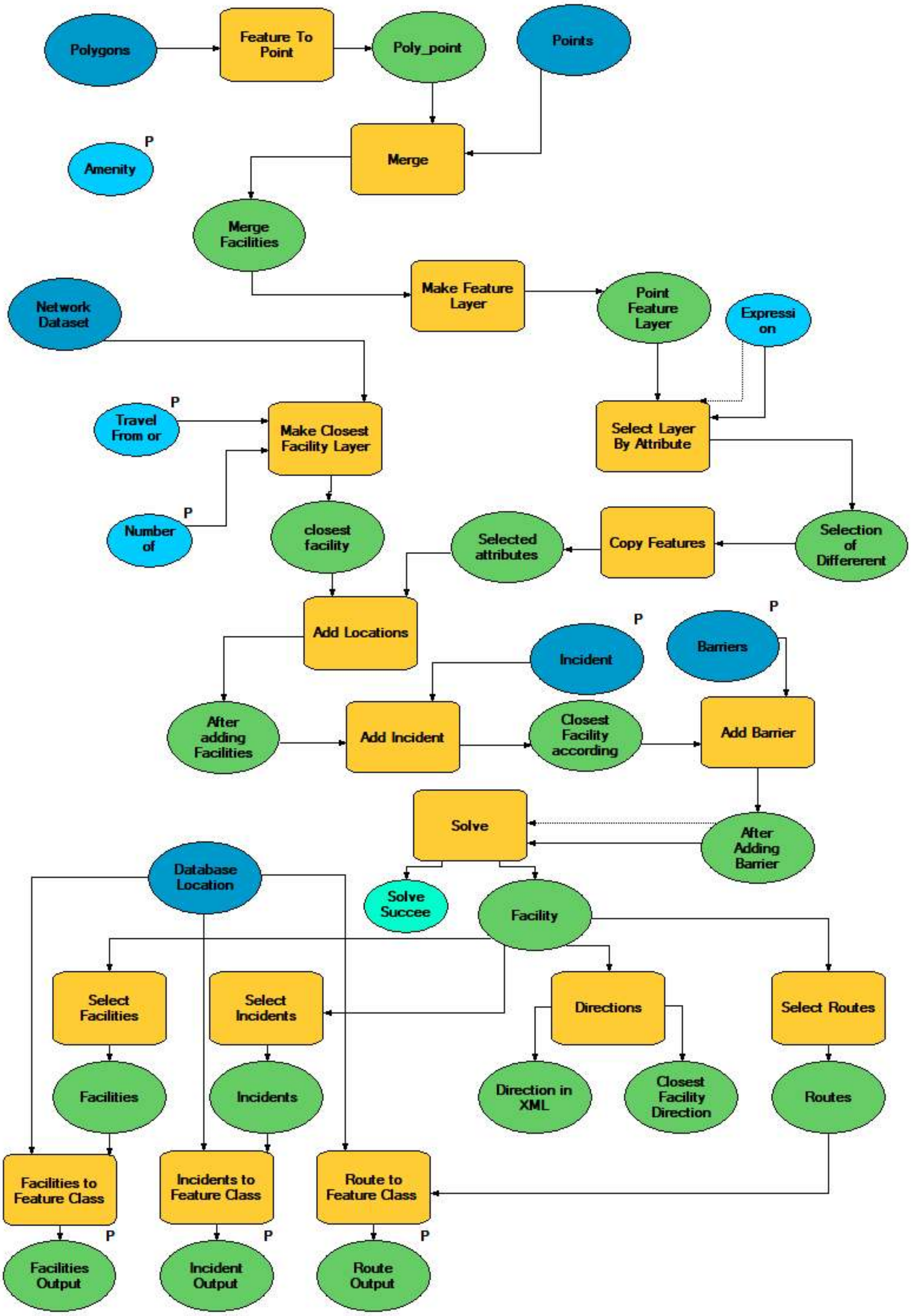
- November 2018
- September 2018
- June 2018
- April 2018
- March 2018
- February 2018
- January 2018
- December 2017
- October 2017
- September 2017
- July 2017
- June 2017
- May 2017
- February 2017
- January 2017
- November 2015
- November 2014
- June 2014
- May 2014
- November 2012
- October 2012
- September 2012
- July 2012

CATEGORIES

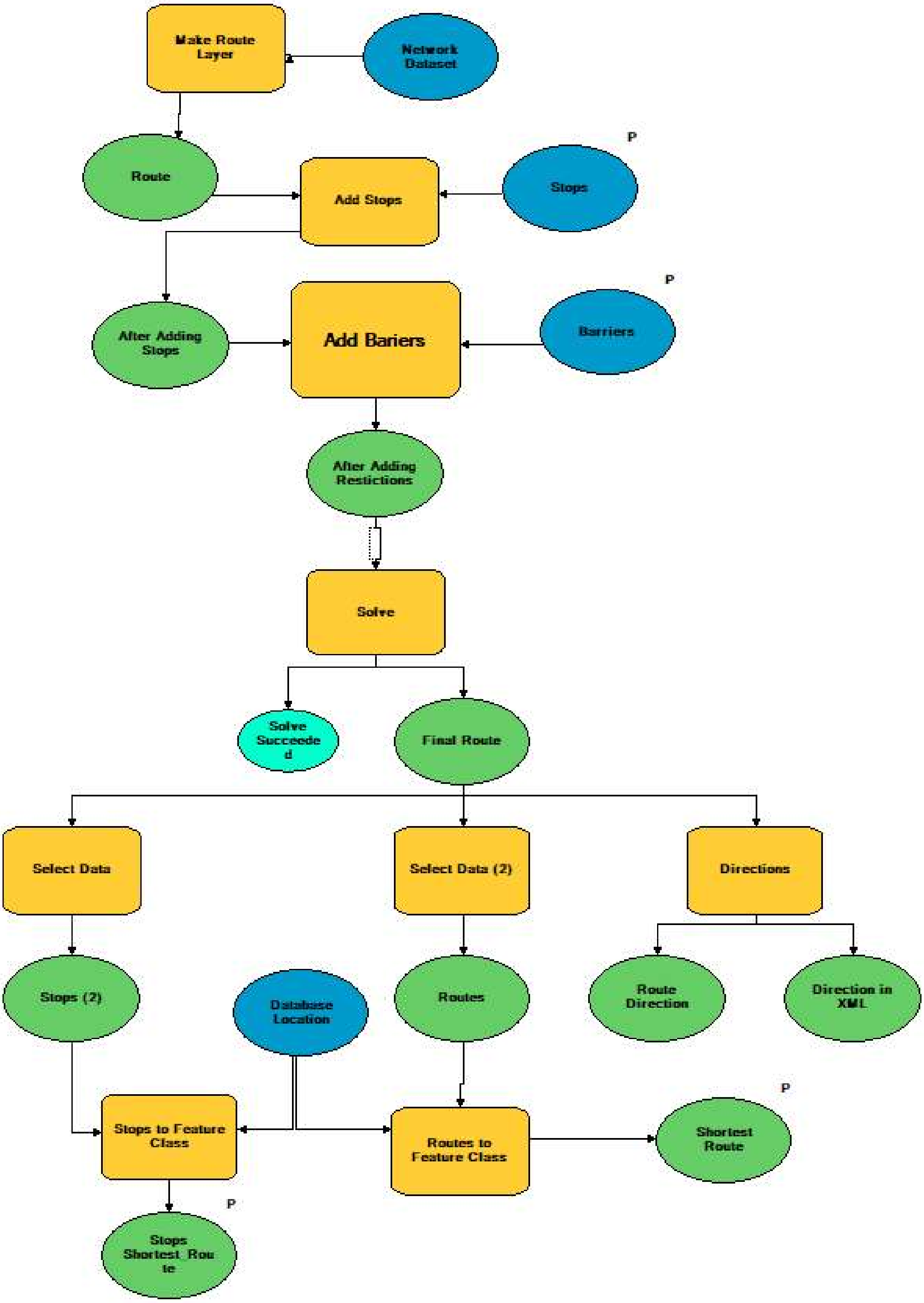
III. Mapathon news hosted in in Geotech website at UJI

In paralell, and in cojunction with the Master in Geospatial Technologies, our student Eliza Shresta organised "Make Castellon Data Better Mapathon". The aim of the mapathon was to validate OpenStreetMap road features of Castellon Municipality and mark important features needed during or after disaster occurrence. The analysis of the results of the Mapathon will be included in Eliza's Master thesis to be defended next year. Some pics from the Mapathon, with more than 20 participants!!

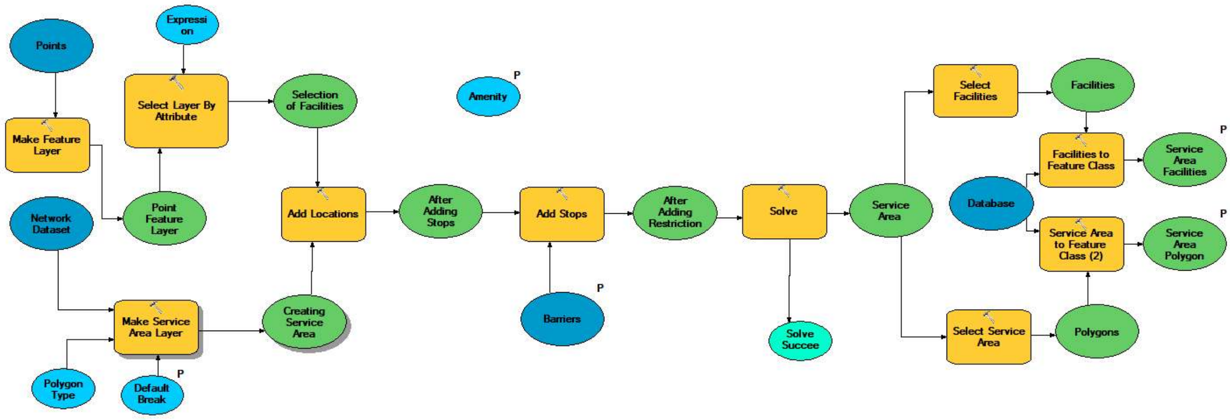
IV. Model for Closest Facility



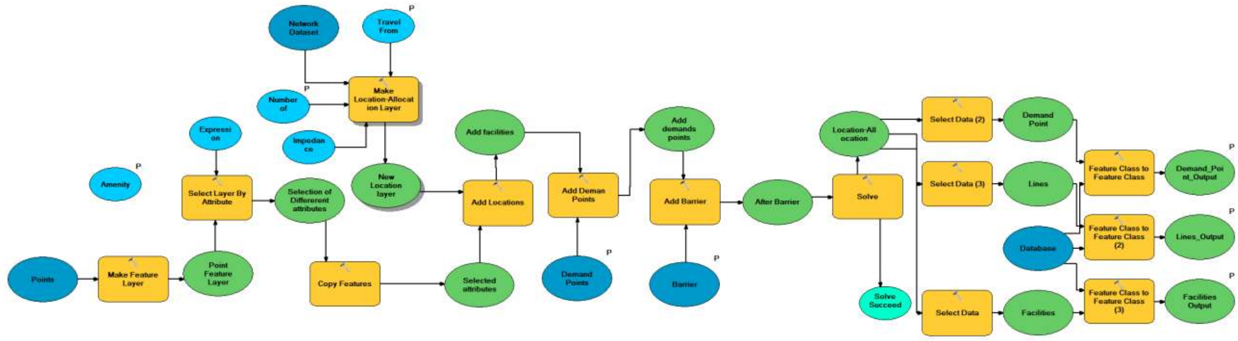
V. Model for the Fastest route



VI. Model for Service Area



VII. Model for Location-allocation



VIII. Evaluation Form for the Application

Response Form

This questionnaire is created to get the response from the user who used the application "Castellon-A step towards Preparedness" developed during the project of "Data validation and Quality Assessment of VGI Road Network of Castellon for Emergency Routing". All the user are encouraged to use the application before answering the questionnaire.

*Required

1. **Full Name** *

2. **Did you participate in the Mapathon that was organized for this project on 14th November?** *

   Mark only one oval.

   - Yes *Skip to question 6.*
   - No *Skip to question 3.*

Questions for those who didn't participate in Mapathon

3. **Have you ever visited Castellon? If yes, what was the duration?** *

   Mark only one oval.

   - I haven't visited Castellon
   - Less than 6 Months
   - More than 6 Months
   - Only visited for few days

4. **Have you heard about OpenStreetMap?** *

   Mark only one oval.

   - Yes
   - No *After the last question in this section, skip to question 8.*

5. **Have you ever contributed to OpenStreetMap?**

   Mark only one oval.

   - Yes *Skip to question 8.*
   - No *Skip to question 8.*

Skip to question 8.

Questions for Mapathon Participants

6. **Did the Mapathon encourage you to contribute to OpenStreetMap?** *

   Mark only one oval.

   - Yes
   - No

7. **Have you contributed to OpenStreetMap after the Mapathon?** *
Mark only one oval.

- ◯ Yes
- ◯ No

General Questions about Navigation

8. **Have you used Maps for Navigation?** *
Mark only one oval.

- ◯ Everyday
- ◯ Never *After the last question in this section, skip to question 11.*
- ◯ Sometimes when I travel to new places

9. **What kind of application/map have you used to navigate?(Multiple Choice)** *
Tick all that apply.

- ☐ Google Map
- ☐ HERE Map
- ☐ OpenStreetMap
- ☐ PaperMap
- ☐ TomTom
- ☐ Other: ____________

10. **Does your navigation application always give you accurate result?** *
Mark only one oval.

- ◯ Yes
- ◯ Sometimes not so accurate
- ◯ No

OpenStreetMap Navigation Issues

11. **If you have used OpenStreetMap, what purpose did you used OpenStreetMap?(Multiple Choice)** *
Tick all that apply.

- ☐ Never Used OpenStreetMap
- ☐ Navigation
- ☐ Rescue Operation
- ☐ Emergency
- ☐ Retrieve OpenStreetMap for other application
- ☐ Other: ____________

12. **If you have used OpenStreetMap for navigation before, did it show you right information? (Multiple Choice)** *
Tick all that apply.

- [ ] Yes
- [ ] It shows wrong result
- [ ] No, It lacks information
- [ ] Other Navigation Application are Better
- [ ] Sometimes it has more information than any other maps

13. **Do you think OpenStreetMap has potential to replace other kind of Maps?** *
Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

Application Feedback for Closest Facility Tool

If you haven't used the "Castellon-A step toward Preparedness"Application, Please navigate to: "http://geotec.init.uji.es/portal/apps/webappviewer/index.html?id=e8c55d5f03434ca18756b7248b66dc6f".
Please go through the application and answer the questions below

14. **Select the "Closest Facility" tool and suppose there is an accident in train station of Castellon. Locate yourself in Castellon Train Station with the incident tool. Then, try to find the closest hospital by choosing "hospital" from the drop down menu of facility. You must add "barriers". Select number of facilities as 1 and direction as "Travel to". What is the total number of Hospital shown in Castellon Area?** *
Mark only one oval.

- ( ) 3
- ( ) 4
- ( ) 5
- ( ) Other: ____________

15. **If you add a "Barrier" within the closest route shown before and run the tool again, Is there any difference in the route and closest hospital shown than the first result?** *
Mark only one oval.

- ( ) Yes
- ( ) No

16. **Please open Google Maps and search Castellon and locate yourself near Castellon Train station and try to find the hospital. Does it show the same result?** *
Mark only one oval.

- ( ) Yes
- ( ) No

17. **Do you think we can rely on OpenStreetMap during emergency for emergency purpose?** *
Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Depends on the quantity and quality of OpenStreetMap Data available

Application Feedback for Fastest Route tool

18. **If you want to navigate from hospital provincial to Parque Rafalafena and find the fastest route. Select the Fastest facility tool and Locate points in Hospital Provincial and Parque Rafalafena and run the tool. Take the same points as input and check in Google Maps. Does the result shown by the application matches with the result shown by Google Maps?** *
Mark only one oval.

- ( ) Yes
- ( ) No

19. **If the result is different, what could be the possible reasons for the difference? (Multiple Choice)** *
Tick all that apply.

- [ ] OpenStreetMap is not qualitative, it misses turns and one way errors.
- [ ] The application does not count traffic information.
- [ ] Google Map are maintained by professionals so they are more accurate.
- [ ] The result shown by OpenStreetMap is right because Google Map has errors.
- [ ] It shows the same result
- [ ] Other: ____________________

20. **If the data quality of OpenStreetMap is enhanced and also the traffic data is included, Will the result be more accurate?** *
Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

Application Feedback Service Area and Location Allocation

21. **Click the "Service Area" tool and Try to find the area covered by hospital in 3 minutes drive time. Select hospital as "Facility" with break values 3. What is the result?(Multiple Choice)** *
Tick all that apply.

- [ ] It covers main Castellon Area in the Ring-Line.
- [ ] It doesn't include Grau.
- [ ] The result doesn't seems right.
- [ ] The result seems right according to the given input.
- [ ] Other: ____________________

22. **Click the "Location Allocation" tool and Try to find out the Police station that can be readily available if any incidents happen. Select UJI, Parque Rafalafena and Parque Ribalta as "Demand points", points where incident might happen" And try to find out which police station can be chosen. Therefore, Select Police as "Facility" with 2 as "Number of Facilities". What is the result show? (Multiple Choice)** *

Tick all that apply.

- [ ] It shows the nearest police location.
- [ ] It gives wrong result and doesn't locate the right police office.
- [ ] Location of the police is wrong.
- [ ] Other

Conclusion

23. **After using this application"Castellon-A step toward Preparedness", do you think OpenStreetMap can be used for navigation for Castellon during emergency?** *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

24. **If there is no missing data in OpenStreetMap and all the data are validated will it increase the quality of OpenStreetMap?** *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Other: ____________________

25. **Will you personally contribute to OpenStreetMap in order to increase its quality?** *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

26. **Do you think OpenStreetMap routes are reliable to be used during emergency in disaster prone areas?** *

Mark only one oval.

- ( ) Yes
- ( ) No
- ( ) Maybe

27. **Personally how do you rate(1-5) the quality of current OpenStreetMap of Castellon?** *

Mark only one oval.

1	2	3	4	5
( )	( )	( )	( )	( )