MASTER THESIS

Prioritizing mapping areas in OpenStreetMap using quality metrics for improving disaster preparedness

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Abstract

According to UN's Sustainable development Goal (SDG) # 11 there exist challenge in measuring the indicators for disaster risk resilience is the availability of data. Most of the developing countries lacks basic spatial data that is required for measuring risk related to disasters. during the disaster unavailability of data causes delays in rescue operation which puts lives in danger. OpenStreetMap (OSM) is often used for disaster rescue operation to produce and exploit spatial information. This is because OSM is free, open and editable and contains millions of spatial features combined with non-spatial information in the form of tags. Due to its freedom the quality of OSM is often questionable and it needs to be assessed. The quality assessment should be application specific to be able serve best to the users.

This study will focus on how spatial data can be produce in OSM to enhance the flood preparedness by prioritising mapping areas and practically implement this by organising coordinated mapping event. This study will analyse the first *who are the users, what spatial data do they require for disasters and what are their struggles while dealing with this spatial data*. **Humanitarian organisations** like Red cross are found to be *users* and they struggles with information about critical infrastructure. Their struggles include completeness, reliability and trustworthiness of information about critical infrastructure and availability of satellite imagery. Two most essential spatial data requirement includes (a) buildings and (b) road networks.

Taking this into account four quality metrics (QM) were developed to prioritise the mapping area which are: (1) Tag completeness focuses on the how complete the information about critical infrastructure is in OSM. (2) Reliability checks the last date and frequency of edits of the features representing critical infrastructure. More recent and frequent the edit is more reliable it is. (3)Experienced mappers check the mappers experience. (4) Application specific QM considers the specific end application and prioritise the areas for mapping. Mapping areas are prioritised using this quality metrics approach in selected study area (Dar es Salaam). Results shows that reliability and experienced mapping have correlation with tag completeness. So, the tag completeness and application specific quality metrics will be used in prioritising mapping areas in coordinated mapping event.

Second important spatial data requirements are *road networks.* Keeping in mind its end application routing algorithm is developed which uses the highway tags to assign speed to the edges. Results shows that *highway:unclassified* is considered as inadequate tag because speed cannot be assigned to edges with such tag. Next three scoring criteria was developed to assess the quality of available satellite imagery.

Combination of QMs, findings from routing algorithm and satellite imagery scoring two mapping areas, Dar es Salaam and Tadjoura were selected to measure the success of this approach. AOI-1 is prioritise for highway tags for better routing and AOI-2 is prioritise for mapping buildings for better flood exposure mapping. For comparison and measuring success of this study, mapathon is divided into two groups. First group mapping area is prioritise using QM approach and second group without. The impact of the mapathon is measured by calculating service areas for hospitals in AOI-1 and flood exposure for AOI-2. The mapathon results in significant improvement in quality of the information for both AOI.

Although the comparison approach found not be successful in comparing both groups because both groups were in a different geographical location in the same AOI. This creates the

comparison and measuring of success of this approach over traditional one difficult. For this reason, hypothetical mapathon is designed which is divided into two mapping tasks in same area instead of two mapping groups in different locations. First mapping task follows the QM approach and second one without but before the second mapping task all the features would be deleted from the first tasks.
In conclusion, this approach is found to be useful in improving the quality of information in OSM. This either by improving the quality of information about geographical accessibility of hospitals in Dar es Salaam or information about number of buildings exposed to floods in Tadjoura, Djibouti. Furthermore, combination of two or more QM found to be more effective than using only the single QM.

Keywords: Humanitarian organisation, disaster preparedness, mapathon, OSM and quality metrics.

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Chapter 1: Introduction and background

1.1 Introduction

1.1.1 OpenStreetMap (OSM)

OpenStreetMap (OSM) is one of the largest volunteer contributed platforms. It is a free, editable and open access geographic information platform. OpenStreetMap (OSM) technology comes under the framework of Web 2.0, which means “Participatory web”. The volunteered generated information in the OSM is referred to as Volunteered Geographic Information (VGI) (Goodchild, 2007). VGI is that geo-referenced information that is created, edited and validated by individuals voluntarily. OSM is such an example because the data is produced by a huge community of volunteers. OSM has millions of mapped features and it evolved by time, due to this evolution, OSM is considered as a powerful tool for up-to-date geo-referenced information in this ever-changing world. These volunteers contribute to OSM for a variety of reasons. The motivation of volunteers is mainly classified as (but not limited to) educational, recreational and career development etc. (Budhathoki & Haythornthwaite, 2013).

OSM data has widely been used for various projects. It has been used ranging from creating the land inventory to disaster rescue operations (Vaz & Jokar Arsanjani, 2015). “Open Cities”, is an extensive project for creating maps for resilient cities relies on the OSM community to enrich their data (The World Bank & GFDRR, 2014). The main goal of this project is to make the maps up-to-date and complete in developing countries prone to disasters (The World Bank, 2014). The most popular example of the disaster rescue project using OSM is “Humanitarian OpenStreetMap Team (HOT)” which is proven to be successful after the mapping initiative of Haiti earthquake in 2010 (Ajmar, Boccardo, Disabato, & Giulio Tonolo, 2015). The mapping by HOT is usually done after/during the disaster by organising the so-called Mapathons (Coetzee, Minghini, Solis, Rautenbach, & Green, 2018). Mapathons is a coordinated mapping event which aims to improve coverage of the map and to help disaster risk assessment (Clark & Guiffault, 2018). HOT has proven useful in the 2015 Nepal earthquake and helped the rescue operation with the help of thousands of contributors from the OSM community by organising “Mapathon”. HOT does not only include mapping for emergency response but also mapping for disaster preparedness. These maps are then used for routing and extraction of ground information. This is also to be noted that during disasters mostly the mapping is done manually and less automatic techniques are used due to lack of knowledge among different stakeholders (Battersby, Hodgson, & Wang, 2012).

1.1.2 Mapping in OSM

Before you can start mapping in OSM for any project it is necessary first to answer a few questions. These questions include: (a) what areas should be mapped? (b) what objects are needed for the purpose? (c) and what attributes of those objects are needed (The World Bank, 2013). If the project is to draw the boundaries of land parcels then answering to (a) would be a city/town administrative boundary, answer to (b) would be properties demarcation and (c) attributes would include the area in sq. meters (Vaz & Jokar Arsanjani, 2015). But answering these questions in projects like the HOT is much more complex. The decision to select an area depends on what type of features are already there and what type of attributes are needed also depends on a certain type of disaster and surroundings.

In OpenStreetMap (OSM) you can map any place in the world with minimum skills. Different types of information can be added to the spatial features such as buildings and roads in the OSM using tags (Olbricht, 2018). This information can be used for calculating different measurable components of risk for example: flood exposure modelling. These models then can further be used for anticipating damage and response due to the disaster (FEMA, 2018).

1.1.3 Mapping in disaster context

Many rescue operators use OpenStreetMap (OSM) for response (Mezzana & Quinti, 2017). This creates the pressure on assessment of the quality of the OpenStreetMap (OSM). These disaster charters are useful for satellite mapping but these mapping lacks the local knowledge (UN HABITAT, 2011). This local knowledge can be brought about by open and freely available tools like OpenStreetMap (OSM) (Mocnik et al., 2019). Which serves the advantage to the rescue operators.

Better preparedness is the key, since disasters are unpredictable and spontaneous (Farthing & Ware, 2014). It also depends whether the data is missing, unreliable or out-of-date (Van Westen, 2013). If we put this in a descriptive way we term this as *low quality data* and this can lead to complications. Spatial data quality includes accuracy, completeness, lineage and consistency (ITC, 2019)(see **Figure 1.1**). Quality is further classified into intrinsic and extrinsic quality (Nasiri, Ali Abbaspour, Chehreghan, & Jokar Arsanjani, 2018).

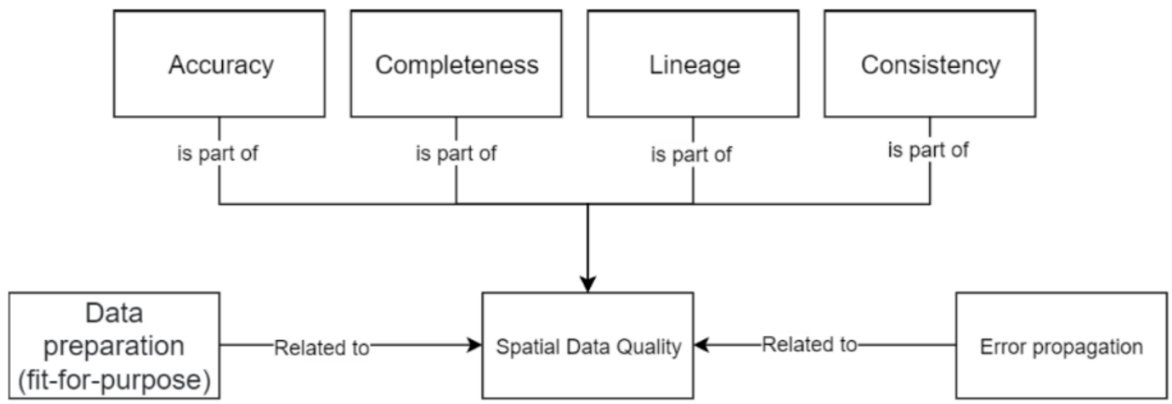


Figure 1.1: Concepts related to and part of spatial data quality according to the living textbook (ITC).

1.1.4 Mapping for routing tasks

One of the important tasks during mapping related to disasters is routing (Kilsedar, Oxoli, Francesco, Michael, & Minghini, 2017). Because people need immediate escape from the affected locations (Huang, Smilowitz, & Balcik, 2013). As routing is the location based service and requires additional attributes which helps define time-distance costs (Neis, Singler, & Zipf, 2010). If these attributes are not present then the routing can be considered as 'incomplete' for disaster scenarios (Neis et al., 2010). These attributes include the capacity, type and surface of the road. These attribute information help define the cost attributes.

OpenStreetMap(OSM) is considered as an important source for routing during disasters (Leonardo, Mooney, & Minghini, 2017). Information about the roads can be added in the OSM in the form of tags **(taginfo)**. To fill this incompleteness mapping events are organised either during the disasters or long-term mapping projects to maintain the mapping quality of the OSM (Humanitarian OpenStreetMap Team, 2019)

1.2 Research problem

As mentioned in the introduction, the quality of OpenStreetMap (OSM) is often questionable because the data is large and is contributed by different volunteers with different levels of experience (Zhang, 2017). Disaster responders rely on OSM as the data source because it is open source and editable so they can update it at the time of disaster according to the changing circumstances (Soden & Palen, 2016). Another reason for using OSM during a disaster is because in many countries, this is the only accessible source (Palen, Soden, Jennings Anderson, & Barrenechea, 2015).

1.2.1 Struggles during disaster

During the Haiti 2010 earthquake, the government buildings and resources for mapping were destroyed and OSM was the only source that was available (Anderson, Soden, Keegan, Palen, & Anderson, 2018). Adding to that, research has shown that the maps of many cities are of poor quality with respect to tag accuracy, update frequency and contributor's profile (Coetzee et al., 2018). If the disaster occurs, lives could be in danger due to unavailability of information.
It is thus important to assess the quality of the OSM before the disaster and also to know the user requirements of mapping quality during the disaster. Timely availability of high-quality data can improve the rescue operation and can save lives (Husen, Idris, & Ishak, 2018). There are various quality attributes such as tags, edit history and contributor's experience that can affect the quality of OpenStreetMap (OSM). The reason for that is the current mapping initiatives are mainly based on the government requirements, media attention and during disasters but the gap identification before the disaster on where and what to map remains tricky (Jaime C, Personal Interview, 28-Oct 2019). The issue of data quality is of interest for the rescue operators, they need to quantify the risky areas on the map with the information that is complete, reliable and trustworthy (Chakraborty, Wilson, Sarraf, & Jana, 2015).

1.2.2 Disaster response routing

The planning of the response routes during disasters is also a controversial issue as road transport is the main source of transport during the disaster (Moradi et al., 2015). Information about the routes is important because during the disaster many of the routes are non-functional (Panjamani, Srinivas, & Chandran, 2011). Road attribute values such as "highway", "max speed", "name" and "oneway" can be considered as incomplete in the case of disaster. These attributes help define the costs. Attributes such as "Avoid Areas" or "Blocked Area" usually required for effective routing during an earthquake (Neis et al., 2010). These characteristics can only be defined by edges (highway) on the map. But if the quality of edges is not being analysed, it can affect the routing during the disasters. To map this, additional presets and metadata will be axiomatically required. Furthermore, data quality assessment for the routes is of interest because if the routing is done efficiently it can reduce the access timing to\from affected areas (Osaragi & Noriaki, 2015).

1.2.3 Quality assessment for disaster applications.

Many countries have OSM mappers with a wide range of experience, and usually contribute in different ways such as mappers, managers and validators. This raises the concerns of the quality of the data produced (Bégin, Devillers, & Roche, 2018). There is an uncertainty that the quality of the OSM is already of an acceptable level and the impact of the quality assessment is not much. Quality assessment in OSM has got many researchers attention (Minghini & Commission, 2017; Zia, Cakir, & Seker, 2019), but it all serves some specific applications. Most literature does not show the specific quality assessment for disaster mapping. Adding to that, Ludwig mentioned in their study that general quality assessment of the OSM is less important than quality assessment for specific purposes such as disaster response preparedness (Ludwig, Kotthaus, Reuter, Dongen, & Pipek, 2017). (Eckle & De Albuquerque, 2015), compares the data produced by experienced local mappers and remote mappers for assessing the quality of OSM for disaster management purposes. This is the only published framework found so far, which covers an interesting point on matters of local knowledge and mapper experience (Eckle et al, 2015).

The impact of the quality assessment methods for disaster mapping purposes should be tested on components that are useful for the users in the disasters. Another reason is to specify some presets for routing purposes which can make the accessibility measurements during disaster optimal (Neis et al., 2010).

1.2.4 Satellite imagery requirement

Not only the quality attributes are important to consider but how to digitise the features (lineage) on the OSM is also challenging (Coetzee et al., 2018). This arose another problem, which is the availability of fit-for-use satellite imagery. Up to date satellite imagery is the main cord for mapping in the Open Street Map (OSM). If the satellite data is not reliable it can cause “blunders” as mentioned by (Epstein, Patai, Julian, & Spiers, 2019) in which thousands of wrong edits were digitised in OSM due to usage of out of date satellite images (Russell et al, 2019). Furthermore, satellite imagery is usually taken from a large number of different open-source imagery providers for Humanitarian OpenStreetMap Team (HOT) projects which exacerbate the problem of *“which source to rely on”* and *“which source is suitable”*. Despite the activation efforts from the International Charter Space and Disaster, there are still delays in the acquisition of high-resolution satellite imagery (Kojima, Yárnoz, & Pippo, 2018). It is also evident from Voigt’s research, who assessed the temporal trends of the satellite-based emergency mapping (SEM) response. Even advancement of technology and satellite data there are still delays in the acquisition of satellite data (Voigt et al., 2016). Impact of these delays is marked as ‘high’ as assessed by the Digital Transformation Monitor of European Commission (Probst et al., 2018). It is necessary to recognise what features are needed and what features are identifiable to know spatial data requirements of satellite images.

1.2.5 Agenda setting

In conclusion, quality assessment, the definition of specific presets and reliable meta-data is needed before OpenStreetMap (OSM) can be made available for a considerable quality (Kounadi, 2009). Different presets and different metadata produce different results on the map (Dittus, Quattrone, & Capra, 2016). As the mapping is usually done with large scale volunteers contribution so there is a need to define certain standards on how the mapping should be done (Coetzee et al., 2018). Rescue operators face difficulties in ranking the mapping areas concerning the mapped quality. Reliable information is desirable, and tasks needed to be done in a very limited time (Khaffaf & Khaffaf, 2016). In these situations, mapping is also done in a very less time which creates coordination for the mapping difficult (Anderson et al., 2018). So, there is a need for an integrated approach that can evaluate the quality of OSM for specific purposes such as disasters. So, that the mapping areas can be prioritised, and mapping can be done systematically and optimally before the disaster occurs.

1.3 Research objective(s) / research questions

1.3.1 Main Objectives

The main objective of this research is to help the rescue operators to prioritise the mapping areas and to develop method(s) to ensure that mapping can be done optimally. These areas can be evaluated first by assessing the quality of the OpenStreetMap (OSM) by developing quality metrics. Second is to test the impact of the quality of OSM related to the specific application i.e. disaster response routing. Once the impact of the quality of OSM is tested, methods to test 'fit-for-purpose' satellite imagery can be evaluated by setting different criteria so not only the mapping areas are prioritised but digitising of the OSM is also underpinned. This as a whole serves in making OSM increasingly self-reliable. Flood disaster will be the focus of this study. There are 3 sub-objectives of this research:

Sub Obj 1. Evaluate methods to determine and visualize the quality of OpenStreetMap (OSM)

Q1.1: What type of quality heterogeneity exists in OSM and what is the influence on specific applications?
Q1.2: What type of quality attribute(s) can be used for OSM quality assessment?
Q1.3: Which element of the OSM quality can be emphasised for specific purposes?

Sub Obj 2. Evaluate the impact of the quality of map related to disaster response routing with respect to the requirements.

Q2.1: What constitutes a suitable disaster response routes model and how can the features related to disaster response routes be identified using satellite images with respect to user requirements?
Q2.2: How can the quality of OSM and its content affect the disaster response routing model?

Sub Obj 3. Develop an integrated approach to ensure that the mapping is done systematically and meticulously.

Q3.1: How can we evaluate if the satellite imagery is fit-for-purpose?
Q3.2: How can the combination of quality assessment methods, disaster escape route application and satellite image quality assessment methods help in defining metadata and presets for prioritising the mapping areas for organising the mapping events?
Q3.3: How much of this integrated approach can help disaster managers in prioritising the mapping areas?
***Critical questions** to answer first are who wants to use this approach? Who is the actual rescue responder? What spatial information is required? And what matters in the disaster scenario with respect to the quality of OpenStreetMap (OSM)?.*

1.4 Summary of the chapters

In this chapter we have discussed the research problem and objective of this research. In Chapter 2 we shall go in detail about the scientific significance of this study. Chapter 3, we will analyse which stakeholders are involved in mapping for disaster and their mapping requirements to set the stage for developing quality metrics. In chapter 4, we discuss the four quality metrics developed. Chapter 5, we apply these four quality metrics developed to our case study area and discuss the results and it can be used for prioritising the areas for mapping. In chapter 6 we take a shift towards developing the routing algorithm for disaster response routing. Chapter 7 we will discuss how to check the “fit-for-purpose” satellite imagery. Chapter 8 we will apply the quality metrics technique by organising a mapping event. Chapter 9, we will discuss the findings and conclusions of this study.

Chapter 2: Scientific significance

2.1 Introduction

In this chapter we shall discuss the contribution of this study to science, UN sustainable development goals (SGDs) and Sendai framework. After this conceptual basis of this study will be discussed.

2.1.1 UN Sustainable development goal (SDG)

Scientific significance of this research lies in struggles during different disaster cycles to reduce the disaster risk as much as possible. Here we will be dealing with the struggles with the quality of the data in the OpenStreetMap (OSM) and how it can affect the different applications during disasters. These applications will give insight about the pros and cons of using this study in practice. Main goal is in line with the UN SDG# 11 to reduce disaster risk. According to the *‘2018 Review of SDGs implementation: SDG 11’* the indicators to measure success and failure of SDG 11 remains challenging due to non-availability of measurable data (United Nations, 2018). Furthermore, timely data availability is the major contribution to success of measuring the SDG indicators related to disaster risk reduction *(Target 11.5, Indicator 11.5.1 and 11.5.2)* (United Nations, 2018). This is because risk can be reduced if we have information about the specific location to allow the integration into risk calculation (Schneiderbauer et al., 2017). Information on local level is required which can bring better risk information which leads to informed disaster response (Gevaert, 2019). Better quality of information in OpenStreetMap (OSM) can contribute in increasing the disaster resilience because of its accessibility (Ospina, 2018).

2.1.2 Sendai framework

This study is helpful for humanitarian organisations such as Red Cross to map developing countries before the disaster occurs by looking at the quality of the OpenStreetMap (OSM) (see: stakeholder analysis). The priorities for action (see **figure 2.2**) stated in the Sendai framework for disaster risk reduction 2015 - 2030 states that its emphasis on disaster preparedness for risk reduction (UNISDR, 2015). One of the strategies for enhancing disaster preparedness is availability of high quality data. OpenStreetMap (OSM) serves best to bring all the information together for disaster response (Zia et al., 2019). Intrinsic quality assessment of OSM will also be a step towards increasing its self-sustainability for disaster purposes.

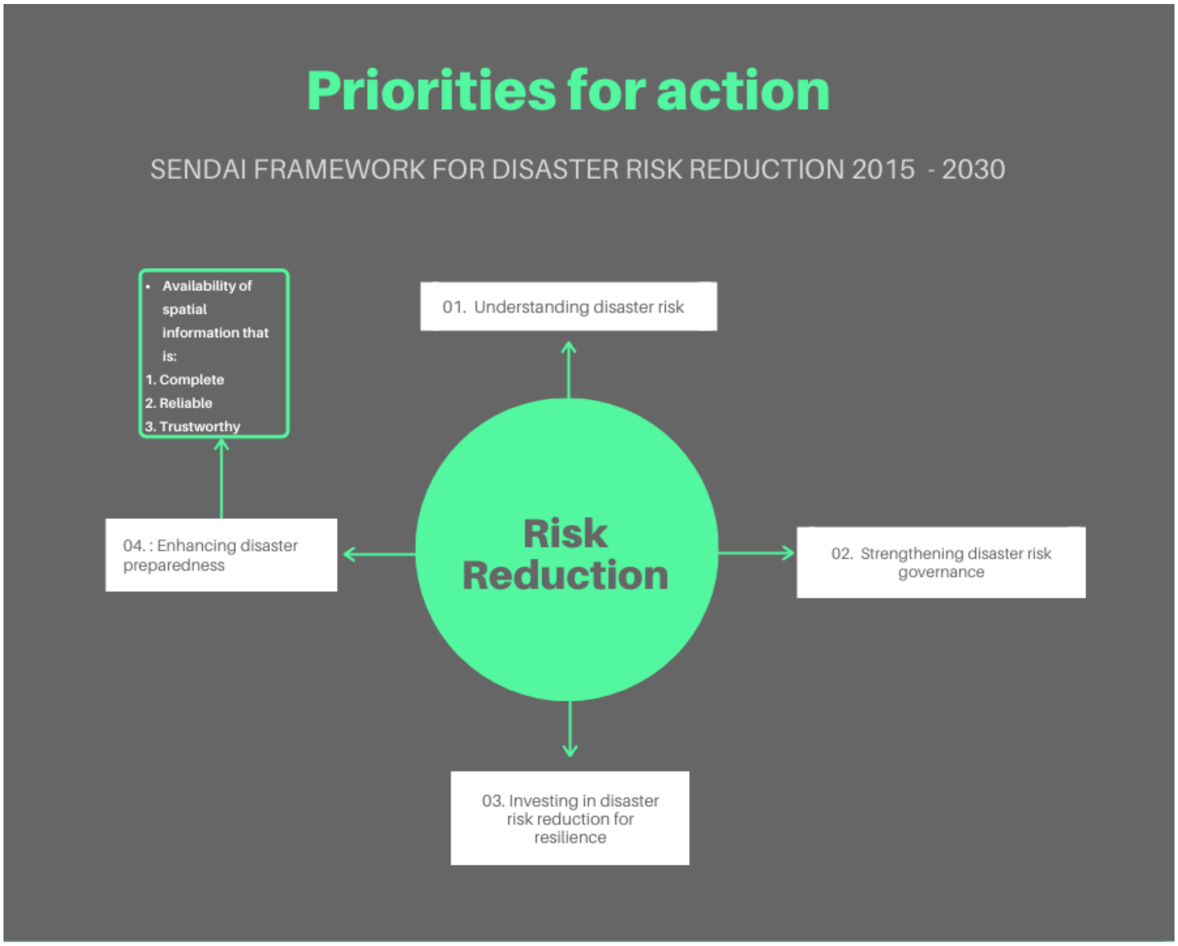


Figure 2.1: Priorities for action according to Sendai framework 2015 - 2030.

2.1.3 Focus of this study

This study focuses on flood related disasters and how the mapping can be done efficiently in order to produce information that is helpful for the disaster response. We will apply this mapping approach in Dar es Salaam as an example study. This study will contribute to the mapping procedures that are followed by different organisations for making the cities prepared for disasters. It also comprehends the stakeholder analysis to get an overview about the actors involved in the mapping for disaster preparation. This overview will give insights to establish the mapping requirements concisely to the subject matter. There is another side to the story as well, when disaster occurs in a country it gets all the media (including social media) attention which fuels the mapping attention (Mezzana & Quinti, 2017). This might be helpful for that location but other (say) developing countries get neglected, which results in lack of information. So, there is a need for a standard procedure for mapping before the crisis, which is not restricted to media or governmental attention.

2.1.4 Disaster cycle

The four common parts of disaster cycle are preparedness, response, recovery and prevention (Kathrin Poser., 2010). Preparedness part is of course the most important and often not taken into account for mapping if we match it to the mapping procedures of humanitarian organisations (Jaime C, Personal Interview, 28-Oct 2019). There are indeed a lot of governmental and non-governmental organisations that contribute to their national mapping for the purpose of disaster preparedness (Aminizade et al., 2017). But the mapping in the under-developing countries has no such detailed national mapping or even such agencies (Kloner, 2019). In order to make things worse these countries are the one that are mostly hit by disasters.

2.1.4.1 Disaster preparedness

Preparedness planning for disaster is very wide with a lot of spatial and non-spatial requirements. This includes community planning, early warning system, monitoring and emergency planning (Neis et al., 2010; UN, 2015). Geo-spatial data acts as the core for the disaster preparedness planning (Ajmar et al., 2015).

The preparedness gets better with time and recurrence of disaster. More experience is gained because the short-comings are recognised after the event (UN, 2015). The quantification of the requirements for disaster preparedness is always a daunting task (Krellenberg et al., 2014). One requirement always remains essential, that is the availability of spatial information.

Example case

Examples are Haiti and Saint-Martin island, which got quite a lot of attention in the humanitarian openstreetmap (HOTOSM). Keyword “Haiti” mapping search results in more than 80 mapping tasks. The attention is not wrong but it is required at the time of emergency, but the issue is that many areas that are disaster prone do not get attention and when the disaster occurs the maps are not complete and emergency mapping campaigns cost time. Recent example includes mapping campaigns in Djibouti (HOTOSM 2020).

2.1.5 Causes disaster-related casualties

One the main reasons for disaster related casualties are the institutions or unavailability of information for disaster related scenarios (Soden & Palen, 2016). This in turn due to unavailability of information about the features that are usually required to quantify the impact of the impending disaster.

All phases of disaster need information that is up-to-date and accurate (Poser & Insight, 2015). Adding to that, the worst time for producing the information is during a disaster because there will be panic and pressure among the mappers and it can cause mistakes (Krellenberg et al., 2014). That is why it is important to produce spatial information before the disaster by anticipating the information requirements.

During the disaster, in many cases there is a chance of overflowing the information from different sources (Aminizade et al., 2017). This hinders the disaster response and can possibly cause delays which results in loss of lives.

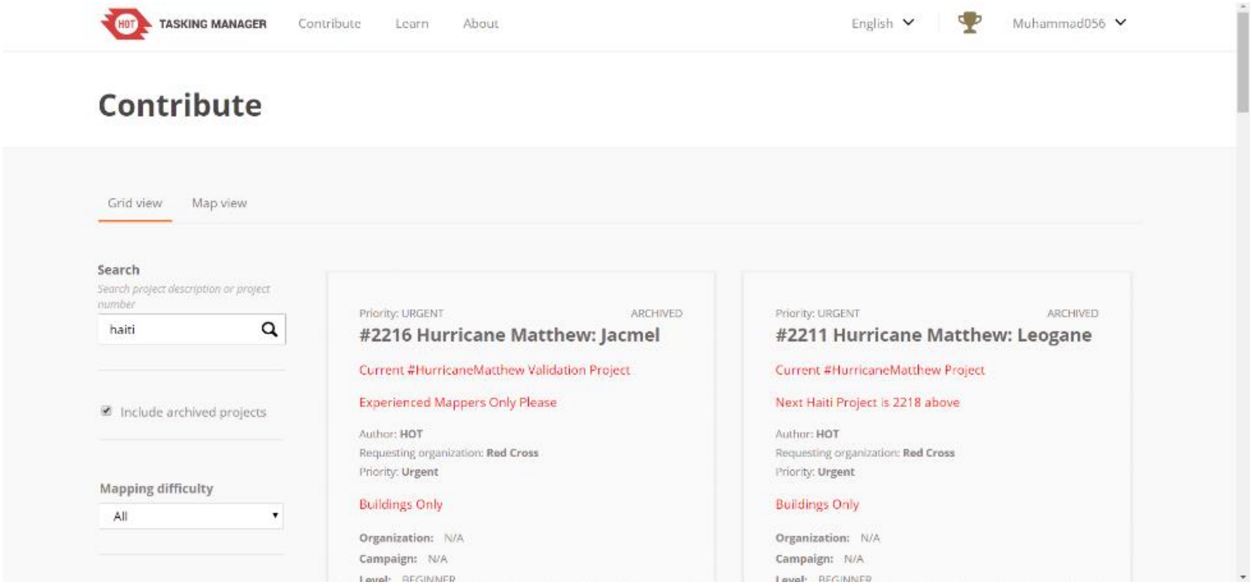


Figure 2.3: HOT tasking manager mapping projects in Haiti. This is an example on how the volunteered geographic information is collected for humanitarian context.

2.2 Conceptual basis of the approach

2.2.1 Purposeful mapping

2.2.1.1 Introduction

As mentioned in the introduction section, the current mapping procedure lacks the mapping for preparedness scenario and there is a need to improve the procedure inorder to exploit the necessary information in time (Jaime C, Personal Interview, 28-Oct 2019). Here it will be discussed in detail the current and proposed mapping procedure.

2.2.1.2 Mapping technology

Maps are used in everyday life and it has various purposes in daily life (Jobst & Gartner, 2019). Maps are used to convey information to the end-user and end-user is the one that wants to use this information in order to utilise this geo-spatial information for its specific purpose (Ajmar et al., 2015). Spatial information requirements vary with the final purpose and user requirements (Voigt et al., 2016). In the context of this research we will look only into the mapping for flood preparedness. Before discussing the final map product let's first look at the process of map making for humanitarian organisations. For risk management four cycle is important to mention here for mapping:

1. Prevention
2. Preparedness
3. Response
4. Recovery

In this study we will mostly be mapping for preparedness which will have impact on prevention measures. Then eventually have impact on response and recovery.

2.2.1.3 Current conceptual relations for mapping

Current concepts that are in place for flood preparedness mapping are usually initiated by the requests from the government that are usually exposed to certain types of disaster (Krijnders K, Personal Interview, Jan 14, 2020). All the user requirements are generated from the government experts and/or expertise from the humanitarian organisation itself (see: actors). These experts define the spatial information requirements which are area and disaster specific. After this, mapping is usually conducted by GIS experts in combination volunteers usually using the open platforms like HOT task manager (https://tasks.hotosm.org/). These types of mapping usually require local mapping which is also one of the reasons for inviting local volunteers for mapping (Mezzana & Quinti, 2017). Usually in developing countries volunteer mappers are not very experienced mappers (Quattrone & Meo, 2015). For these reasons GIS experts/experienced mappers enhance the maps by validating the edits that are made by those mappers.

2.2.1.3 Proposed conceptual relation for mapping

Mapping for the flood disaster should start with the recognition of the hazard type and level of severity in an area and impending disaster can cause damaging effects (direct and indirect). This hazard information can be and usually exploited using open sourced hazard models like thinkhazard.org which is the initiative of the world bank (Fraser et al., 2017). After recognising the disaster prone area, mapping requirements can be exploited by interviews with humanitarian organisations and literature review.

Existing research found interviews with local communities useful in recognizing the spatial information requirements as well (Poiani, Rocha, Degrossi, & Albuquerque, 2016; Schnebele, Cervone, & Waters, 2014). These requirements can be fed as quality standards and criteria for the quality metrics which will be discussed later on. Then it can be used for developing mapping strategies depending on requirements and available resources. This will be discussed after the results from quality metrics. **Figure 2.4** summarises the proposed conceptual relation for mapping.

2.2.1.4 Defining *purposeful mapping*

Now we are in position to define purposeful mapping for this analysis. According to the analysis that is conducted in the research, mapping is considered as purposeful when it has an impact on certain applications used for humanitarian purposes.

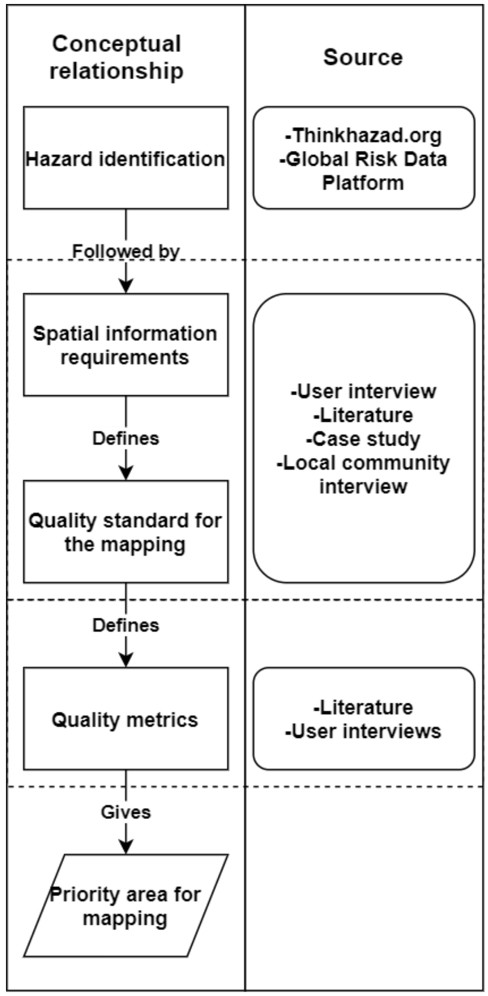


Figure 2.4: Conceptual relations for prioritising the mapping areas in the context of disaster.

2.2.2 Scope

1. The main challenge with the proposed procedure is as it tends to generalise the mapping requirements irrespective of the location. There are several location specific factors that can also control the spatial information requirements. These requirements can be specified by interviewing local communities (Mezzana & Quinti, 2017).
2. Another challenge is the uneven distribution of internet access (WMO, 2017). This creates the digital divide and creates the tradeoff between local knowledge and access to technology. In order to optimise the mapping both the local knowledge and access to technology is important (Fraser et al., 2017).
3. The hazard information can also be unavailable or not accurate.
4. There are other techniques to prioritise mapping areas using more advanced algorithms and advanced indicators. These AI techniques can give much faster results than the one proposed here.

Chapter 3: Defining quality/mapping requirements

3.1 Introduction

To know what should be on the map, first it is important to know who has the most influence on the mapping contributing to disaster preparedness (Farthing & Ware, 2014). This will help in identifying the users and helps on who to interview, which literature to review for the purpose of setting spatial data requirements and spatial data standards. This will finally help in defining the requirements for the disaster preparedness maps. **Figure 3.1** summarises the steps for defining the quality metrics through mind-map. This analysis will help in determining which quality attributes can be used for prioritising the areas to be mapped with certain spatial requirements (see: sub-obj-01). This is necessary to analyse to know what kind of information should be available for flood preparedness and can be added by which stakeholder and how it can be added to OpenStreetMap (OSM).

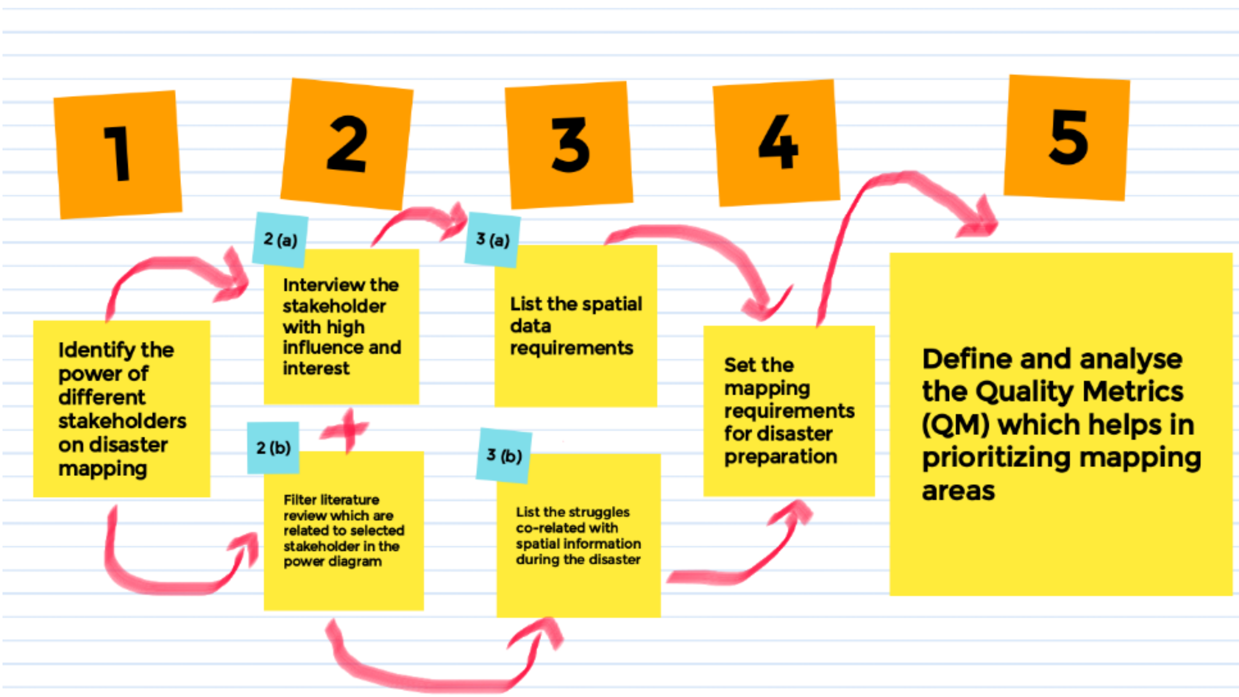


Figure 3.1: Mind-map for the steps for defining the appropriate quality metrics. This mind-map represents the work-flow in defining the quality metrics for the purpose of flood preparadness.

3.2 Actors

When it comes to disaster there is no single entity that manages different phases of the disaster (UN, 2015). Involvement of actors varies with disaster cycles (Pratzler-wanczura & Sapountzaki, 2014). Different actors contribute with respect to their interest and power to influence in prioritising the mapping areas which is the ultimate goal of this study. Furthermore, this study is about the engagement of OpenStreetMap (OSM) in disaster preparedness and OSM exercise depends on the engagement of different stakeholders (Gunawan, Fitrianie, Yang, Brinkman, & Neerincx, 2012).

We shall view these actors in their influence and interest in prioritising mapping areas for disaster scenarios by looking at their interests in each disaster cycle.

1. Mappers
2. Disaster managers
3. Society
4. Humanitarian organisation
5. Media
6. Private sector

3.2.1 Stakeholder analysis

After the recognition of major actors involved in disaster mapping, stakeholder analysis is done by scoring each actor. Scoring is done between 1 to 3, where ‘1’ represents low. ‘2’ represents medium and ‘3’ as high. Same scoring criteria is used for grading ‘interest’ and ‘influence’ and both of the criteria have been graded separately and then added.

With the help of literature review we scored all six actor’s influence and interest in mapping before and after disaster. Stakeholder analysis will give for whom the objective of this research serves the best and how much influence and interest do they have. Results can be seen in **table 3.1**.

3.2.1.1 Mappers

Mappers here are the combination of people that are skilled and unskilled volunteers that make themselves available during a mapping campaign (Arsanjani, Mooney, Helbich, & Zipf, 2015). They mostly follow what is required from them and follow the instructions that were provided to them during the mapping event (Coetzee et al., 2018). They use their level of expertise to add as much spatial data as possible and as per required by the task assigned (Westrope, Banick, & Levine, 2014). They have very less influence on selecting an area to be mapped as they map according to the task that is given to them (Clark & Guiffault, 2018). Nevertheless, they have very high interest and motivation to contribute to the humanitarian cause (Budhathoki & Haythornthwaite, 2013). Their interest can be used in advantage for mapping to reach specific requirements.

3.2.1.2 Disaster managers

Usually state actors that are professional in planning, governance etc are meant here. disaster managers are usually highly skilled and have global agreements with international organisations to aid their operation (Caulker, Katsea, & Shraiman, 2018). Usually G8 industrialised countries have access to *systems of systems* by which they assess the risky areas and perform the risk

assessments and information gap analysis (UN, 2015). While there are global organisations but there are governmental level organisations that are much older than these international organisations like GEOSS, UNDRR and copernicus etc meaning the governmental organisation should have much more local information than international organisation. This is also indeed due to the fact that there exists the tradeoff between financial sustainability and technological choices (Caulker et al., 2018). This financial trade off makes their interest on only the matter that is most important to the governements. This makes the production of spatial information before the disaster difficult for many developing countries (Amade, Painho, & Oliveira, 2018).
Even if the governmental disaster responders are available with resources they are still bound to legal boundaries which might cause delays in decision making before the disaster (Jerneck & Olsson, 2008). In conclusion, they have interest in producing spatial information but in developing countries due to financial constraints makes their influence on this matter less than required.

3.2.1.3 Citizens

In case of developing countries citizens don’t have much influence on prioritise mapping areas unless there is previous disaster event and enough capacity development (Ngwese, Saito, Sato, Boafo, & Jasaw, 2018). If there is a certain level of awareness then the motivation to map his/her area would increase because of the interest and knowledge (Haklay, 2013). The research has shown that well aware citizens can bring influence and attention about prioritising the mapping areas even before disaster (WMO, 2017).
During and after disaster citizens act as sensors by reacting on their social media accounts which has geo-reference as well. Many workflows have been used to locate these tweets (for instance) to prioritise areas for rescue and mapping (Meier, 2012). But the data collected from the crowd usually have quality issues (Haklay, 2013). This makes the influence less as compared to other stakeholders.
In conclusion citizens have very less influence on prioritising mapping areas before disaster (our case) given that the capacity development is low amongst them (developing countries). This is important to mention the level of awareness because areas with less capacity development are the ones most affected (UN, 2015). Furthermore, the citizens' interest and influence is a complex phenomena during the disaster so it is very hard to generalise (Aminizade et al., 2017). Discussion about prioritising the areas for capacity development can be useful but it is beyond the scope of this study. This study generalises this statement while there can be many variables that can actually define the power of citizens in disaster mapping which is out of the scope of this study.

3.2.1.4 Humanitarian organisations

Humanitarian organisations here include those NGOs and global organisations that work for the quick response in the cause of disaster and work for improving the response using measures before disaster using ICT. Their aim is usually to work for the humanitarian cause and save lives in an emergency situation (UN, 2015). This aim builds trust in these organisations among the general public and governmental institutions (Caulker et al., 2018).
They are the ones that have very high influence on how mapping resources should be provided and used because of their experience and trust. Before the disaster they follow the mapping

request made by different governments with specific requirements (Jaime C, Personal Interview, 28-Oct 2019). Furthermore, they are also influenced by the media to map or prioritise certain areas for attention (Velev & Zlateva, 2012). During the disaster all humanitarian organisations become very active and start collaborating with each other for data sharing and communication and play a major role in producing spatial information for quick response (Caulker et al., 2018). In general humanitarian organisations have high influence and interest on how spatial data should be produced and used. For this reason this actor will be the centre of attention in this study.

3.2.1.5 Media

Media serves an important role in engaging stakeholder's attention to certain locations by conducting reporting from the affected area (A. Nelson, Sigal, & Zambrano, 2010). Media's coverage fuels the motivation of mappers, citizens and humanitarian organisations to contribute more to a certain cause (CARISMAND, 2020). This results in more mapping in the area of media coverage. This is how media plays a role both before and after the disaster in prioritising the mapping area. Of course media coverage before the disaster is questionable and rather limited (CARISMAND, 2020). There also exists a problem of communication being cut-off due to the impact of the disaster (A. Nelson et al., 2010). This situation is very common during floods which subordinates the influence of the media.

Non-state media's interest lies in developing stories which have higher impact on viewers, such as devastating disaster, underlining poverty and war etc (Moeller & Moeller, 2020). This interest is useful only after and during the disaster not before strictly speaking for the interest of prioritising mapping areas. As the news travels international humanitarian organizations start taking actions. This conclusion put state media with greater pressure of analysing their news contents for better risk reduction strategy (CARISMAND, 2020).

3.2.1.6 Private sector

Private sector comprises commercial companies that have their own mapping services like Google, Bing and other commercial satellite imagery providers. These companies collect spatial data for commercial purposes according to their client's requirements (Anderson, Sarkar, & Palen, 2019). The clients here can be disaster managers or governments that are seeking to develop disaster preparedness plans.

Due to the availability of state-of-art technology for meeting the data requirements during and after the disaster they have high influence on where spatial data could be added (Chandra, Moen, & Sellers, 2016). Also many commercial satellite companies release high resolution imageries according to the international space charter for assisting the affected countries (UNOOSA, 2019). Usually due to high costs it has not been used for mapping in developing countries (Pabian, 2015). This makes their interest and influence low in developing countries. In developing countries more freely available satellite imageries are used for disaster mapping purposes but it has doubtful quality (Pabian, 2015). We shall discuss this more in detail in chapter 7: fit-for-purpose satellite imagery.

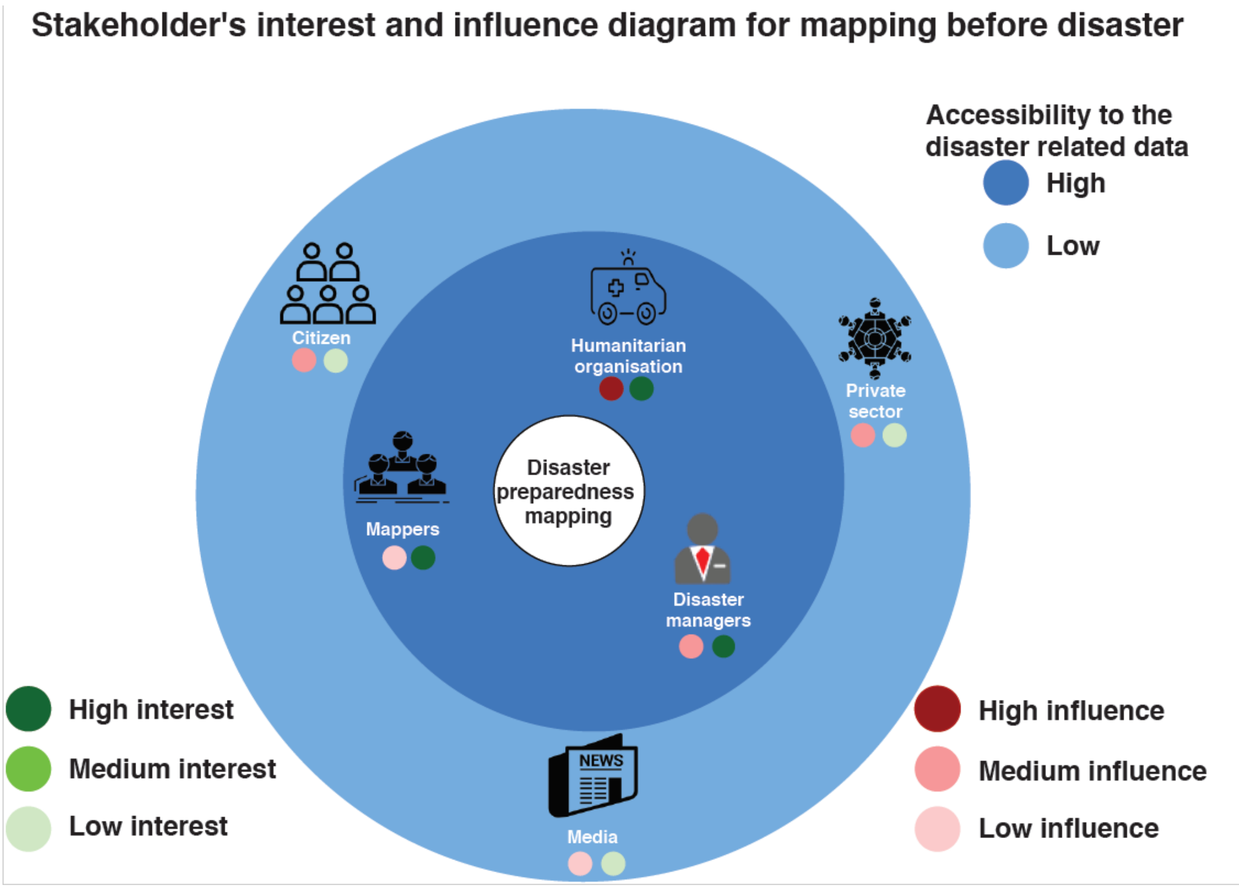


Figure 2.2: Stakeholder analysis for the actors involved in the disaster scenario with their level of interest and influence. Where The concentric circles qualifies the controls over disaster related data (see: spatial data requirements).

Table 2.1: Scoring results from the summary of the findings discussed above.

Actors	**Score**			
	Before disaster		**After disaster**	
	Interest	**Influence**	**Interest**	**Influence**
Mappers	3	1	3	2
Disaster managers	2	2	3	3
Citizens	1	2	2	2
Humanitarian organisations	3	3	3	3
Media	1	1	3	3
Private sector	1	2	3	3

3.2.2 Results

Table 2.1 displays the results from the literature review and scores for each actor discussed. From the above discussion and table 2.1, it is clear that humanitarian organisations have one of the highest interest and influence in disaster management and in selecting the mapping areas. There is also the matter of accessibility to add/edit spatial information for different purposes. The **figure 2.2** also highlights how accessible is the disaster mapping for different stakeholders. Inner circle represents that these stakeholders have relatively high accessibility to the disaster mapping before the disaster with the exception of private sector as they might or might not have access to the disaster mapping, but according to the definition of the humanitarian organisation that is used in this study if these private sectors act for the cause of humanity voluntarily. Then private sectors can also be included in this category if they do so under certain circumstances. In some other cases private sectors do have access to the spatial data as a contractor and/or consultant but that is usual for the developed countries which are not the target of this study (Pabian, 2015).

3.2.3 Outcome of stakeholder analysis

The stakeholder analysis is important because it will narrate us the mapping requirements by taking the actor with high dominance in the stakeholder's power diagram as a user (**figure 2.1**). Using this we will focus on the requirements of humanitarian organisations for mapping in scientific and grey literature. This can be done by filtering literature and interviews which are correlated to the humanitarian organisations. In the coming sections (a) We shall discuss the spatial data requirements for before and after the flood. (b) After that the issue struggles with different kinds of information during the disaster. The combination of (a) & (b) will set the standard information requirement for the formulating quality metrics.

3.3 Spatial data requirements

Exploration of the spatial data requirements will give insights about what is actually needed during the disaster, what can be made available before the disaster. Water, food, waste disposal, health care and energy are the basic needs of humankind, these needs usually go scarce during the time of need such as disasters (Caulker et al., 2018). Information about the above-mentioned basic needs is required for different purposes and this depends on different types of disaster. For instance the specific data and location of hospitals or shelter can help affected populations to navigate.

Spatial data requirements differ for different applications (Meijer et al., 2015). For the scope of this study, spatial information requirements for flood related disaster will be discussed. Even for flood scenarios there are different requirements with respect to different disaster cycles.

3.3.1 Basic spatial data requirements

The spatial data requirement analysis is done to bring improvements to 'poorly organized' information as stated by Flanagan and Metzger (Metzger, 2007) and also it gives the fit-for-purpose statement for disaster preparedness mapping. There are indeed first standard requirements that a country should satisfy for the basic urban development (Open Geospatial Consortium (OGC), 2018). According to the UN report on geospatial science and technology for development (2012), there are three basic layers which are mentioned as follows:

1. Natural environment
2. Infrastructure network layer (water, drainage and transport etc.,)
3. Buildings (including purpose of the buildings)

These layers are usually followed by the increasing level of details with respect to the specific application (Un. These requirements matter mainly on the urban planning side and it is not part of this research. The spatial data requirements for the flood preparedness mapping would be the center of attention here in this study. This is worth mentioning here because many countries don't even have these three basic layers of information and it raises an alarming situation (WMO, 2017). This increases the usefulness of the OpenStreetMap (OSM) for those countries because these layers are available and are editable in OSM (openstreetmap.org).

3.3.2 Exploring spatial data requirements

The spatial data requirement is scrutinized by literature review, case study review and user interviews. We will discuss the methods used for each review and interviews.

3.3.2.1 Scientific literature

Systematic literature review was done to define the data requirements before and after the flood. This should be noted here that the literature review was not extensive nor limited. Keywords used with logical AND/OR operators were used to combine one concept "disaster mapping" and one *term* "OpenStreetMap (OSM)" or concept "VGI". Following things were kept in mind while reviewing scientific literature:
P.1. What kind of damage do the literature and lessons learned scientific literature states?
P.2. Insight on what kind of data was necessary for conducting rescue and relief operations.
P.3. Legends that were used in the maps also represent the data requirements as it was collected from different sources.

3.3.2.2 Case studies

The purpose of studying the case study reports was to see what kind of spatial information was used before, during and after the disaster. This information defines the spatial data requirements. The reports from UN, WMO and UNISDR were reviewed for analysing the spatial data requirements from the lesson learnt. Furthermore, following mapping campaign were explored for checking the data requirement for the buildings:

1. Meteor/Dar es Salaam/Urban-Development- Mchikichini
2. Meteor/Dar es Salaam/Industrial-Development-Zone_2
3. Meteor/Dar es Salaam/Single-Family-Residential
4. Meteor/Dar es Salaam/Informal-zone

These were explored since it is very context specific and related to our study area (discussed later: 4.1.1 Case study: Dar es Salaam). This project description already gives the criteria for prioritising the areas for mapping. This criteria includes high density areas, rural settlements, informal settlements and urban development zones (William Perry, 2019). These areas are very broad, meaning that a lot of resources will be required if all of these zones needed to be covered in a given time (Jokar Arsanjani, Zipf, Mooney, & Helbich, 2015).

3.3.2.3 User interviews

Total of three interviews were conducted, one skype interview, one personal and one by email. All three were from different organisations. Organisations include Red Cross the Netherlands, Red Cross Red Crescent Climate Centre and Humanitarian OpenStreetMap team Tanzania. Interviews with officials from Red Cross the Netherlands and Red Cross Red Crescent Climate Centre were unstructured and personal. While interview with Humanitarian OpenStreetMap team Tanzania was semi-structured and by email.
Interviews have been conducted in different phases of this research. The MSc thesis period is rather dynamic so new concepts develop from time to time. So, there exists inconsistency in the interviews conducted. Due to these reasons it was not possible to add a benchmark with respect to different phases of disaster to the data requirements stated by the interviewee. To avoid this uncertainty general data requirements for disaster mapping will be mentioned here.

3.3.3 Before floods

In this section we will share the results of the exploration of scientific literature and case studies. Scientific literature for data requirements for flood preparedness or information required before the flood is explored that can be qualified for spatial data requirement in OSM. Scientific article and case study with the information requirements stated in that article is presented in **table 2.2** and **2.3.**
This is very difficult to define, since the reports about disasters are published during or after the disaster and very less literature about it is available that analyse the requirement before the disaster. User interviews are much more useful here as it gives direct insights about what data should have been available beforehand for the rescue.

Table 2.2: Results from five scientific literature review for the information requirement before flood disaster.

Article	**Information requirement stated**
(Poser & Insight, 2015)	Type of building
	Condition of the building
(Amade et al., 2018)	Building height
	Schools
(Farthing & Ware, 2014)	Extent of flood plains
	Routes for emergency access and evacuation
	Bridges
	Landmarks
	Health centres
	Water sources
	Land use
	Schools

(UN, 2015)	Network measurements
	Satellite imageries
	Digital elevation model
(Mocnik et al., 2019)	Drinking water/ water source
	Building density

Table 2.3: Results from two case study review for the information requirement before flood disaster.

Case Study	**Data requirement stated**
Jakarta floods (Indonesia) (WMO, 2017)	Shelters,
	Logistic centres
	Evacuation route
Pakistan floods 2010 (WMO, 2017)	Infrastructure across the water bodies (before and after)
	Airport
	Bridge
	Barrage (flood gates)
	Train station
	Power plant
	Railway track
	Classified roads as important legends

3.3.4 During/after flood

In this section we will share the results of the exploration of scientific literature and case studies that represent the data requirements during/after flood. Scientific article and case study with the information requirements stated in that article is presented in **table 2.4** and **2.5**.

Main target of the mapping during disaster is to map disaster-stricken areas (Estima et al., 2016). Nevertheless there are various aspects that need to be visualised using different means and sources of information (Ajmar et al., 2015)**.**

Table 2.4: Results from four scientific literature review for the information requirement after/during floods.

Article	**Information requirement stated**
(Linard, Gilbert, Snow, Noor, & Tatem, 2012)	Water source
	Fuel stations
(Poiani et al., 2016)	Roads

	Buildings
	Damaged buildings
(Stancalie & Craciunescu, 2011)	Flooded area
	Affected area
(Farthing & Ware, 2014)	Bridges
	Extent of flood
	Damaged buildings
	Damaged roads
	Damaged hospitals
	Location of relief agencies
	Public relation information

Table 2.5: Results from seven case studies review for the information requirement after/during floods.

Case study	**Information requirement stated**
Pakistan floods, 2010 (WMO, 2017)	Infrastructure across the water bodies
	Airport
	Bridge
	Barrage (flood gates)
	Train station
	Power plant
	Railway track
	Classified roads as important legends
	Evacuation routes
	Affected people location
Queensland and Victoria flood (Australia, 2010/2011) (WMO, 2017)	Affect areas through geo-locating pictures
	Affected people
Jakarta floods (Indonesia) (WMO, 2017)	Buildings
	Critical infrastructure (school, hospitals, place for worship and neighbourhood boundaries)
	Evacuation sites (before after during)
Uttarakhand floods (India, 2013) (WMO, 2017)	Affected people
	Bridges

	Roads
	Buildings
	Cleared area
	Relief camps
	Medical centers
	Road networks
Colorado floods (USA, 2013) (WMO, 2017)	Affected infrastructure
	Flood levels
Ebro river floods - Zaragoza (Spain, 2015) (WMO, 2017)	Affected area (overflowed river)
	Affected population
WMO, 2017 (General requirement)	Flood heights
	Flood depths
	Flood extent
	Health care
	Shelter
	Relief camps
	Food supplies
	Energy supplies
	Disperse people

Note: From the case study analysis it is also clear that for developing countries the basic data such as buildings and critical infrastructure was collected during the disaster while for the developed countries such as Australia there was very less problem with the available data infrastructure. Furthermore, case study of Indonesia shows that the data collected enabled the integration to calculate the hazard exposure information, this will be discussed in the late stage of this thesis (exposure model). High resolution imagery is found to be common requirement for before and after disaster this will further explored in chapter 7.

3.3.5 User Interviews results (before and after disaster)

In this section we shall discuss the summary of the data requirement stated by the users that were interviewed. Interviewees were asked two common questions (a) what do they considered as good map? and (b) what features would you prioritise first for the mapping?. The questions were specifically for the flood disaster and with respect to OpenStreetMap (OSM).

Table 2.6: Results from three interviews for the spatial data requirements and sub-requirements that increase the level of detail required in a *good map*.

Interviewee	Data requirement stated	Sub-requirements
Red Cross Red Crescent Climate Centre (Jaime C, Personal Interview, 28-Oct 2019).	Type of building	Residential, commercial or governmental
	Built environment	Not mentioned
	Construction material of buildings	Not mentioned
	Roads	Not mentioned
	River basins	Not mentioned
Red Cross the Netherlands (Krijnders K, Personal Interview, Jan 14, 2020).	Building footprints	Not mentioned
	Roof material	Not mentioned
	Construction material of buildings	Not mentioned
	Type of road	Primary, secondary or residential
	Critical infrastructure	Bus , fuel station, train station, schools and medical posts
	Type of the building	Residential, commercial or governmental
	Bridge	Not mentioned
	Building capacity	Not mentioned
	Sanitation facilities	Not mentioned
	Water sources	Not mentioned
Humanitarian OpenStreetMap team Tanzania (Kombe E, Email interview, Mar 11, 2020).	Building footprints	Not mentioned
	Transportation facilities	Highways, waterways, airways and waterways

3.4 Struggles during disaster related to information

By struggles we shall only discuss struggles over information and spatial information production in the context of disaster (Cosgrave, 2014). This will result in finding the additional temperament (quality) of the spatial data requirements that can affect the disaster operation. Lessons learnt are usually from the struggles that rescue operators faced while converting spatial data into information (Wassenhove, 2012). This will help in standardising the quality requirement of OpenStreetMap (OSM) and establish the objectives for purposeful mapping (purposeful mapping).

To analyse this user interviews and literature (Grey and scientific) were evaluated. The struggles with information while using OpenStreetMap (OSM) and other open source tools as a source of information was investigated. It is to be noted here that case studies analysed here are not only for flooding but also for similar phenomena such as cyclones and typhoons as well. As the purpose of this section is to see what type of heterogeneity exists in OSM data.

3.4.1 User interviews

Just the polygons of the features are not enough, we need more details about that object (Jaime C, Personal Interview, 28-Oct 2019). High level of detailed information is required for the bridge and if the bridge truly exists as shown in the map or collapsed or damaged? (Krijnders K, Personal Interview, Jan 14, 2020). Type of the building is emphasized in all three of the interviews. The most critical point is to know where the people are located and how much (Krijnders K, Personal Interview, Jan 14, 2020). There should be roads that are classified appropriately following the OSM hierarchy of road classifications (Krijnders K, Personal Interview, Jan 14, 2020).
One of the main struggles that interviewee mentioned was keeping the maps updated and having more active mappers (Jaime C, Personal Interview, 28-Oct 2019). Incomplete map is the most dangerous situation where there are no features mapped (Jaime C, Personal Interview, 28-Oct 2019). Wrong classification of roads categories (Krijnders K, Personal Interview, Jan 14, 2020). Edits are too old to be considered as reliable and trustworthy (Kombe E, Email interview, Mar 11, 2020).

3.4.2 Literature review

Main cause of delay in rescue operation is lack of information. Furthermore, using OSM data for disaster response raises the doubts of reliability and trustworthiness of the data because of the way it is produced (WMO, 2017). Due to the dynamic nature of our planet detailed spatial data is increasingly unavailable for the developing countries (Chakraborty et al., 2015).

Table 2.7: Results from scientific literature review for the information struggles in disaster context

Article	**Struggles stated**
(UN, 2015)	Network measurements
	Satellite imageries
	Digital elevation model
(Mocnik et al., 2019)	Trust in information source
	High resolution satellite imagery
(Yeboah, Pitidis, & Albuquerque, 2019)	Incomplete information
(Amade et al., 2018)	Reliability
	Overlapping of information
	Consistency of the information
(Poiani et al., 2016)	Low expertise

(Bégin et al., 2018)	Low engagement of contributors
	Low expertise
(Aminizade et al., 2017)	Unavailability of local mappers
	Uncoordinated voluntary activities
	High resolution imagery
	Low expertise

3.4.3 Case studies

The case studies for floods, cyclones and tropical storms were explored to get the idea of the struggles during the disaster with respect to the data. Each case study was analysed, and results are presented in **table 2.8**. Again, incomplete information remains the major part of the struggles.

Table 2.8: Results from scientific literature review for the information struggles in disaster context

Case study	**Struggles stated**
Bangladesh (Cyclone, 2017) (American Red Cross, 2015)	Poor quality data results in poor designing and implementation of the interventions.
Philippines (Typhoon, 2013) (WMO, 2017)	Less awareness among the people, low expertise available.
Dar es Salaam (2012) (UNISDR, 2012)	Incomplete information
	Low expertise
Cuba tropical storm (1998 - 2008) (UN, 2015)	Incomplete information
	Low expertise
Pakistan flood (2010) (WMO, 2017)	Incomplete information
Jakarta floods Indonesia (WMO, 2017)	Trustworthiness of the crowd sourced information
	Incomplete data

3.5 Forming quality standards for mapping

3.5.1 Integrating data requirements with struggles.

It is safe to say now there exists an immense amount of scientific and grey literature which can be used to exploit spatial data requirements and struggles that could be useful for the disaster preparedness planning and mapping (Cosgrave, 2014). The struggles during the disaster with respect to information is the reliability and trustworthiness of the information. Integration of mentioned information requirements with struggling points will be used to set the scale for quality metrics in coming sections.

Another reason for integrating relevant data requirements is because this study is focusing on developing countries and for these countries having a disaster preparedness plan is important because their systems are usually out-of-date or unavailable (Farthing & Ware, 2014). Moreover, it is also important to set quality metrics because according to the case studies there are many developing countries that are lacking even basic standard spatial data requirements as stated in basic data requirements. This also makes the comparison of the quality with ISO standards for geographic data difficult (Muttaqien, Ostermann, & Lemmens, 2018).

3.5.2 Needs assessment

The previous sections help us define what constitutes as a *'good map'* with respect to data, trustworthiness and reliability requirements. These requirements can serve as the theoretical and practical base for our quality metrics that are discussed in the next chapter (Chapter 4: Development of Quality Metrics). Following findings can be concluded from this chapter:

F3.1. Information **completion** in the OSM is emphasized in both interviews and literature. For that reason there should be a quality metric set for assessing the quality of critical infrastructure (see definition: Critical infrastructure).

F3.2. Critical infrastructures such as health care, water sources, fuel stations and houses etc, are considered as the main requirement as discussed in the spatial data requirement section.

F3.3. If the maps are not regularly updated raises the issue of **reliability**. Critically speaking the inactivity of the mappers in the area could lead to **untrusted data** due to the inactivity it can lead to staleness of the data (Coetzee et al., 2018). **Expertise** in the population is required to produce trustable information (Mobasheri, Zipf, & Francis, 2018) (see: 3.4.2 Scientific literature review, 3.4.3 Case studies).

F3.4. Mapping requirements should be specific and varies with respect to area and type of the disaster. Quality metrics that do not tend to generalise the mapping requirements can help in setting the specific mapping requirements. As if we have studied the analysis for earthquake the requirement would have been different (Anderson et al., 2018).

F3.5. Fit-for-purpose satellite imagery is required for all mapping in all phases of disaster.

F3.6. Data about **buildings** and **roads** are most essential for flood response.

Chapter 4: Development of Quality Metrics

4.1 Introduction

To get to the point of quality metrics first it is necessary to know what quality attributes need to be considered and why they are important for specific purposes (Anderson et al., 2018)**.** After concluding the needs assessment, we can start formalising the findings into *a gate-keeping* format .i.e quality metrics. In this chapter, we will discuss four quality metrics that are formed using the findings from the previous chapter. We shall further define different attributes that are useful in the analysis of quality metrics as well. These quality metrics should have relevance with specific case-study as well to quantify its impact.

4.1.1 Case study: Dar es Salaam

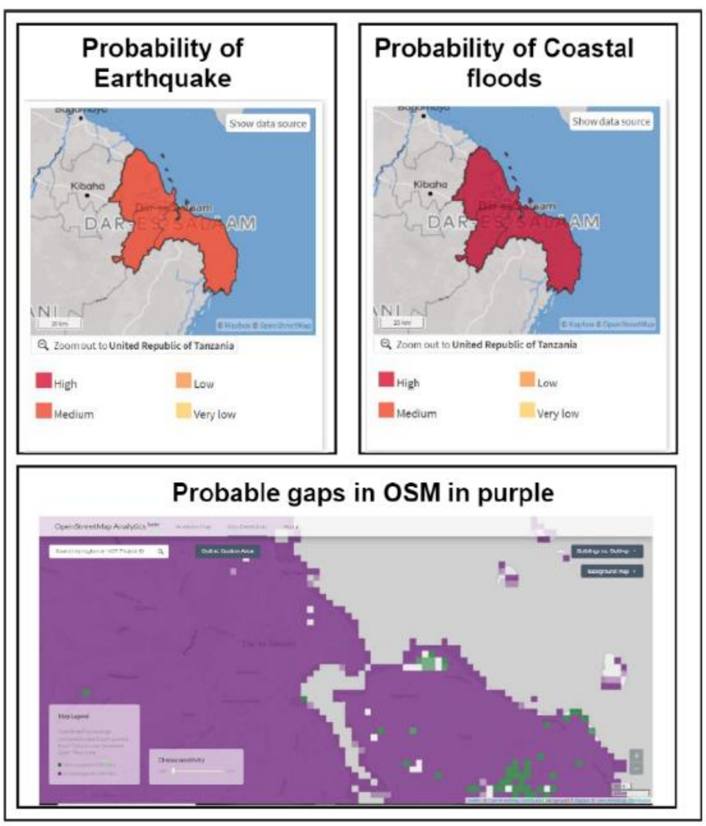


Figure 4.1: Hazard probabilities in top left and right and the likelihood of gaps in the OSM data in the bottom.

Dar es Salaam Tanzania is selected as the study area. The study area is selected on the basis of 3 factors. First, there is a probability of 2 types of disaster according to the ThinkHazard that is coastal flood (high) and earthquake (medium) (**Figure 4.1**) (Fraser et al., 2017). Secondly, it is found that there exists a gap (incompleteness) in the OSM data after visualising the gap detection tool in OSM analytics. Thirdly, it should be noted that thinkhazard is on national level and not local level, but due to unavailability of other local level hazard information this can be used. Completeness is one of the quality metrics in sub-objective 1. Lastly, it is found that there exist a lot of recent edits from 366 mapped buildings in 2015 to 24,089 mapped buildings in 2019 which implies (a) sudden massive edits shows existence of mapping project which can also mean the possibility of staleness of data after the project, (b) massive edits means massive volunteer contribution with different level of mapping experiences which can create variation in the quality of data.

4.2 Quality metrics

In order to make the OpenStreetMap(OSM) self-reliable intrinsic quality is assessed. There are four important quality metrics that can help the humanitarian organisation (results of stakeholder analysis). These are formed from the findings of the needs assessment section. Following are the quality metrics with reference of findings from the needs assessment.

QM-1: Tag completeness of critical infrastructure (F3.1; F3.2)
QM-2: Reliability of meta-data (F3.2; F3.3)
QM-3: Experience of mappers (trustworthiness) (F3.2; F3.3)
QM-4: Application specific (F.3.4)

4.2.1 QM-1: Tag completeness

4.2.1.2 Introduction

This quality metric is defined as the *gatekeeper* for the information completeness or attribute completeness. In OSM information about any geographic feature can be added by tags (Kunze & Hecht, 2015). The idea behind this metric is to assess the completeness of information about *critical infrastructure* that is necessary for flood response. In other words, this metric is developed to visualise the gaps in the depth of information about critical infrastructure mapped in the OpenStreetMap (OSM).

4.2.1.3 Critical infrastructure

4.2.1.3.1 Generic definition

Definition chosen for critical infrastructure for this study is *“organizational and physical structures and facilities of such vital importance to a nation's society and economy that their failure or degradation would result in sustained supply shortages, significant disruption of public safety and security, or other dramatic consequences“* (Fekete, 2019)**.**

4.2.1.3.2 Regional definition

It is necessary to know the regional definition of critical infrastructure for our case study Dar es Salaam, Tanzania. According to The Regional Centre for Mapping of Resources for Development (RCMRD), infrastructure that provides following services are considered as critical infrastructure: Railways, Bridges, Airports, Education, Health, Power, Roads, Harbours, Water, Telecommunication (RCMRD, 2013). Which compliments the general definition.

4.2.1.3.3 Identification of critical infrastructure

Identification of the critical infrastructure is important because these infrastructure have interdepencies in the case of disaster (Dierich, Tzavella, Setiadi, Fekete, & Neisser, 2019.). For simplification only unidirectional interdependence of the critical infrastructure is used while interdependency of critical infrastructures are rather complex in urban environments (Dierich et al., 2019; Räikkönen et al., 2017). **Figure 3.1** shows the dependency direction. Types of interdependencies considered are physical, informational, geographical and logical (Rinaldi, Peerenboom, & Kelly, 2001). After considering this for our study are the quality metric is divided into two sub quality metrics:

QM-1.1: Dependable infrastructure.
QM-1.2: Dependent infrastructure.

4.2.1.4 QM-1.1: Dependable infrastructure

This gives insight about what infrastructure people depend on in the case of an emergency. This can be infrastructure that can be converted into shelter or can be dependable in the case of disaster such as injury, relocation and water etc. These are concluded as follows:

1. Hospitals
2. Place of worship
3. Schools
4. Government offices
5. Bridges
6. Water and fuel amenities
7. Sanitation
8. Water sources
9. Fire brigade
10. Building companies
11. Bus and train station

For the sake of this research the most important ones are short-listed for analysing the tag completeness. This has been short-listed according to the emphasis in literature and interviews.

A. Hospitals
B. School
C. Place of worship
D. Government offices
E. Bridges
F. Water sources

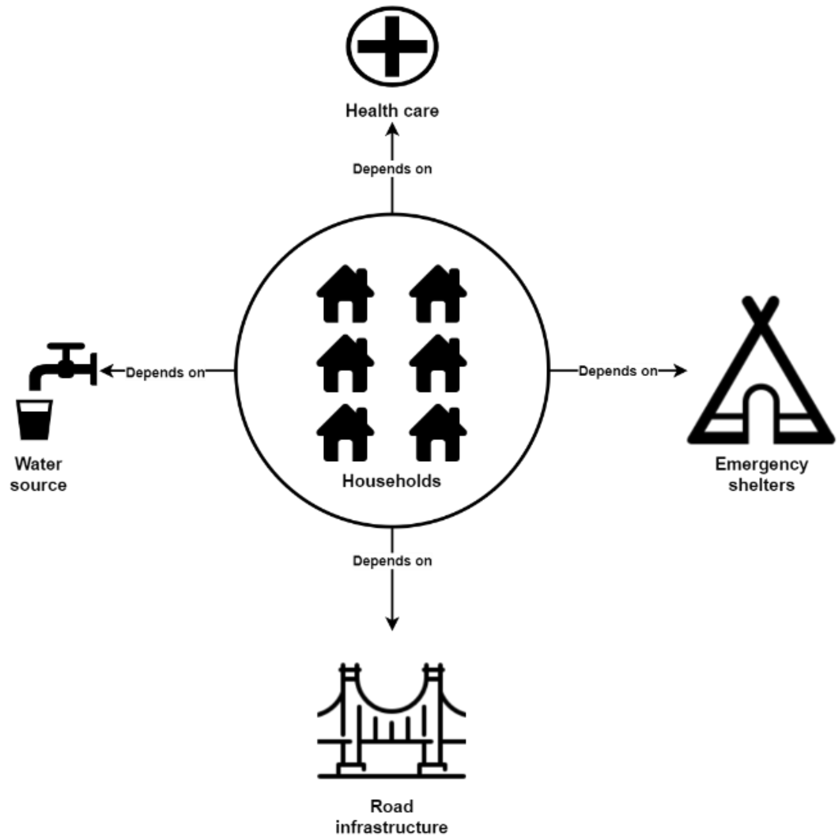


Figure 4.1: Dependency of households in the case of disaster.

Now, there is a matter of tag selection. Which tags should be checked for completion. This is taken from the tagging scheme of METEOR Project in Tanzania and the tagging priorities mentioned by the Red Cross officials. Both of these parties have different interests which will be discussed in the stakeholder section. It should be noted that there are several workflows for analysing the tag completeness, but this one is designed for flood preparedness by analysing the specific data and quality requirements. **(Note: we have integrated the road infrastructure with hospitals, water sources and shelters which is considered separate in previous chapter)**

4.2.1.5 QM-1.2: Dependent infrastructure

The other side of the pre-disaster mapping is to see where people live and how the information on it can help in predicting disaster impact. So, in this case are buildings in general then residential buildings. Same technique is used to get the tagging scheme.

4.2.2 QM-2: Reliability of the critical infrastructure data

Criteria for checking the reliability is how decisive the data about the critical infrastructure is in OpenStreetMap (OSM). In this quality metric dependable critical infrastructure is prioritised for the analysis. Because the reliability of hospital features are more important than for the buildings

(Wassenhove, 2012). This quality metric has 2 parts. Because there are different types of meta-data to be checked with respect to the quality standard.
QM-2.1: Date of the edit
QM-2.2: Edit frequency

4.2.2.1 QM-2.1: Date of the edit

Date of the edit defines how recently the mapped feature has been touched/edited/altered. More recent is the edit more is the reliability. Because the recentness shows that the mapped feature is existing. Recentness also shows how active the mapping activity is in certain areas. In general it shows how recent the map is. Meta-data has been extracted on a yearly basis starting from 2014 till 2020. We considered features older than 2016 as non-reliable. More discrete quality standards could be set depending on the type of feature and growth rate of the location.

4.2.2.2 QM-2.2: Edit frequency

More the editing frequency of a feature in OSM, the more it is reliable. Quality standard cannot be set the same for all the critical infrastructure because there exists heterogeneity of feature versions (No. of times feature is edited). This heterogeneity is presented in table 3.1. So, the quality standard set here is normalised to the highest number of versions of the selected feature. More the number of edits higher is the quality (Mooney & Corcoran, 2012a). There are indeed many exceptions to this case.

Table 4.1: Maximum number of edit version for different critical infrastructure from meta-data extracted on 10/01/2020

Feature	**Maximum number of versions**
Hospital	4
School	4
Bridge	11
Government office	7
Water source	5
Place of worship	5

4.2.3 QM-3: Experience of mappers

According to the OSM mapping guides there are five common scenarios that cause the bad edits, which are: *mistakes by inexperienced mappers, HOTOSM team projects, intentional bad eidts, undocumented imports and automated edits*. These *mistakes by inexperienced mappers* are relevant in this context and it usually covers the bad edits by HOTOSM team projects. The users that are much more experienced tend to make less intentional mistakes (Dittus, 2017). Furthermore, development of quality metric based on mapper’s experience encourages the new mappers to map more and it can possibly retain mapper's interest for longer time. Moreover, the experience of the mappers are easily quantifiable as compared to other causes of bad edits (Jokar Arsanjani et al., 2015) and there are significantly effective workflows available for filtering the bad edits but very few for inexperienced mappers.

This quality metric is very complicated because we cannot judge objectively from the number of edits made by a certain user. Quantification of this needs more details of the mapper like linkedin profile which shows the mapper experience outside the OSM community (Dittus, 2017). First step is to check how the OSM data is diversified with respect to experienced mappers. To do so, top 20 mappers (w.r.t number of edits) with edits more than 10000 are taken as standard and normalised.

4.2.4 QM-4: Application specific

The limitation of QM 01 to 03 is that it tries to generalise the whole study area with respect to certain tags or requirements. This creates a burden on the mapping activities by increasing the magnitude of tasks, which also makes the tasks less attractive for the mappers (Budhathoki & Haythornthwaite, 2013; Solís, McCusker, Menkiti, Cowan, & Blevins, 2018). So, there is a need to have a quality metric that takes into account the application strictly and analyse the quality of the features that are critical for that application. This will filter out several tasks that are crucial. For example, for flood scenario information completion of the buildings lying within the flood plain is important as compared to the whole area.

4.3 Possible impact of the quality metrics

Different humanitarian organisations use different predicting variables which can only be possible if the data on the map is complete. Assessment of the predicting variables is not part of this research but how to make the data on the maps in complete and reliable form is. The delay in the prediction is mostly due to unavailability of the information on the maps.

Furthermore, completion of specific tags in OSM beforehand can help the emergency mapper in predicting the condition of certain features. For this research, flood preparation is taken into account. Example is taken to see the impact of the missing tags of hospital specialisation on the number of houses (residential, apartment, home and house) is shown in **figure 4.2**. If the numbers are observed, the number of houses within 1km of hospitals that can be affected by the missing tag "health-care" which is considered as essential information dropped from 50227 to 24621. Meaning that 25606 house have no information hospital specialisation within 1 km.

For the sake of simplicity binary visualisation (affected vs unaffected) of the number of houses that can be affected by the missing information of hospitals in the selected bounding box of Dar es Salaam. Figure 3.3 shows the area where houses can be affected by the information tags. This is to check how much impact missing tags of the hospitals can have in the bounding box. This effect will be further analysed by the results of the Mapathon. At this point this analysis serves the purpose of explaining the impact of the quality metrics. In later stage routing algorithms will be developed in which some pre-details will be explained for understanding of the impact of the quality metrics in more detail.

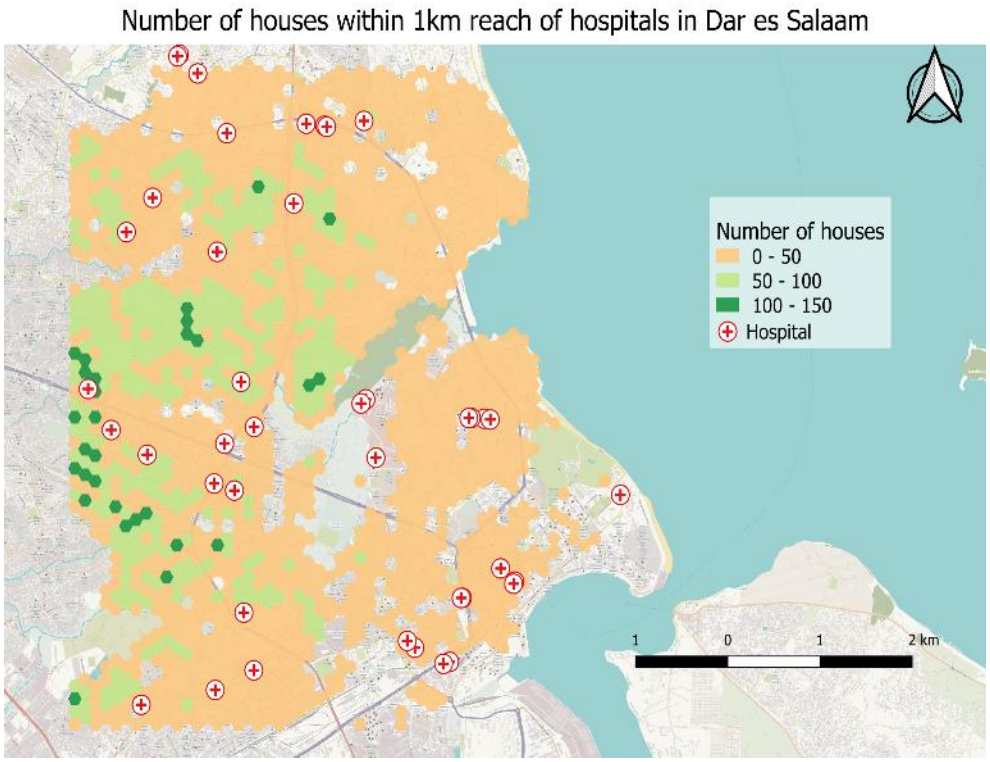


Figure 4.2: Number of houses within 1km of hospitals in Dar es Salaam

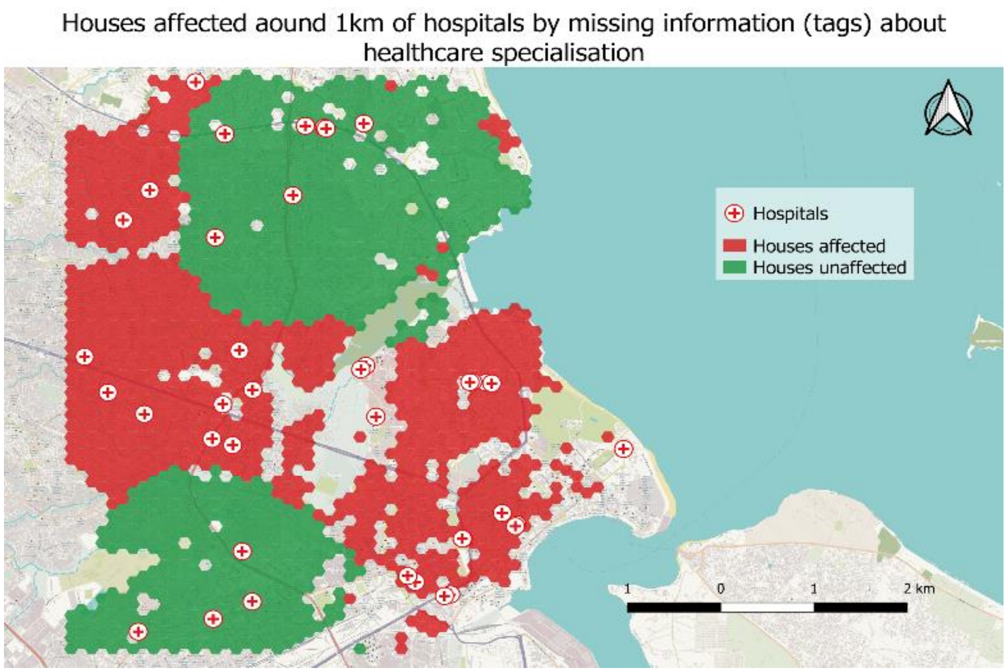


Figure 4.3: houses that can be impacted by the missing information of hospitals

Chapter 5: Application of quality metrics

5.1 Methodology

5.1.1 QM-1: Tag completeness

In order to analyse the tag completeness for QM-1.1 and QM-1.2 the level of detail that is required to be completed according to different tag combinations is checked. Tag combination depends on type of the feature. This quality metric is worked as follows:

1. First key is chosen such as amenity or building etc.
2. Then the main tag of that key that is critical infrastructure (hospital, government offices etc) is entered into the query.
3. It is then checked for completeness of OSM with respect to other source(s) (if available).
4. Most common tags combination are check with the increasing level of details
5. At least three level of details is checked and each of it is visualised by creating a quality metric.

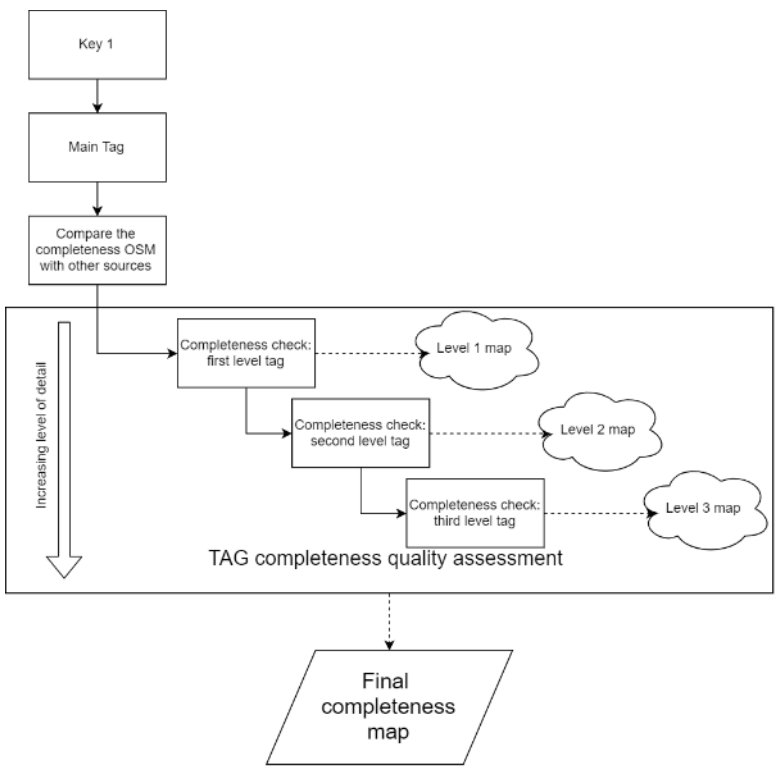


Figure 5.1: Workflow for getting final completeness map

For visualizing the level of details different types of maps are used but all of it has only one formula common for calculating the quality index (QI) for completeness. Given that n_i is total number of features in grid cell i, then QI for completeness will be.

$$QI(c) = \frac{a_i(x)}{n_i} \qquad \text{..eq 5.1}$$

Where a_i is the total number of features with tag combination x. This will give the normalised value from 0 to 1. Where '1' represents the complete tag information x in all the feature n_i and vice versa for '0'. Figure 5.1 summarises the workflow that has been followed for this quality metric. It is to be noted that tag hierarchy depends on what is actually required from the mapping (Krijnders K, Personal Interview, Jan 14, 2020). We shall discuss this with different examples in the coming sections (see: results). For this research we are only looking for the use case of floods and what are the user requirements for the spatial information that is required during the floods.

5.1.2 QM-2: Reliability of the critical infrastructure data

For this analysis we will be looking at the *lineage* part of the quality. It means we would be looking at the historical data of features specifically critical infrastructure. Methodology is simply to extract the meta-data of the selected critical infrastructure and visualise on the basis of last date of edit and number times the features has been edited.

For the number of versions we will not set a specific standard, instead we shall set a relative quality index (QI) (max=high QI and min=low QI). For date of edit, we consider currentness is directly proportional to the level of reliability. Standard is set to 4 years, meaning anything edited earlier than 2016 is considered as less reliable and outdated is earlier than 2014 (Kombe E, Email interview, Mar 11, 2020). It is also due to the fact that there is no literature or case study standard which constitutes the OSM features as old, it only states "it shouldn't be too old" or "outdated" (Dittus, 2017; Nasiri et al., 2018). So, it is difficult to generalise the standard for edit frequency. It is important because there is a high possibility that the object has been edited by several other contributors (Mooney & Corcoran, 2012b).

5.1.3 QM-3: Experience of mappers

Mappers activities were extracted from the Meet Your Mappers API (https://mym.rtijn.org/). This gives the CSV file of all the mappers that have been mapped in the selected area. As this is the measure of the trust, and trust is considered as relative (Muttaqien et al., 2018). So, we do not set the certain number of contributions from the mapper as a reference. We took out the top 20 with respect to the number of edits in the region and visualised it. This criteria will also result in mappers that could possibly have local knowledge because they contributed the most in a certain geographical location. Longer contributions of a mapper in certain areas represent higher expertise in that area (Budhathoki & Haythornthwaite, 2013).

This can partially serve as an assessment for local knowledge expertise as well. Complete analysis requires further analysis such as in-depth interviews with the mappers (Van Exel, Dias, & Fruijtier, 2010). There are usually few editors that are editing in a certain study area (Mooney & Corcoran, 2012b). This gives the edge to this quality metric as expertise is one of the dimensions of credibility part of the quality definition (Muttaqien et al., 2018). After the mapper's stats is sorted ascending order with respect to the number of edits. Overpass API is used to extract the building edits made by top 20 users in the study area.

5.1.4 QM-4: Application specific

For this quality assessment we took two approaches which can serve the purpose of this study. First is tag completeness of the bridge crossing the waterways and second is the tag completeness of the buildings within 100 meters proximity of the river.

5.2 Results of Quality metrics

5.2.1 Introduction

The quality metrics give interesting insights about the mapping activities, if we visualise the results. There are different ways by which the quality metric results can be visualised as mentioned in the section. One of the ways that is used here is by grids and making feature classes depending on the quality standard. In this section results of each quality metrics will be visualised and discussed with the case study example of Dar es Salaam. All overpass queries can be found in GitHub repository (https://github.com/MuhammadSaleem056/osmqualityassessment).

5.2.2 Types of maps

Method on how to visualise the quality metric is also an important factor for accuracy or to avoid any misleading information. Definition of each type of map has been taken from GISgeography blog. (GIS geography, 2019)

Dot maps

This is the point representation of an object on the map. More the number of points means higher value.

Firefly maps

This uses the glowing symbology to emphasize certain points of interests (J. Nelson, 2016).

Square grids

Square grids are used to represent the gradual intensity of certain objects or phenomena on a map. This is used here to represent the number of features per square area. For some maps where there are only point features square grids are used for giving emphasis. Furthermore, for the mapathon quality metric results are visualised using square grid because the tasking manager is configured for handling the square grids.

Hexagonal binning

It is near to circular grids which is efficient for visualising big data (Hao, Dayal, Sharma, Keim, & Janetzko, 2010). Furthermore, For analysis hexagonal grids were used for visualisation because it can cover wider area of interest and gives better visualising effects (Apte, Agarwadkar, Azmi, & Inamdar, 2012).

Network flow

Network flow maps represent the flow in certain networks. In this study it is used to visualise the quality of roads with respect to certain tag combinations.

Isochrone

Isochrones represent the breaking polygons at which you can travel with given contour values. This is used in accessibility studies and will be used for disaster routing for analysing the hospital accessibility and impact of quality.

5.2.3 QM-1: Tag completeness

5.2.3.1 QM-1.1: Dependable infrastructure.

Level 1: tag:emergency (key=hospital)

All of the hospitals that are in the area of Dar es Salaam are extracted using the overpass API. Specific tags were checked for the analysis. First the tag for emergency is checked because this is important information to know whether the hospital has an ambulance service. The **figure 5.2** shows the results of the completeness analysis. Out of 80 hospitals only 8 hospitals have information about tag ‘emergency=*’. This results in only 10% of hospitals with completed tag information about emergency ward. Completeness patterns are irregular and it does not follow the fact that the centre of the city is mapped with high detail as compared to the outskirts.

Quality index with respect to tag completeness: emergency for hospitals

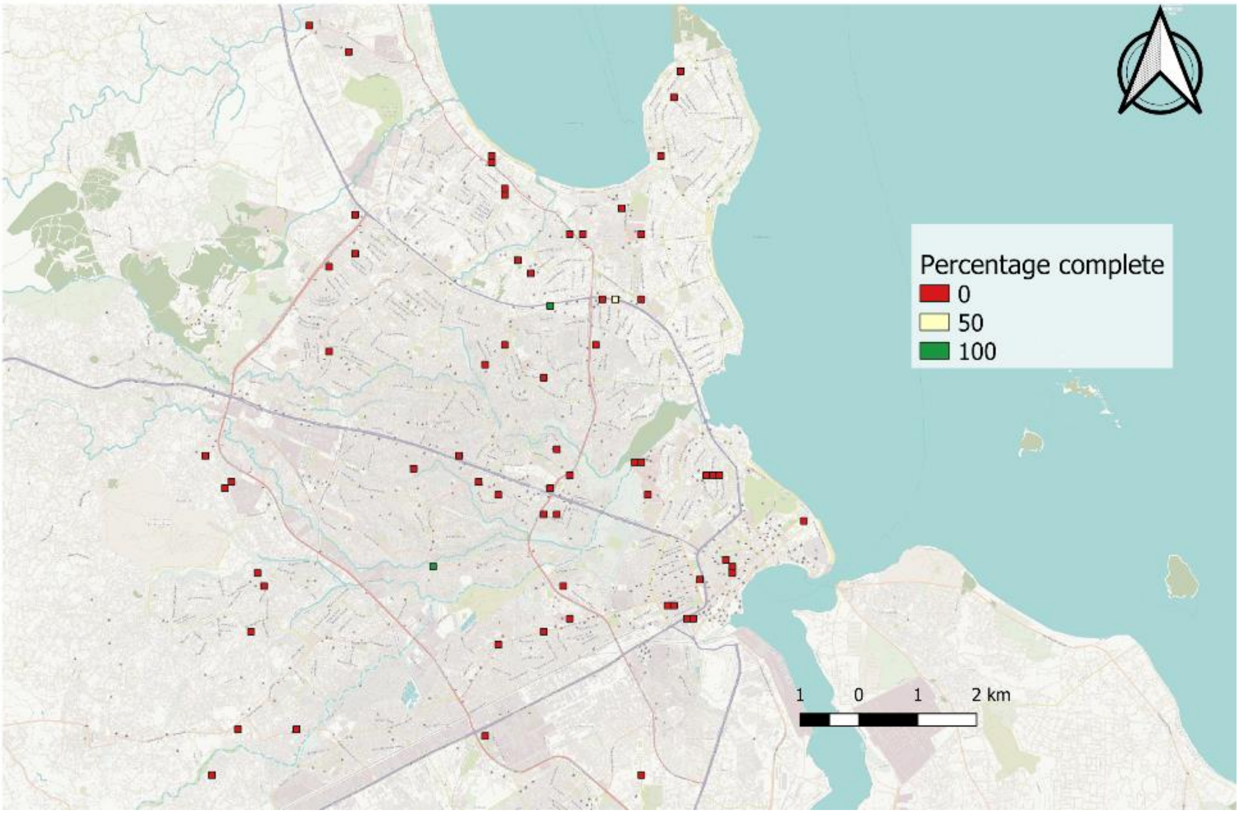


Figure 5.2: Quality index representing the completion of emergency tag. Red represents that all of the hospital features inside the grid do not have an emergency tag, yellow represents half of the hospital features inside the grid have emergency tag and green represents 100%.

Level 1(a): tag: healthcare:speciality (key=hospital)

Apart from the emergency tag there is information that is important is what type of health speciality the hospital has or serves. This information is important to know what kind of treatment can be done in a certain hospital in your proximity (Xu, Zhang, Zeng, Yang, & Wang, 2019)**.** This can be useful information even for the current Coronavirus situation where patents need to be transferred from one hospital to another. **Figure 5.3** shows the results of the healthcare:speciality information completeness for all the hospitals.

Quality index with respect to tag completeness: healthcare:speciality

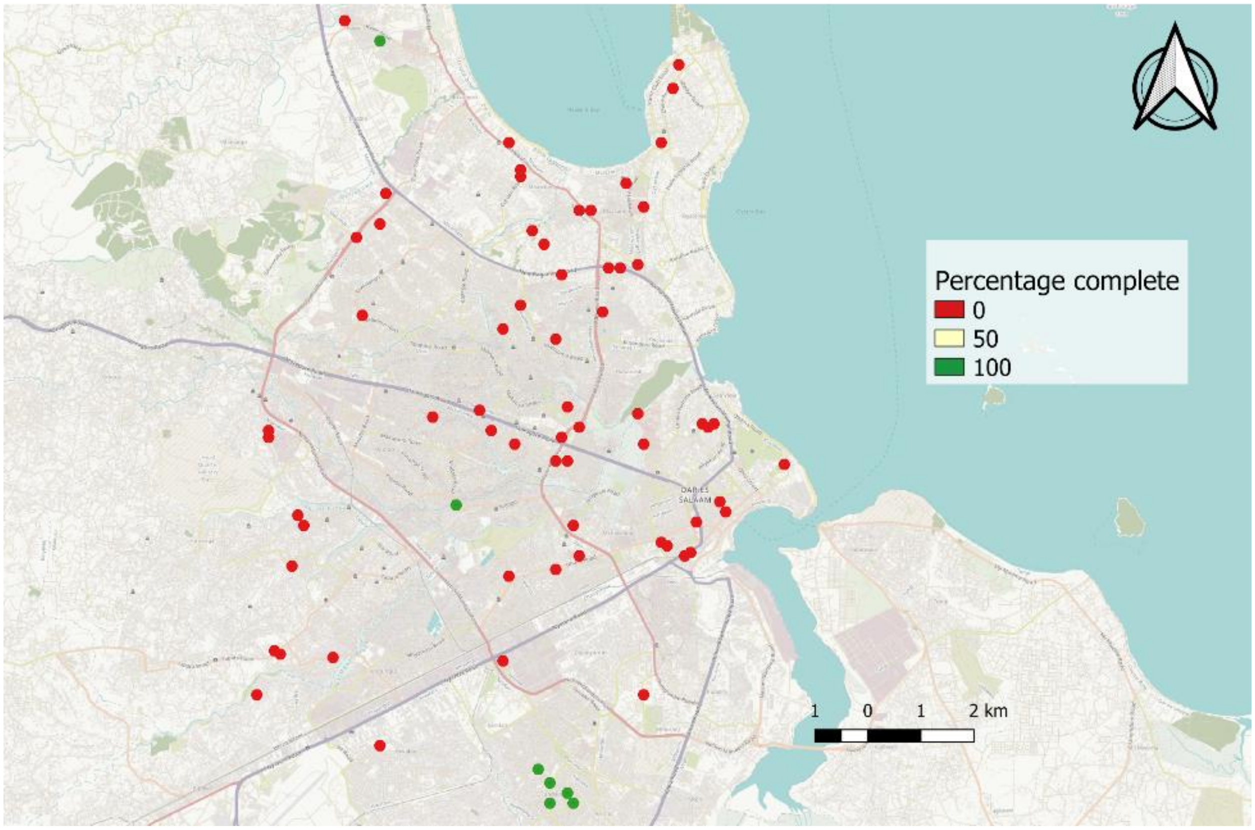


Figure 5.3: Quality index representing the completion of healthcare:speciality tag. Red represents that all of the hospital features inside the grid do not have any healthcare:speciality tag, yellow represents half of the hospital features inside the grid have healthcare:speciality tag and green represents 100%.

Interesting findings: it is interesting to see that many hospitals have high completeness percentages in the south of the city. Which is unusual to have high quality data on the outskirts of the city. Later it is found that there were projects in the tasking manager related to tag completeness of the buildings. This insight shows that if the mapping is done with a purpose could lead to useful information for disaster response as this study indicates.

Level 3: tag: healthcare:speciality + scope + activities (key=hospital)

More details can be assessed using the overpass API such as activities and scope of the healthcare facilities in the hospital. This can give the idea of the working of the hospital. **Figure 5.4** shows the results of the tag completeness for scope and activity tags.

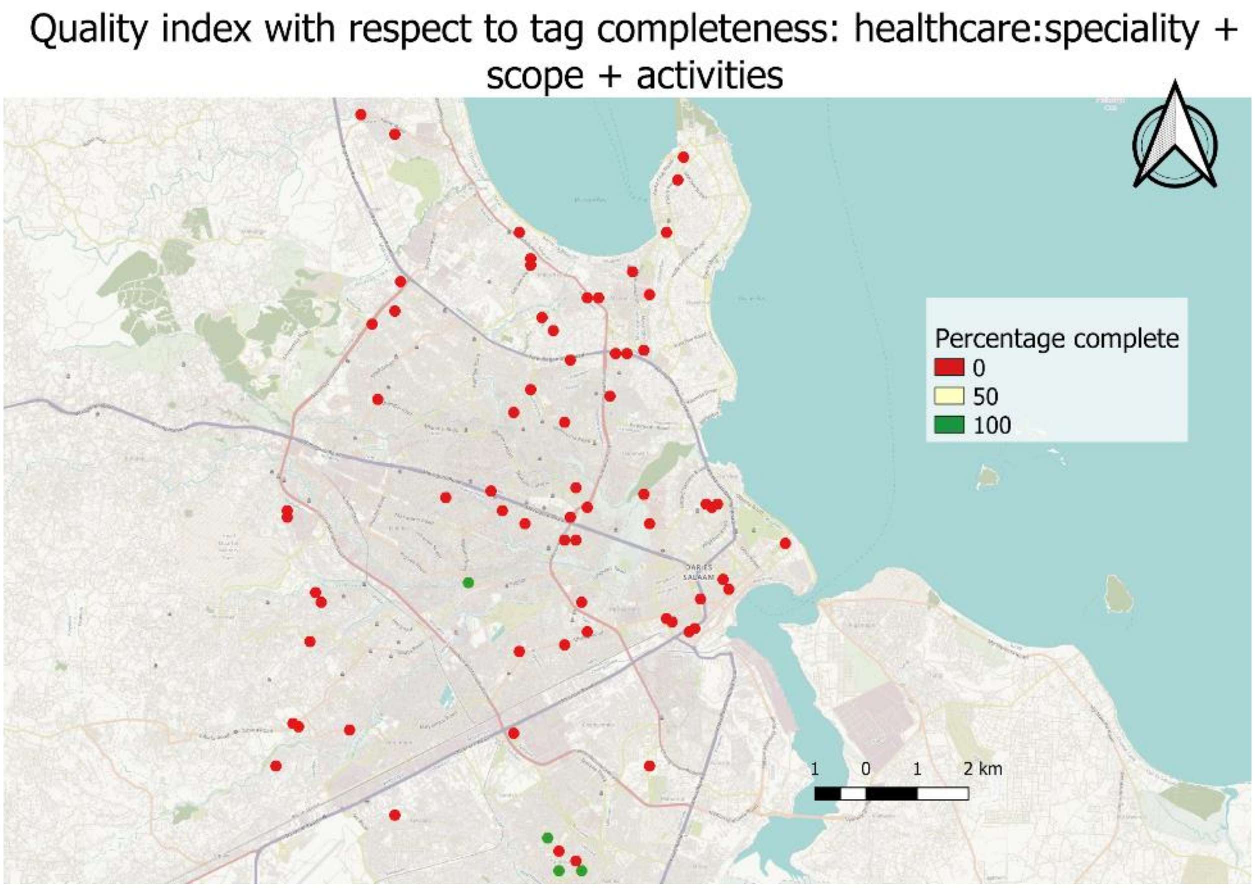


Figure 5.4: Quality index representing the completion of tag combination of healthcare:speciality + scope + activities.

Level 1(c): tag: beds (key=hospital)

The most crucial information about the hospital that is required is the capacity of the hospital. Unfortunately, in our study area there is no hospital that has that information in the OpenStreetMap (OSM). This information is found very rarely in the OSM even if we visualise it for a developed country like Germany. While this information can give disaster planners a good estimate on how many people can be accommodated with certain proximity (Luis & Cabral, 2016). This tag is so useful, so underused. In **figure 5.5** shows that Germany has only 39 features with the tag combination of ‘hospital’ and ‘beds’.

Figure 5.5: Hospital features in Germany with information about number of beds in OSM.

Feature: water sources

Level 1: more than one tag

While analysing the water source features there found inconsistency in the level of tag combinations such as pump:activity or building material of the water source structure. First we checked if there are more features tagged as water sources with more than one tag to give us the idea how detailed the water sources are mapped. This is another way of assessing the tag completeness of the certain feature with unknown tag schema. In depth research about what information is important for the water source is still needed to be done.

Outcomes of dependable infrastructure tag completeness

We have analysed hospitals with respect to different tag combinations. Now what does it mean for the humanitarian organisations and for the mapping? The areas that are probably 'red' needs to be completed with additional information which is helpful in the times of emergency. Timely availability of high-quality data is crucial for better response especially about critical infrastructures. This information can improve the risk that a city has because of lack of information during the disaster. As for the rare tag 'beds', this should be highly emphasised as this information can be used for various purposes.

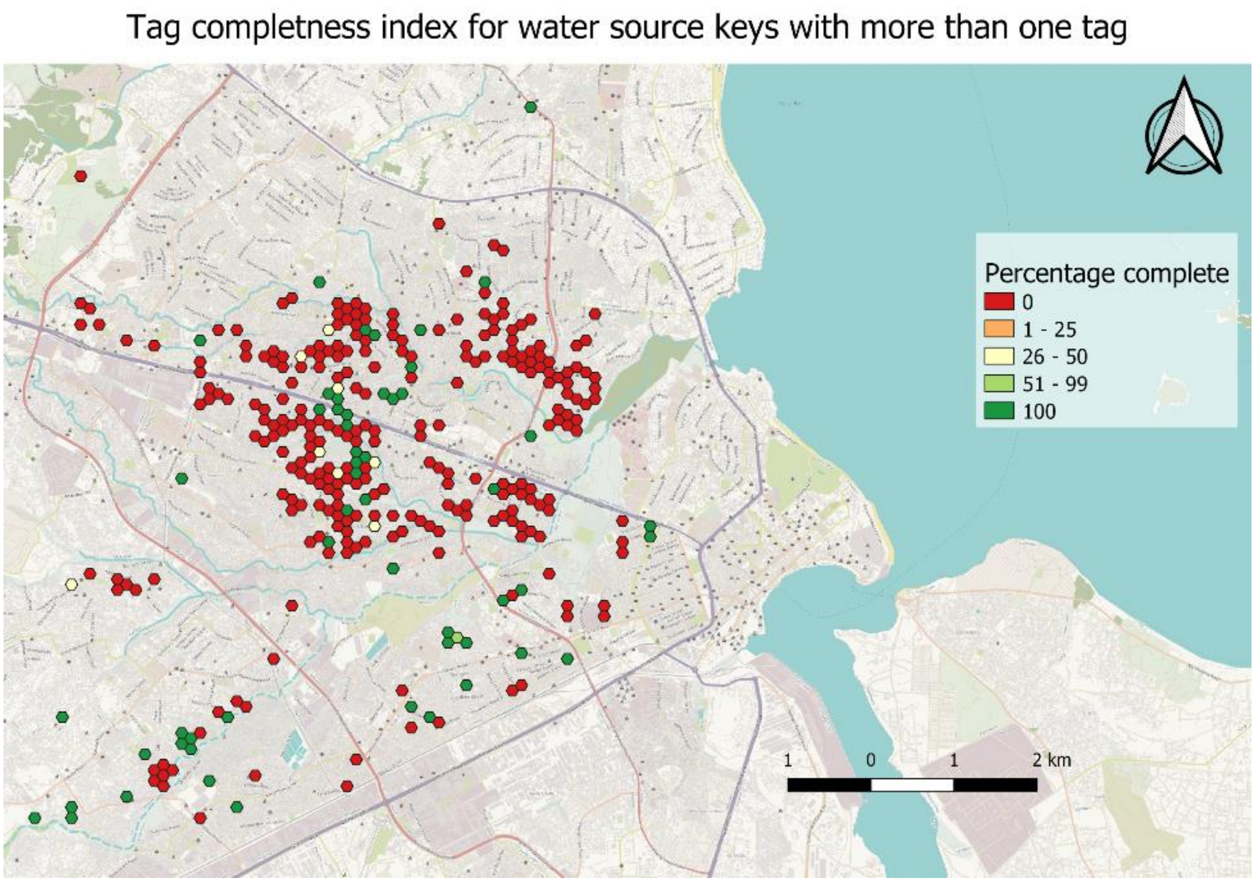


Figure 5.6: Quality index for water source features tag completion. Where green shows that all of the water features have more than one tag. While red shows that none of the water features have more than one tag.

5.2.3.2 QM-1.2: Dependent infrastructure.

The dependent infrastructure is the infrastructure including the buildings and residence that can be affected. In order to measure the amount of risk and anticipate the effects of the disaster certain sets of information are required as mentioned in section (3.3 Spatial data requirement). This information gives the information on how much exposure to the disaster will affect the functionality of these buildings (Unger et al., 2019). Hexagonal grids are used to map because a lot of data is to be presented and square grids resulted in edging effect **(see appendix A, section A.2 figure A.3)**. We follow the level of details as follows:

Level 1: tag: building:material

It can be seen in the **figure 5.7** that it doesn't follow a regular pattern meaning that grids disperse with respect to different classes. This is further analysed and found that some informal settlement was part of the METEOR project Dar es Salaam, which aims to increase the spatial information availability for informal settlements (William Perry, 2019). Nevertheless, there are still very few grids with 100% completion.

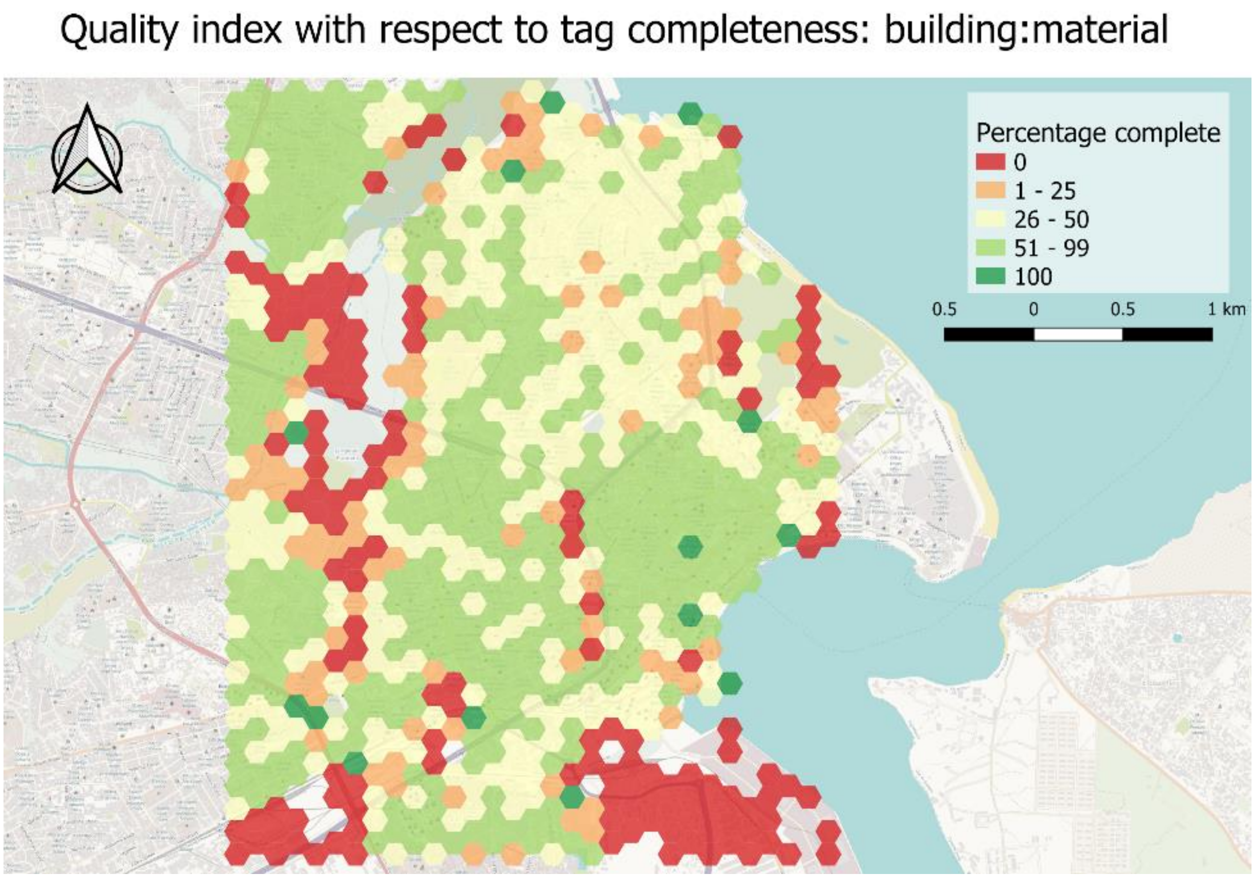


Figure 5.7: Quality index for building features with respect to tag completion: building:material. Where green shows that all of the building features have the mentioned tag. While red shows that none of the building features have the mentioned tag.

Level 2: building:material + levels

The next level of detail to be followed is building level or number of floors. This information is second most essential because it gives the estimate of the population living in the certain area. In **figure 5.8** shows clearly that outskirts of the city have missing information about the number of floors. Patterns in and near the city centre remain similar which suggests the mapping focus in the area of Dar es Salaam.

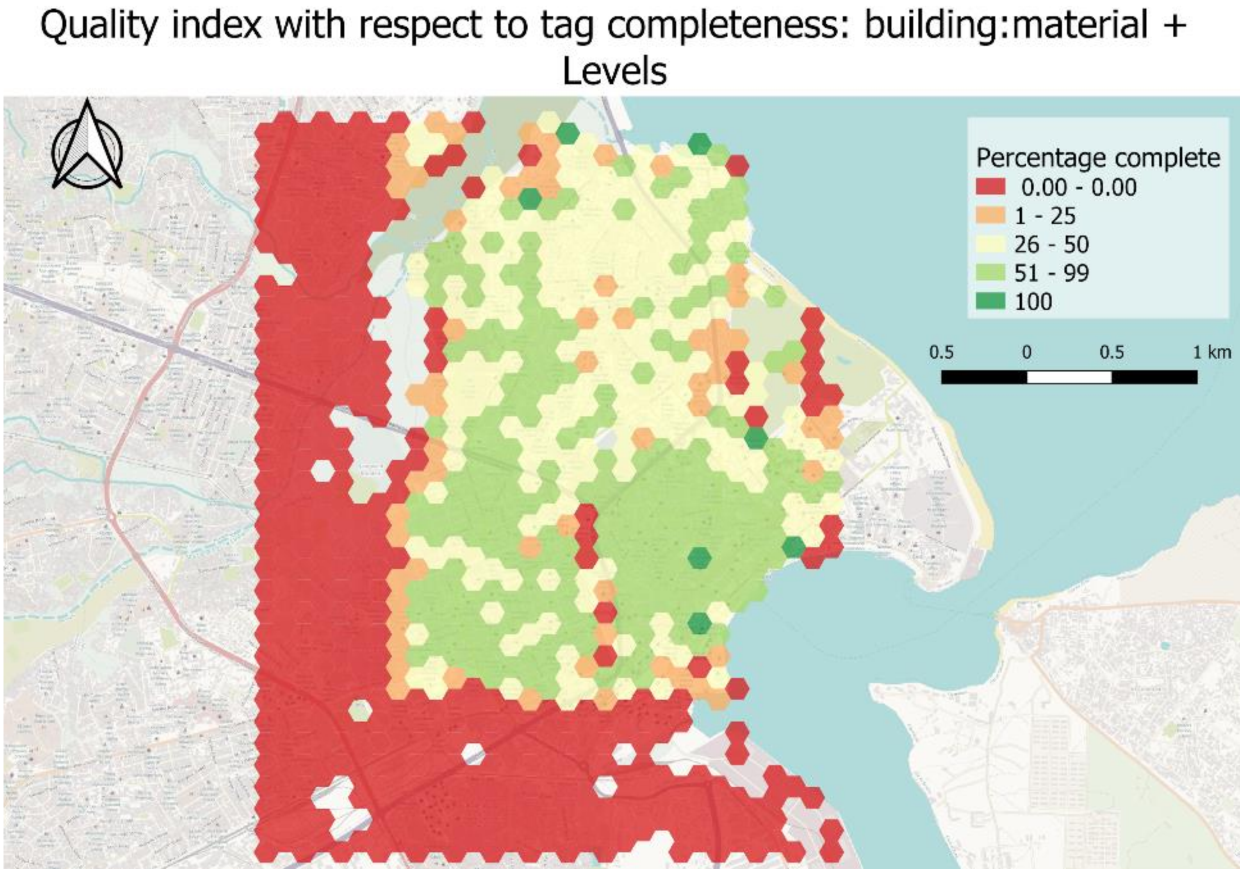


Figure 5.8: Quality index for building features with respect to tag completion: building:materials levels. Where green shows that all of the building features have the mentioned tags. While red shows that none of the building features have the mentioned tags.

Level 6: building:material + levels + roof material + age + condition + capacity

Results from level 3 to 5 tag completeness map can be found in the **appendix A.** This is because the maps started to follow the same pattern. We checked the information till level 6 to check how much detailed mapping has been done in our study with respect to the other parts of the city. **Figure 5.9** shows the pattern.

Outcomes of dependent infrastructure tag completeness

Different level of detail maps can be used to identify two main things. One is clearly which areas are under mapped. Secondly, what type of information is required to be mapped for better estimation of measurable risk components such as exposure. Furthermore, it also gives the areas where a specific information is missing. This makes it easy for the humanitarian organisations to actually visualise the missing information.

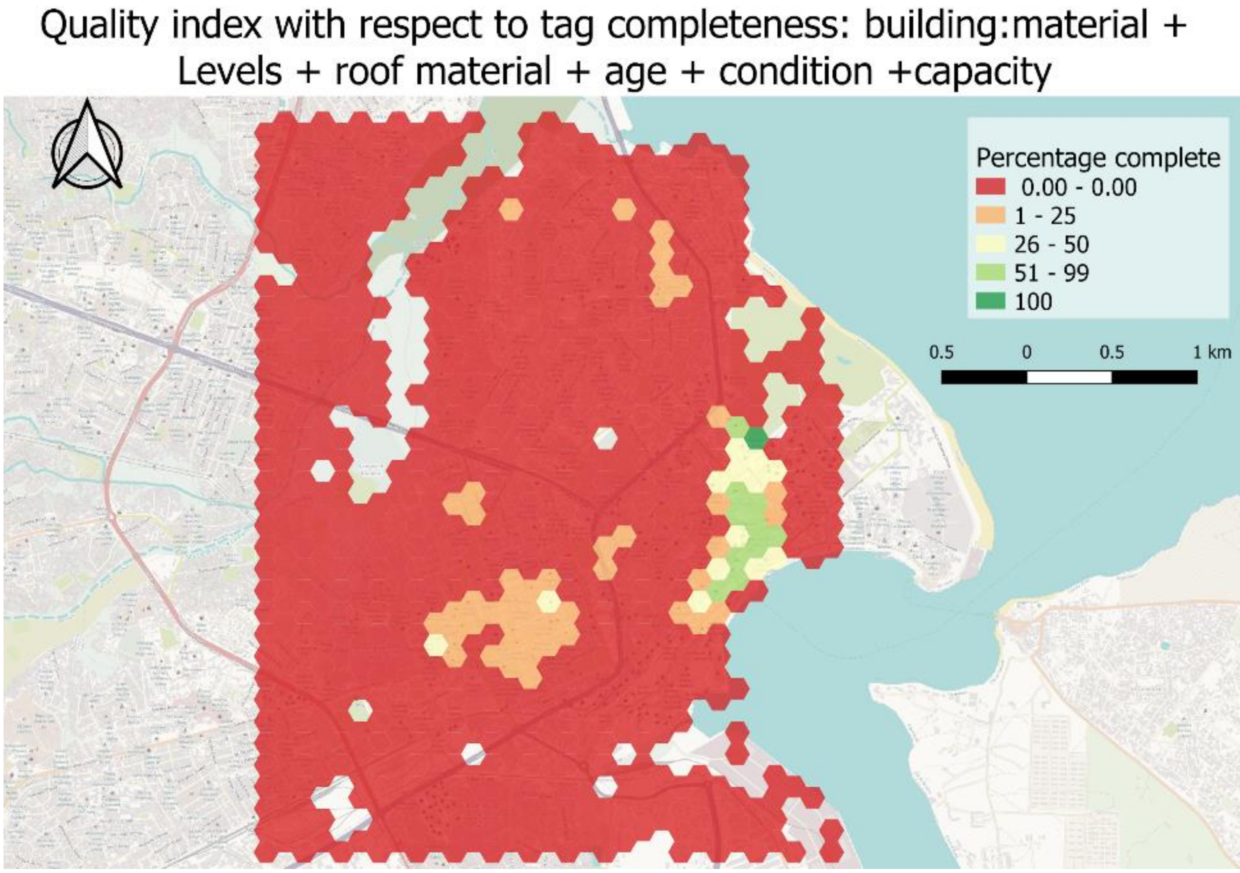


Figure 5.9: Quality index for building features with respect to tag completion: building:materials levels + roof material + age + condition + capacity. Where green shows that all of the building features have the mentioned tags. While red shows that none of the building features have the mentioned tags.

5.2.4 QM-2: Reliability of the critical infrastructure data

5.2.4.1 QM-2.1: Date of edit

By extracting the metadata for different critical infrastructure features it can give us information about the last date of the edit. Analysis of timestamp of critical infrastructure data gives the level of reliability. Older the feature edit less it is reliable is its information and vice versa. Dot map with varying symbology is used to represent the date of edits for hospital and schools features.

Feature: Hospital

Figure 5.10 shows the hospitals with the year at which it has been last edited. Most of the hospitals have timestamps recent than 2016 which means that data of the hospitals are up-to-date and the data is reliable. This also reveals that critical infrastructure as hospitals should be updated more frequently by adding further information that is mentioned in **QM-1.1**.

Year of edit for hospital features

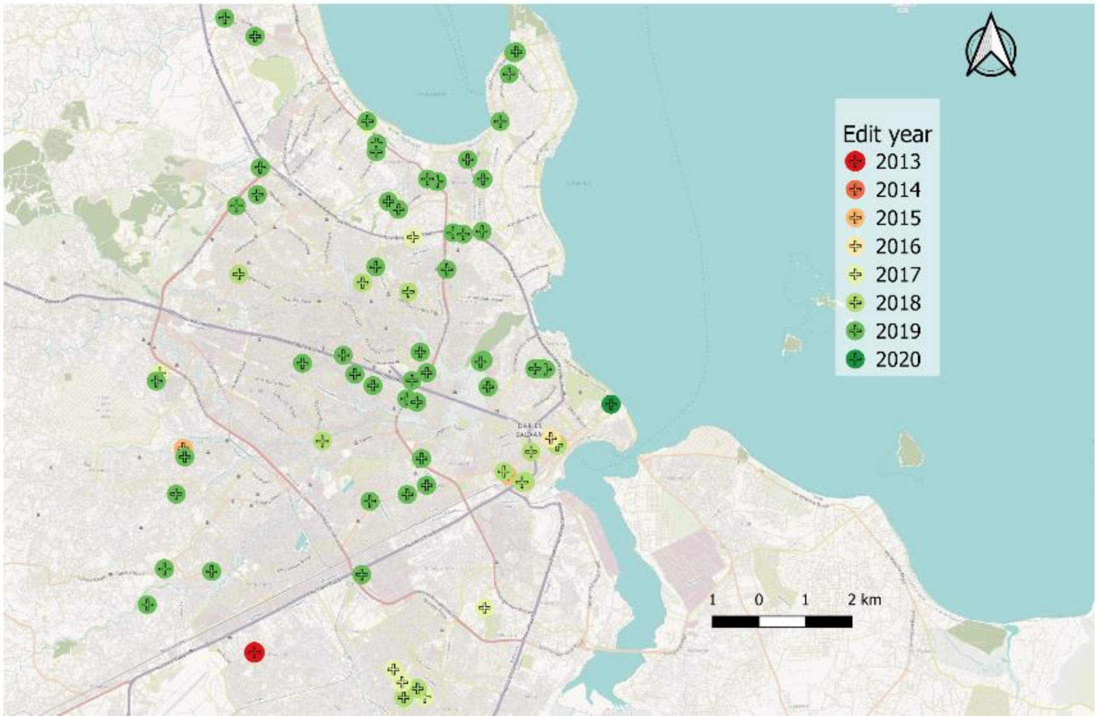


Figure 5.10: Year of last edits for hospital features in OSM.

Year of edit for school features

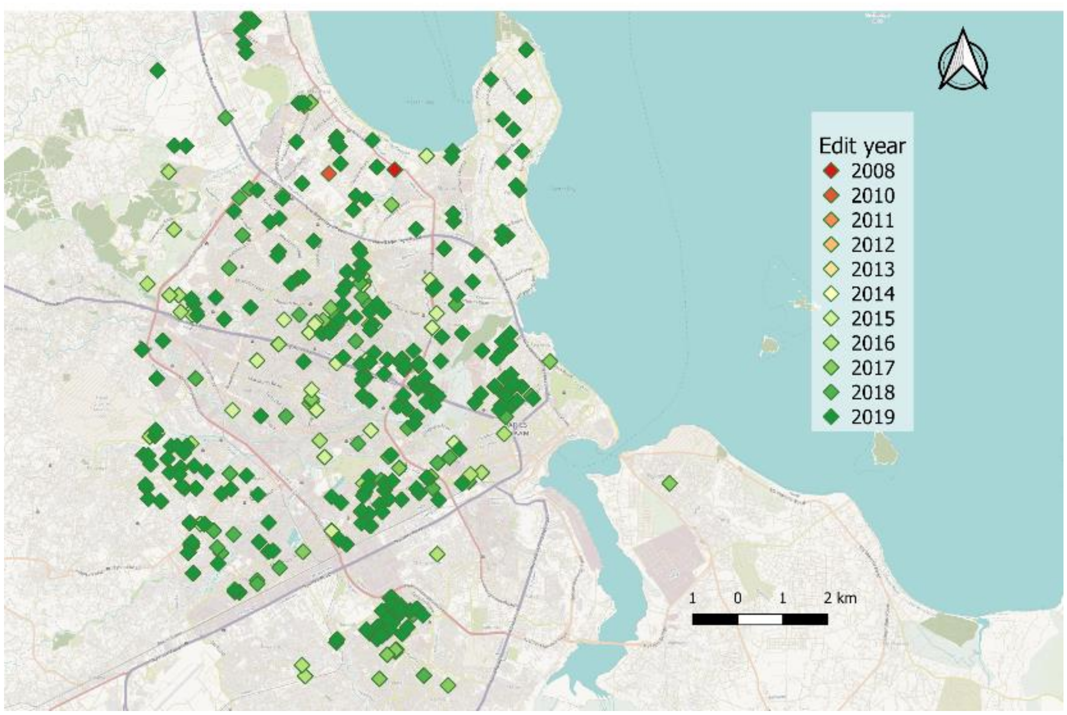


Figure 5.11: Year of last edits for school features in OSM.

Feature: Schools

Another critical infrastructure analysed was schools. The location of schools are found to be quite vibrant as compared to hospitals and it can serve as emergency shelters. The **figure 5.11**, shows the last edit year of school features in Dar es Salaam. It shows that most of the features are recently edited. Which stands for more reliability.

Outcomes date of edit of hospital and school features

Last edit date gives information about how operational the mapping activity in an area is. For our study area it is found to be quite operational and edits for the schools and hospitals were recent. There are not many old edits of critical infrastructures because we are in the well-known city and mappers are quite active. If we analyse a city such as Juba in South Sudan the case will be different. As it is found in **figure 5.12** most hospital feature edits were older than 2016. This is also evident from the Juba case that there are very few as 9 hospitals were mapped, which can be due to less mapping activity. From the mapping point of view areas where the mapped features such as hospitals or schools are not recently edited, it should be prioritised for mapping.

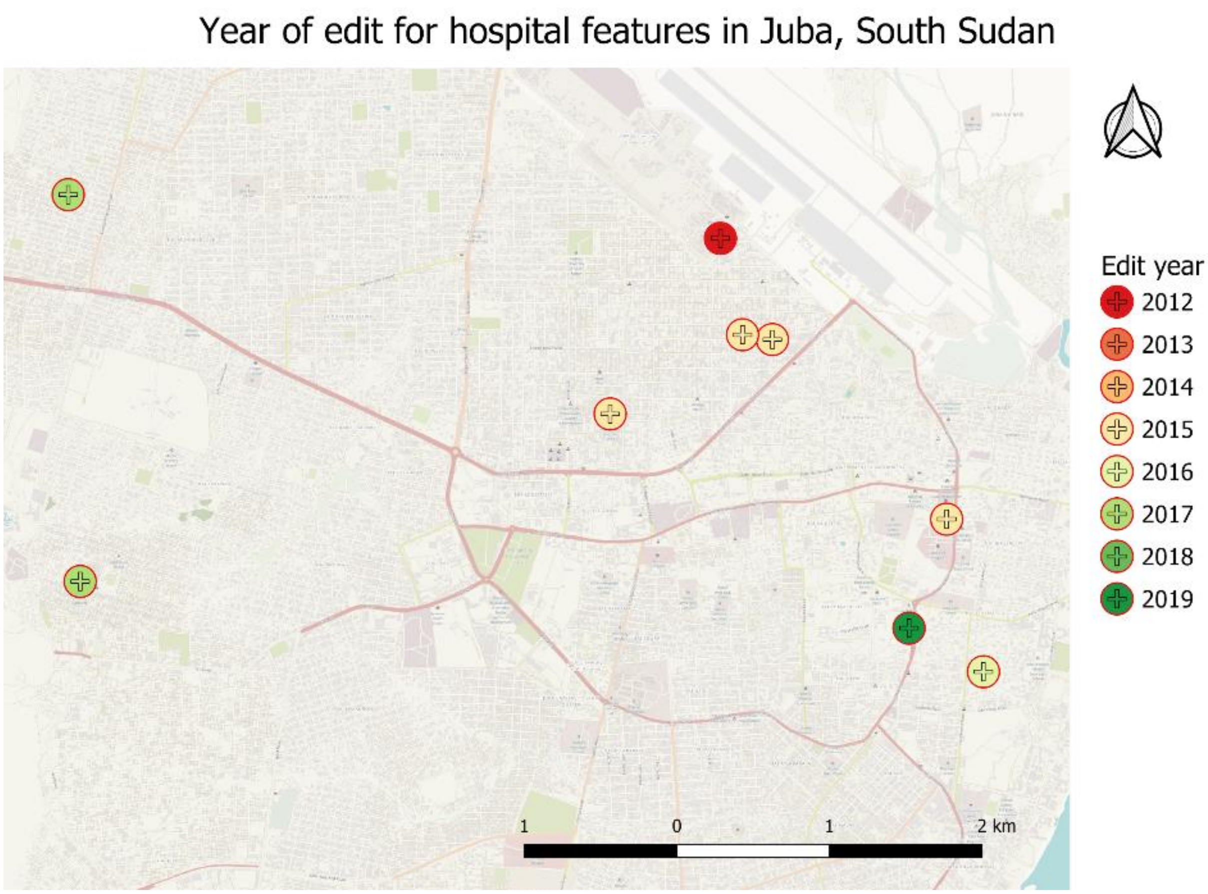


Figure 5.12: Year of last edits for hospital features in OSM for Juba, South Sudan.

5.2.4.2 QM-2.2 Edit frequency

Meta-data extracted from overpass API also gives the number of times a feature has been changed or altered. Dot map with varying symbology is used to represent the number times a feature has been edited for hospital and school features.

Feature: Hospital

Figure 5.13 shows the edit frequency of hospital features in Dar es Salaam, Tanzania. Greater the number of versions more is the reliability. The pattern is quite diverse with respect to location and more editing frequency of hospital features are found in the north east of the city.

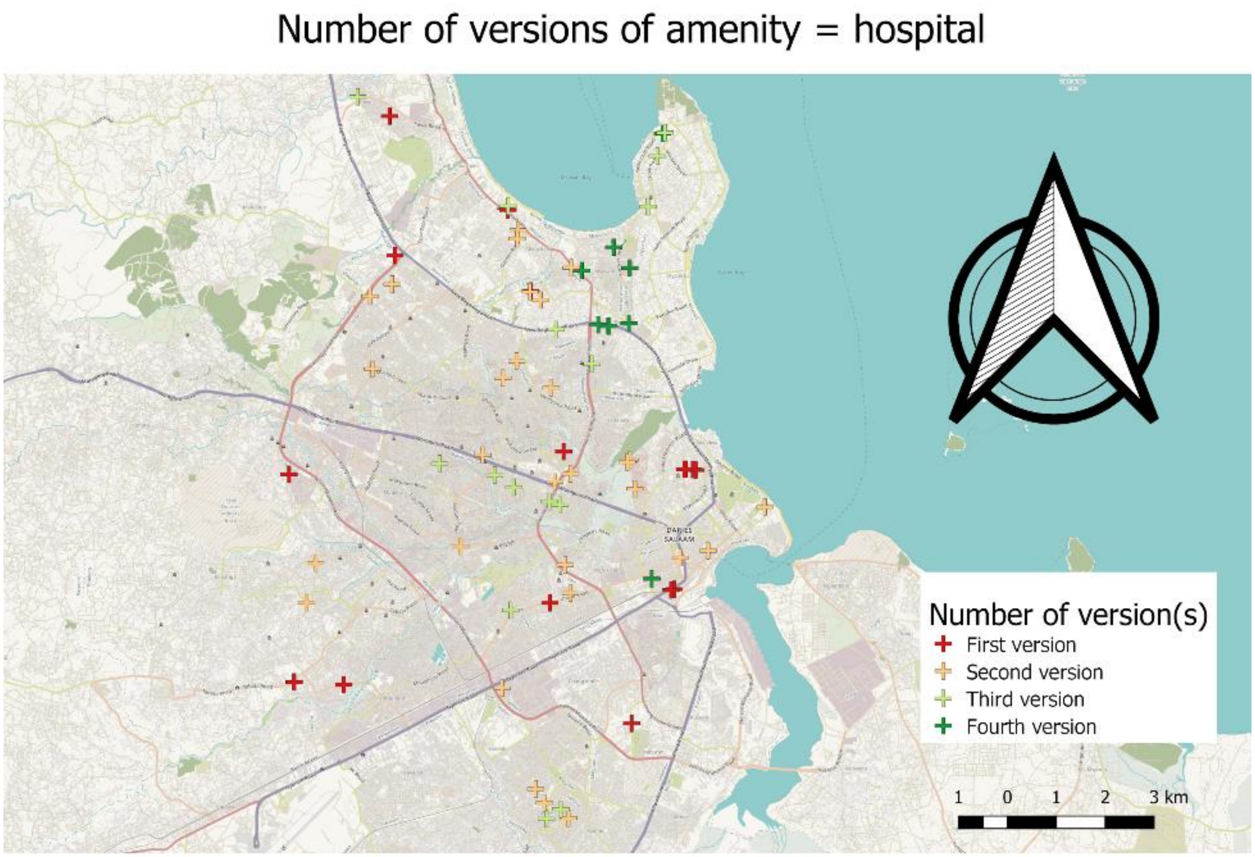


Figure 5.13: Number of times hospital features has been edited to represent ordinal number of versions.

Feature: Schools

Figure 5.14 shows the edit frequency of the school features. The pattern is also diverse with respect to the number of versions. It is evident that the maximum number of schools are more than that of hospitals which shows the vibrant behaviour of school locations or data.

Number of versions amenity = school

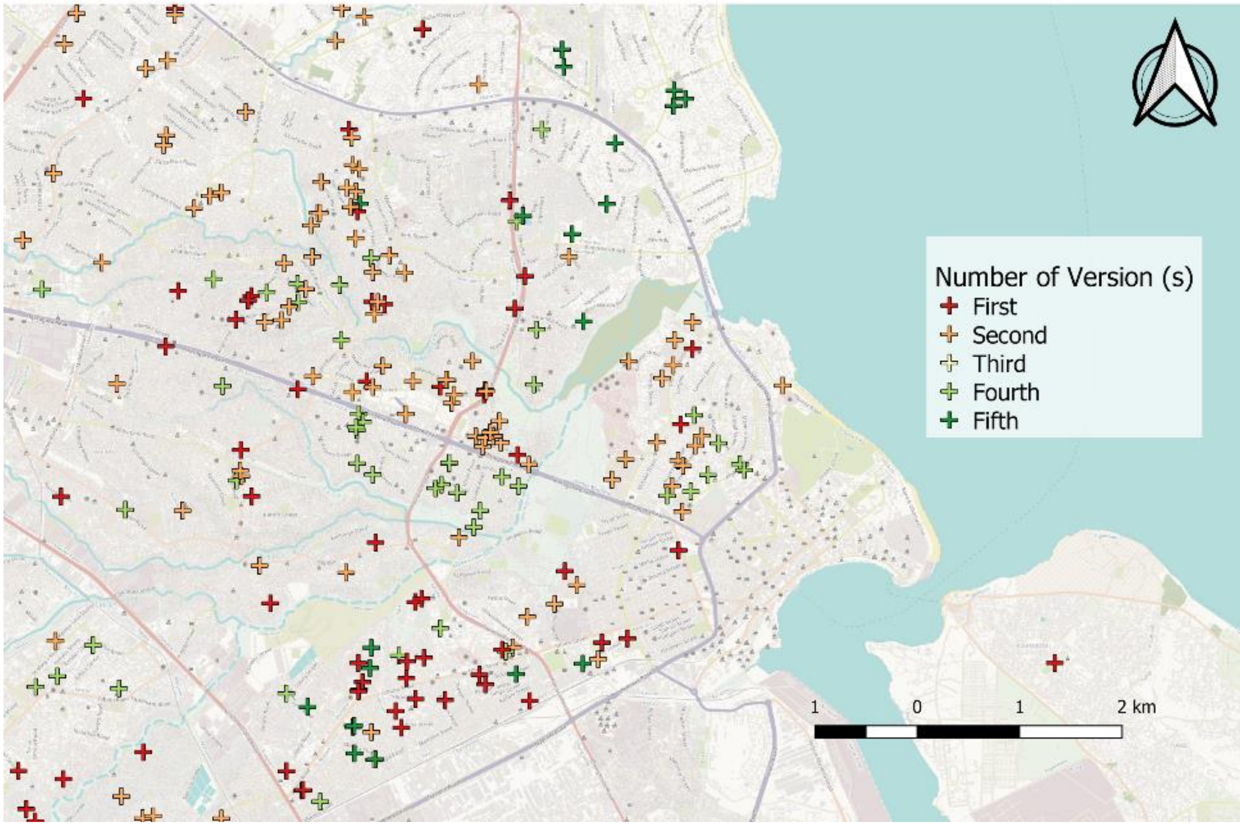


Figure 5.14: Number of times school features has been edited to represented in ordinal number of versions.

Outcome of edit frequency of school and hospital features

The main purpose of this analysis is to see first if edit frequency has an effect on improvement of the information .i.e tags. As it should be axiomatic that greater is the edit frequency, richer is the information it holds. In order to correlate this number of versions of the hospitals that have a tag combination of healthcare:specialisation is visualised in **figure 5.15**.

It is evident that hospital features with greater than one versions have detailed information about healthcare:specialisation and emergency. But the data must be analysed carefully because there is a possibility that a number of versions may be due tag war or just name is changed (Hecht et al., 2017). so supplementary analysis is necessary to correlate only the relevant tags that are required for the specific application. Emphasis should be given to map the tags that are relevant for flood preparedness as discussed in chapter 3. For mapping prospective, mapping activity should take place to map the critical infrastructure that are out-dated or not edited frequently. This will decrease the risk of staleness of data and increase the mapping activity in OSM (Palen et al., 2015).

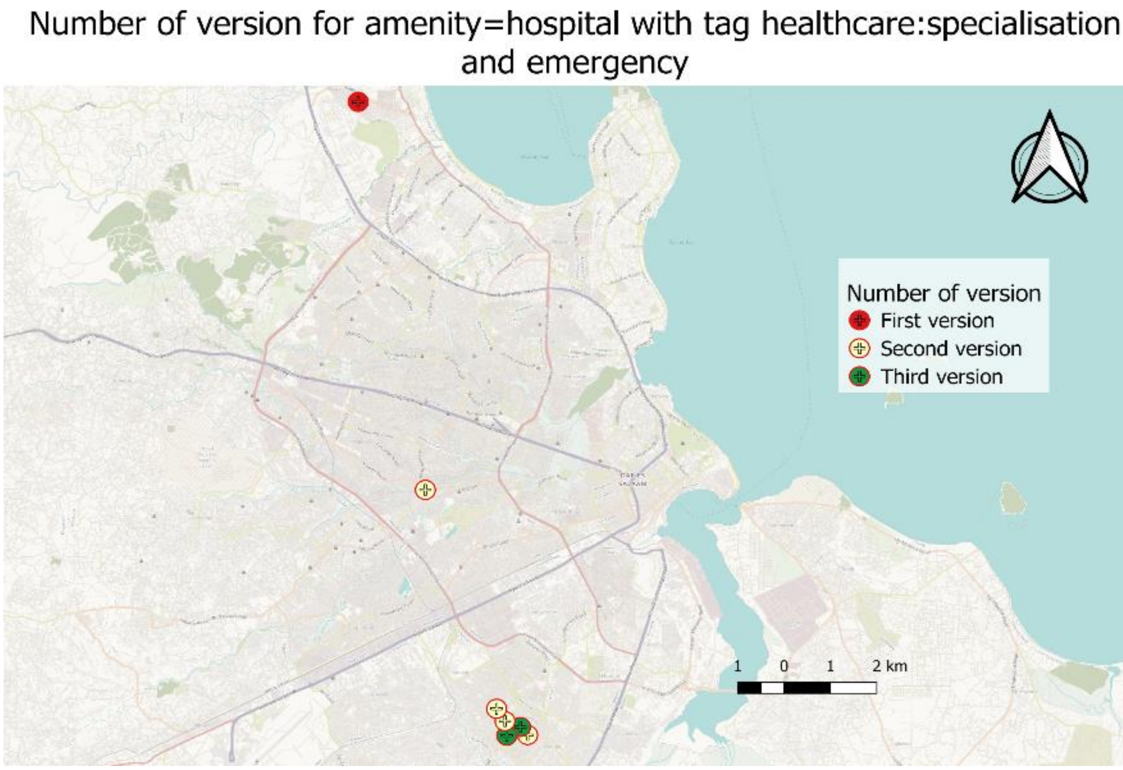


Figure 5.15 : Number of versions for hospital features with tag combination of healthcare:specialisation and emergency.

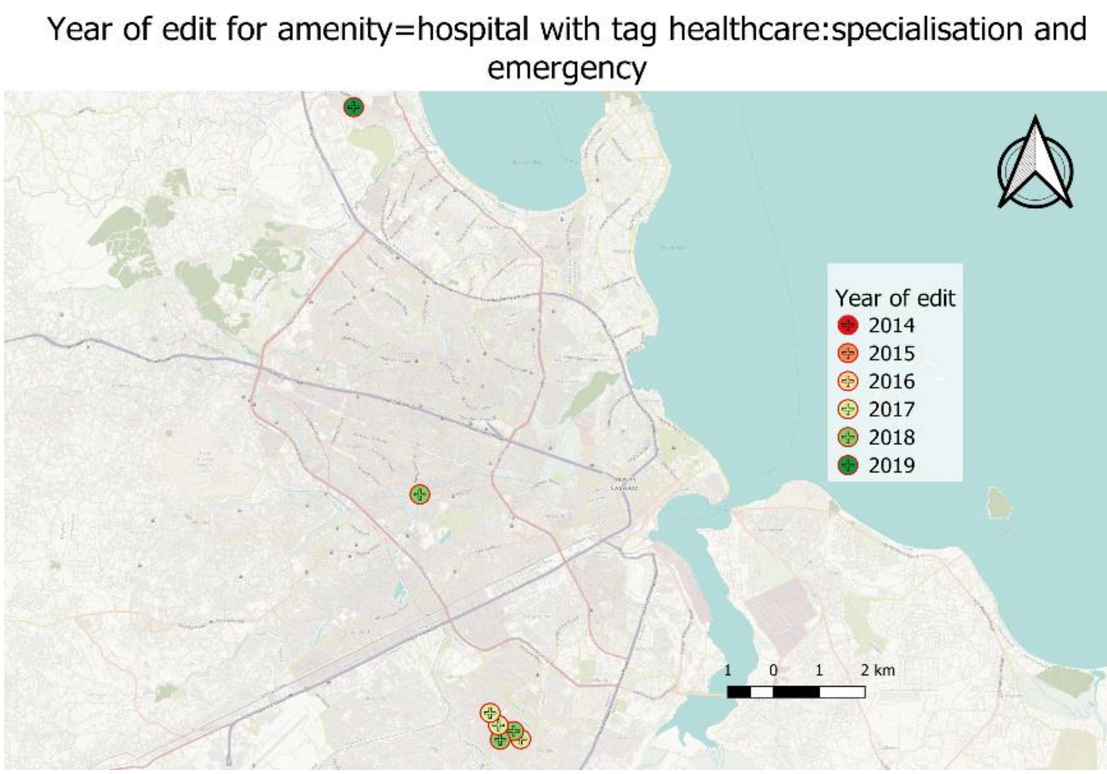


Figure 5.16: Year of edit of hospital features with tag combination of healthcare:specialisation and emergency.

As mentioned in the section of date of edit, more recently the edit indicates the active mapping. Active mapping indicates an increasing number of details. To elaborate this date of edits for hospital features with tag combination of healthcare:specialisation and emergency. Features with more information are dated recently as shown in **figure 5.16**.
Note: As observed there are uneven patterns with respect to experience and specific tags. Therefore, there is a need for standardised approach to do mapping in a way that serves the specific purpose.

5.2.5 QM-3: Experience of mappers

Results show that 51% of total edits are done by top 20 mappers and the area mapped is also quite large. Then rest is below the standard but the results of these can only result in validation of that mapped area (more in 5.4 mapping strategy). There is more to see than only the number of edits. Such as the difference between the first edit date and last edit date and how it is diversified in our study area.

Table 5.1: Mappers stats in the area of Dar es Salaam

Number of edits by top 20 mappers	330,418
Total edits	644,149
Percentage edited by top 20 mappers	51.30 %

Edits by top twenty mappers with respect to total number of edits are visualised in **figure 5.17**. Results pattern shows that there are more edits by the experienced mappers in the compacted areas as compared to the less compacted urban areas. Square grids are used for this QM because gradual representation of percentage of edits by experience mappers are visualised. For visualizing the edits by experienced mappers **eq 5.1** can be modified. Given that n_i is total number of features in grid cell i, then QI for experienced mappers will be. Where a_i is the total number of features edited by top 20 mappers.

$$QI(e) = \frac{a_i}{n_i} \times 100 \qquad \text{..eq 5.2}$$

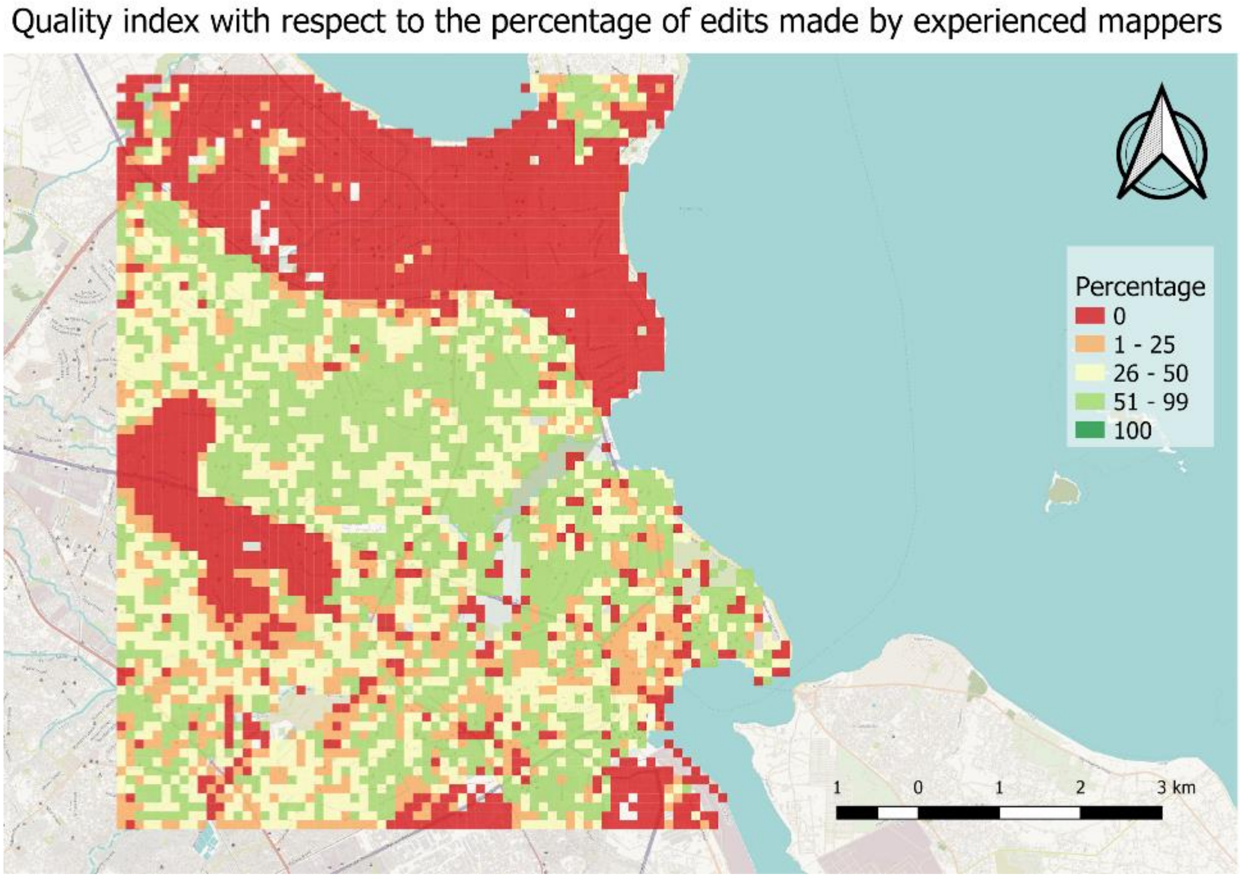


Figure 5.17: Quality index with respect to percentage of building features edited by top twenty mappers.

Outcome of experienced mapper quality metrics

The result from this quality metric is hard to quantify. We again take an example of the hospital feature and take only hospitals with a tag combination of emergency and healthcare:specialisation. The example results in that most of the edits for these hospitals were done by the top 20 mappers (**See appendix A**). Which concludes that there is a high possibility that information added by experienced mappers has a higher level of detail as compared to inexperienced mappers. This has not been analysed.

5.2.6 QM-04: Application specific

For this study, flood preparedness is emphasized for this quality metric. We took two examples to discuss what can be included in this quality metric.

5.2.6.1 Feature: bridge

For location-based services (LBS) it is important to know which bridge can be in potential danger. In order to find that OSM has set an important tag for the bridges that are crossing a waterway. Missing tag for a waterway can give false routing results if not analysed before because it can give the user information about where the flood levels are high and where there are bridge crossings. For the Dar es Salaam case there are very few bridges or overpasses with tag information about the waterway. As seen in the **figure 5.18** even the primary road with river crossing bridge missing the waterway tag. Firefly map is used for visualising the bridge features because the length of the bridges are small and 'glow' produced due to firefly affect helps in clear identification (J. Nelson, 2016).

Bridges crossing river with and without waterways tags

Figure 5.18: Tag completeness for Bridges and overpasses highways crossing.

5.2.6.2 Feature: buildings within 100m of the river

Flood impacts would be more severe in near proximity of the river than far. Therefore, it is important to complete the information about the buildings before completing it for the buildings with high proximity from the river. Results in **figure 5.19** gives interesting insights about where the information is lacking about the building material. It is interesting because it highlights the missing information at the North of Dar es Salaam which is an informal area and probably comparatively more vulnerable also due to its close proximity to the river (UNISDR, 2012). In figure 5.7 there was a huge amount of data represented for the whole area but this map specified the information missing for the buildings that are possibly most endangered. Equation 5.1 is also used here.

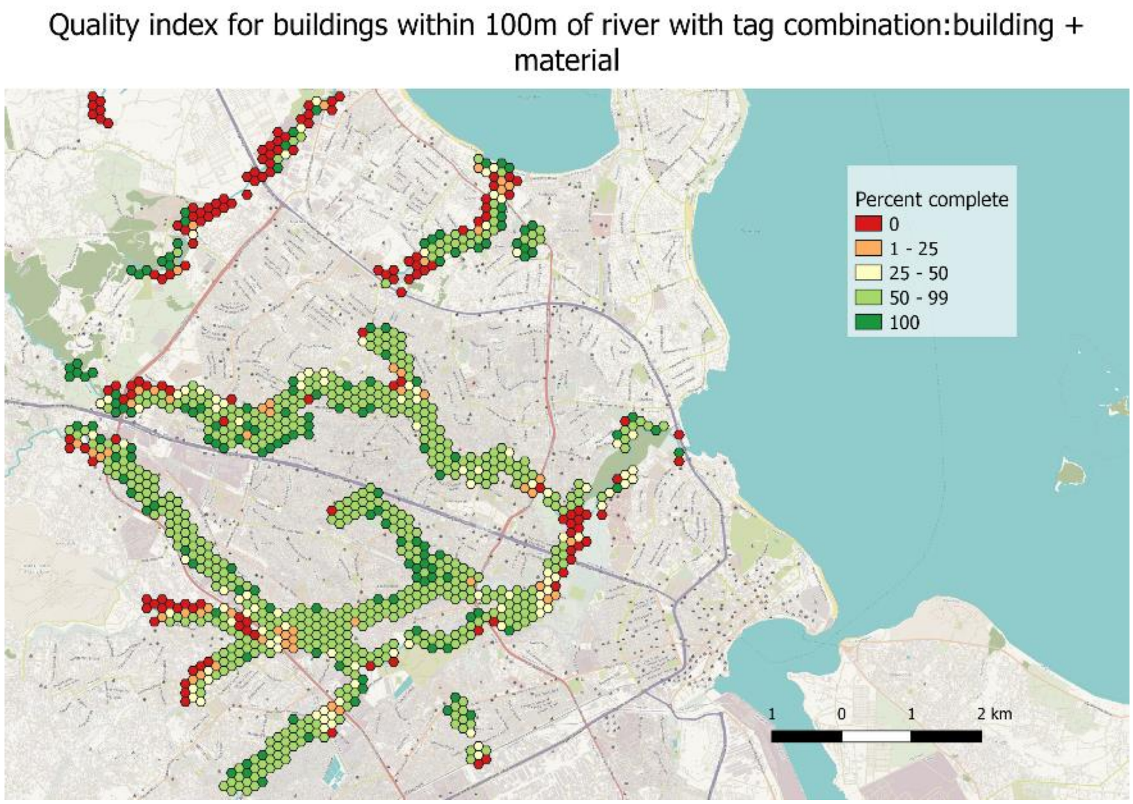


Figure 5.19: Quality index with respect to buildings in 100m proximity of river.

5.2.6.3 Feature: highway with tag number of lanes

For routing purposes there are some additional information about the roads required to make the routing realistic such as capacity of the road (Li, Tu, & Zhuo, 2018). One of the components in calculation of the road capacity is the number of lanes (Huff & Liggett, 2014). Using overpass API highways without the number of lanes tag is visualised using network flow map in **figure 5.20**. This can be used for mapping specific tags when mapping roads, but mapping roads require very high resolution satellite imagery which are usually not available freely for developing countries (Davidovice, Mooney, Stoimenov, & Minghini, 2016; Mooney & Corcoran, 2014). This will be discussed in chapter 8.

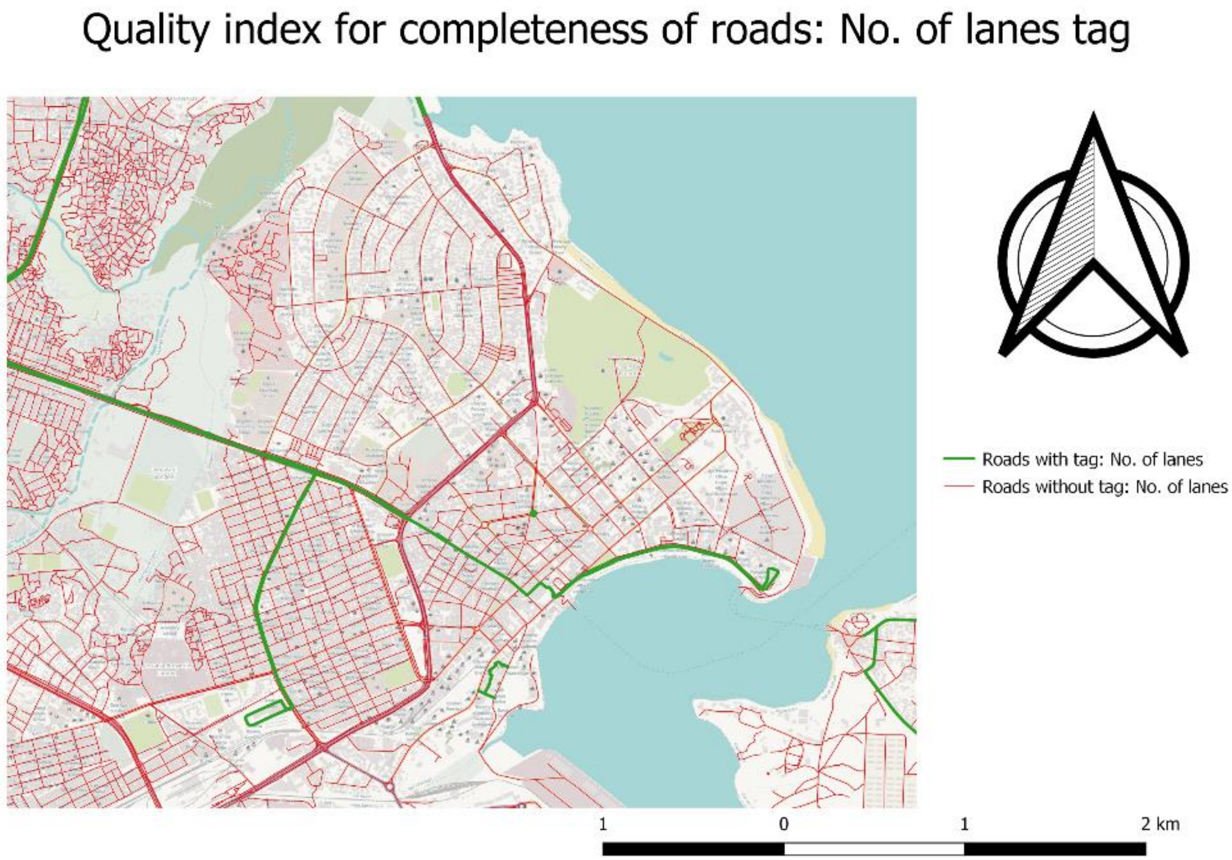


Figure 5.20: Quality index with respect to highway:lanes tag completeness.

5.3 Conclusion

5.3.1 Tag completeness

It should be noticeable that more emphasis was given to the tag completeness and most of the analysis is for the critical infrastructure for the quality metric 1. This is because the information completeness is of high priority as seen from user interviews, literature and case studies. The other quality metrics reliability and trustability are supplementary to the information completeness.

5.3.2 Reliability

QM 2 should be analysed with extreme care and only when the quality standard of the maps in the OSM is very low. For example if the last edit of a large number of hospitals is 7 - 8 years old, then it is required. Number of versions is important to give us the idea that more mappers have been looking at a certain feature. This can provide us how accurate information could be because the more the feature has been touched the more (ideally) more improved information should be. This was not observed in the case of the school, but it was observed while analysing the hospitals. As the number of versions increased the amount of the detail (tags) increased.

5.3.3 Experience of mappers

Issue of the experienced mappers can be biased, because certain mappers can be a GIS expert but never mapped in the OSM can be considered as 'untrustable' according to our analysis (Krijnders K, Personal Interview, Jan 14, 2020). Nevertheless, for our analysis it gives some patterns on where the most experienced OSM mappers have been contributed to. This gives us the area in the map that was not given attention for the mapping in the OSM and compliments the tag completeness. These areas we will be focusing on in mapathon in Dar es Salaam and quality metrics for mapping in Tadjoura Djibouti.

5.3.2 Application specific

This quality metric highly depends on the application and purpose of your analysis as an end result. For our case that is flood preparedness, we already know that buildings and infrastructures with low proximity to the water bodies are more exposed to floodings than with higher proximity. We use only assumption based analysis for information completeness within 100 and 200 meter proximity of water bodies.

5.4 Mapping Strategy

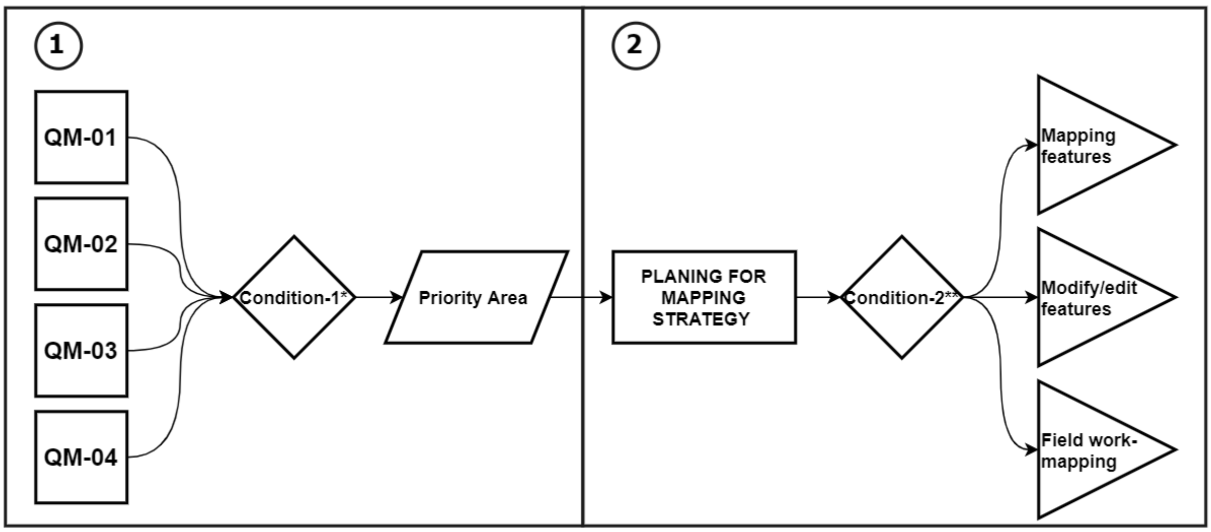
We have discussed the quality metrics in detail now practical implication will be discussed. In this section we will discuss the mapping part of **figure 2.3**. This will also include the process starting from the quality metrics. It should be noted that here the strategy is defined as ***procedure not conceptual relation*** and here conceptual classes are used as steps. **Figure 5.19** shows how the mapping area should be strategized. Box 1 is followed by the Box 2 from left to right and shows the proposed procedure that would be followed for the mapping and the impact of this proposed procedure will be discussed in chapter 8.

5.4.1 BOX-1: Priority area for mapping

The quality metrics are filtered out by the user requirements, literature and case studies to prioritise the mapping area for specific purpose .i.e floods. The spatial data requirements for the flooding scenario is discussed in section spatial data requirements. Condition 1 in **figure 5.20** also includes the quality standard for quantifying priority areas for mapping. For instance mapping can be prioritised in all the grids from **figure 5.18** lies in zero percent complete is prioritise for mapping.

5.4.2 BOX-2: Planning for mapping strategy

Planning for mapping in the priority area depends on what is the context of the analysis required (Matthews, 2019). The strategy depends not only on the physical mapping requirements but also what process should be followed to improve the map in the prioritised area. This requires resource management and how the available resources can be utilised efficiently. This also depends on what can be mapped remotely and what information can only be added by field work. For example the healthcare:specialty can only be added by field work, while missing building foot-prints can be added remotely. Modify/edit feature means that the tags of certain feature needs to be altered or add tag to improve the quality of information. Condition 2 also includes quality assessment of available satellite imagery in certain location. This will be discussed with practical application in chapter 8. There are of course different types of voluntary activity in disaster situations (Sauer, Catlett, Tosatto, & Kirsch, 2014) but here we will only discuss only the process that humanitarian organisations could use to navigate these voluntary activities. In chapter 8, procedure stated in the **figure 5.20** will be used to map the areas of interest.



*This condition depends on the user requirements and/or the mapping requirements on how the mapping area should be prioritize
**This condition further depends on the resources such as satellite imagery, volunteers and place of mapping (remote or local).

Figure 5.20: Shows from left to right the process that should be followed to achieve the final goal of this study.

Chapter 6: Routing in OpenStreetMap (OSM) for disaster scenario and impact of quality

6.1 Introduction

Routing is an important component for disaster response. The routing should be efficient and more importantly reliable (Zheng, Xia, Ambinakudige, Qin, & Li, 2019). For disaster preparedness point of view routing is useful in calculating if there are reliable resources accessible for most of the households in the city such as hospitals (Campos, Bandeira, & Bandeira, 2012).
During the disaster scenario average working routing model is usually enough to operate and estimate the potential accessibility inside the city (Krijnders K, Personal Interview, Jan 14, 2020). Although the Dijkstra shortest path algorithm is usually enough and has been used in Open source platforms like Openrouteservice (ORS). These routing services need modifications in their working according to specific purposes. Usually if the isochrones/service areas are analysed use the test version of ORS it overestimates the time and makes the isochrones larger than the actual travel time **(see figure 6.1)**. in this chapter we will discuss the how fit-for-use algorithm is developed to be used for calculating service areas of hospitals in Dar es Salaam. Impact of the quality of OSM on service areas will be discuss in chapter 8.

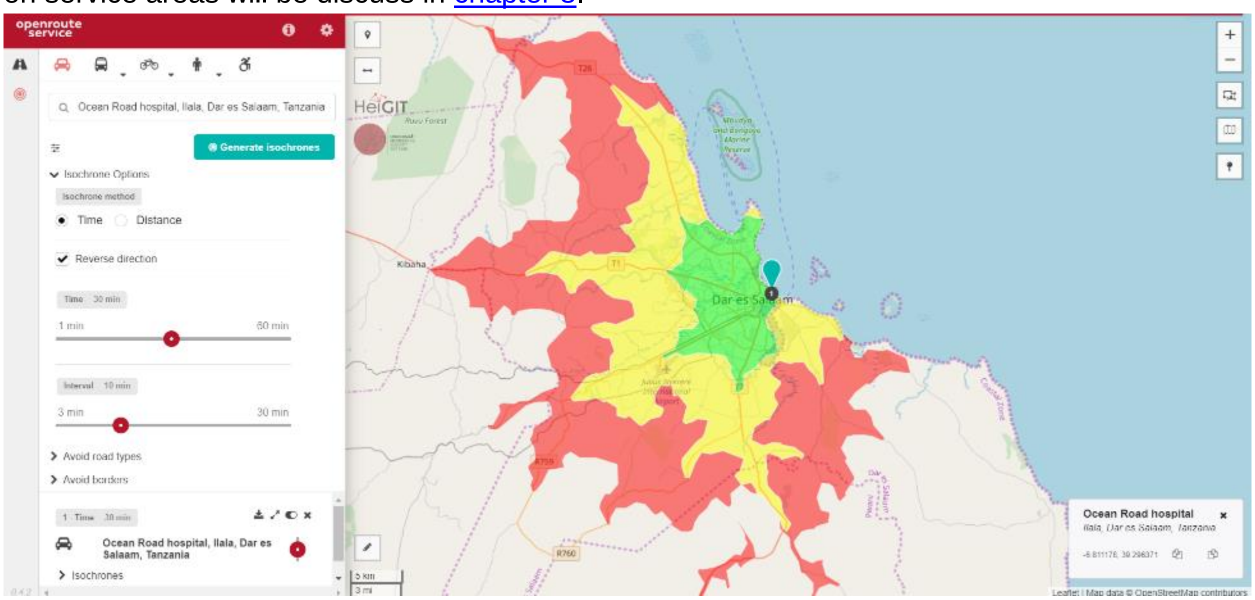


Figure 6.1: Isochrone for one hospital in Dar es Salaam. ‘Green’ areas are within 10mints reach, ‘yellow areas are within 20mints and ‘red’ areas are within 30mints. These time costs seem unrealistic as it is impossible to cover the whole Dar es Salaam metropolitan area in 10mints.

6.2 Highway classification

This research will not look into the complexity of the routing algorithms but how (an adequate) routing algorithm can be affected by the quality of OpenStreetMap (OSM). Furthermore, it will also explore how the population can be affected by the non-reliability of the information available in the OSM such as ‘unclassified’ roads. Highways are planned in hierarchy and this hierarchy depends on the traffic capacity it can carry (Goto & Nakamura, 2016). Speed in which vehicle could move depends on the traffic capacity (Halder & Engineering, 2013). Speed reduces if we move from top of the hierarchy (primary or trunk) to down (Residential) **(figure 6.2)**. In OSM information about classification of highway can be added using tags. Reliable time-travel prediction can only be made if this information (tags) about highway classification are added correctly. Two of the major problems that were addressed during the interview with the officials from 510global were unmapped roads and roads that have strange tags and tagged as ‘unclassified’ which creates the information about ground truth unreliable (Krijnders K, Personal Interview, Jan 14, 2020). This will be considered a major point in formulating routing algorithm and mapathon.

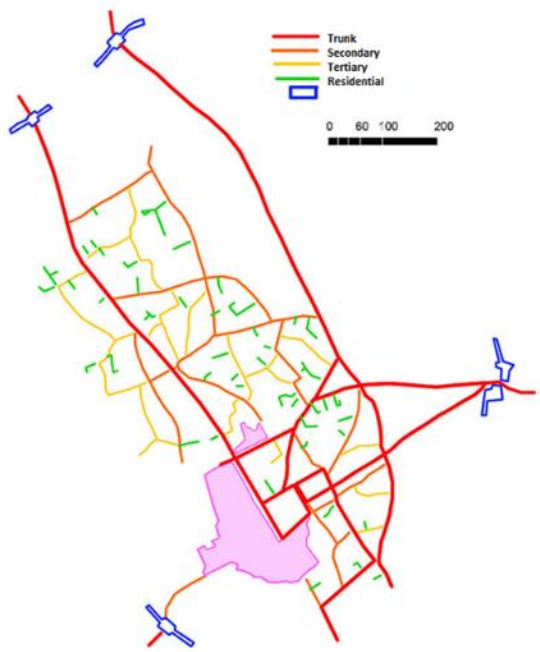


Figure 6.2: Hierarchy of highway in Dar es Salaam (Dar es Salaam City Council, 2008)

6.3 Routing algorithm

Before discussing the developed algorithm it is first required to define what is considered an adequate routing algorithm. From the user point of view the routing in the disaster scenario is considered as *good enough* when the roads are characterised correctly and are in general complete. Furthermore, availability of good enough routing information in time is more crucial to assist rescue workers is better than having a complex routing model in which much time is consumed in producing information to feed into the model than getting actual results (Krijnders K, Personal Interview, Jan 14, 2020). Here the consideration of the algorithm is also based on the user requirements which is fast and easy to understand even for the non-technical people, because the communication between different levels of stakeholders (see level of stakeholders) is important for faster response (Medford-davis & Kapur, 2014).

6.3.1 Inadequate highway tags

In this context tag highway=unclassified is considered as an inadequate tag for the roads in terms of assigning speed to it. This is because of a variety of reasons. First of all, there exists uncertainty in assigning a defined speed to these links/edges because there is confusion in understanding of this tag (Krijnders K, Personal Interview, Jan 14, 2020). This tag should be assigned to the least important roads, but in our study area (Dar es Salaam) there were several roads that were inside the Central Business District (CBD) and connecting to the residential areas but still tagged as unclassified which proves the claim made by the interviewee. Main misunderstanding is claimed to be that mappers think that it is the road that cannot be categorised. Which is not the case, the roads that cannot be classified should be tagged as '*highway=road*' **(OSM wiki, 2020)**. Another reason is that in Dar es Salaam city master plan there is no such road classified as *"unclassified"*. So, we cannot predict the traffic capacity. Other inadequate highway tags includes *"highway=yes"* or *"highway=road"*.

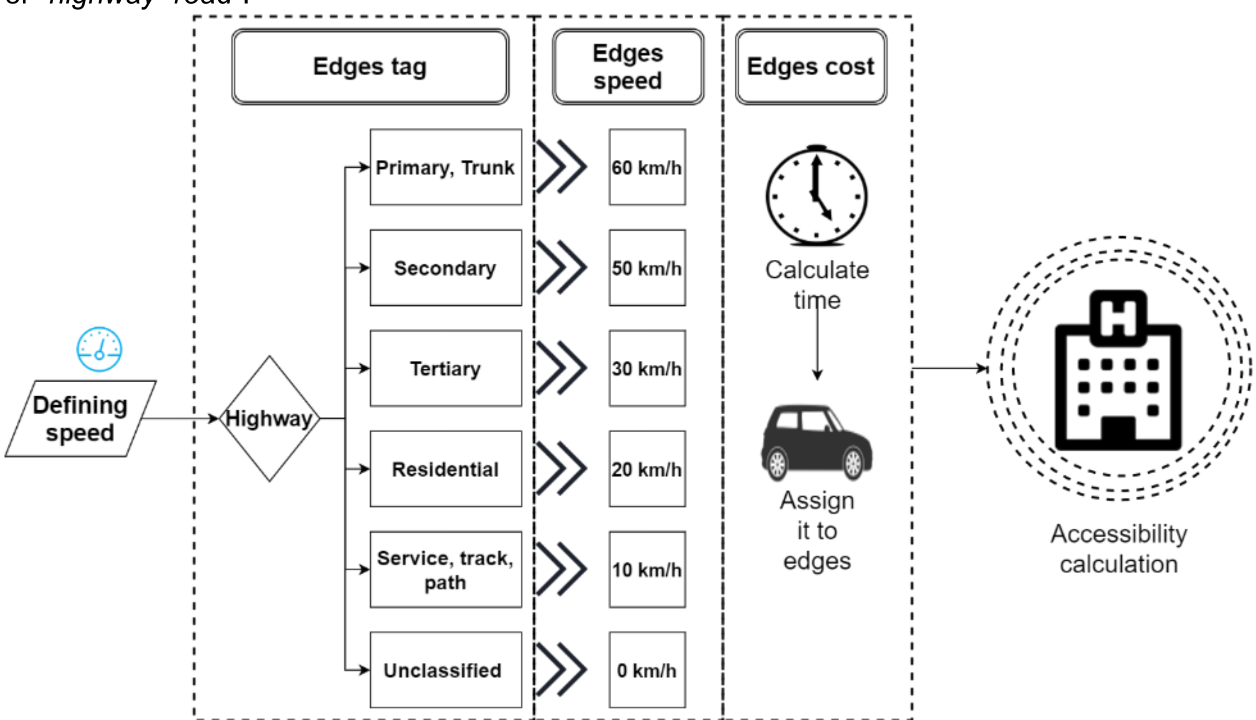


Figure 6.3: Shows the working concept of the developed routing algorithm. Accessibility calculation will give the service areas for the hospitals.

6.3.2 Algorithm creation

Routing algorithms should be dynamic such that it matches on-ground time-travel conditions (Zheng et al., 2019). In order to make a dynamic algorithm, variation in speed in the edge according to the classification of the road. The speed is taken from Dar es Salaam Transport Policy and System Development Master Plan (Dar es Salaam City Council, 2008). This algorithm is meant to assign dynamic speed to the edges depending on the capacity of the road that is defined by the classification of roads in the OSM. Above figure shows the algorithm implications to calculate the service areas of hospitals. **Figure 6.3** shows the working of the algorithm for calculating the service area of hospitals. SQL queries used to assign the speeds to the edges is given in **Appendix A**.

6.3.3 Impact of quality on routing

The impact of non-reliable tags or tags for 'highway' in OpenStreetMap (OSM), can make the routing non-reliable. This can affect the accessibility calculation of the healthcare services during the disaster. Reliable and complete accessibility information can help local governments to plan for improvement in their hospital and infrastructure capacity (Kim, Byon, & Yeo, 2018; Mathew, Rekha, Wajid, & Radhakrishnan, 2017). Without the high-quality information the accessibility analysis can create misleading results. Impact of the quality will be discussed and visualised in detail in chapter 8 where we compare the datasets from before and after coordinated mapping event.

Chapter 7: *Fit-for-purpose* satellite imagery for mapping

7.1 Introduction

During the disaster scenario various space charters become active to provide the satellite images of the affected areas to estimate damage and accessibility of the area (UN, 2019). The charter is only activated in the merge of disaster or governmental requests (International disasters charter, 2018). Thus, these imageries cannot be used for the disaster preparedness scenario under normal circumstances and according to the conclusion from need assessment satellite imagery is the cord of the mapping during all disaster cycles.
There is an increase in freely available satellite imagery sources which increase the confusion of which satellite imagery to use (Pabian, 2015). Thus, it is important to discuss the requirements of the satellite imagery that is needed to map different features in the OpenStreetMap (OSM). Here we shall only discuss the satellite imageries that are freely available in iDeditor of OpenStreetMap (OSM). Esri and Bing are the most commonly used satellite imagery while mapping in OSM (Krijnders K, Personal Interview, Jan 14, 2020). We shall create scoring criteria for grading satellite imagery on the basis of this criteria and set the final scoring range that can be considered as FIT. These images can be used for mapping and also the meta-data such as date of acquisition can be used to define mapping areas, given that the mapped features are edited before the acquisition of satellite images in OSM.

7.2 Objectives

The case of Haiti earthquake in 2010 shows that there were upto 10,000 NGOs active which due to no standard requirements, caused duplication of efforts (Kerle, 2015). OSM has a very large database and wide range of spatial information that can be added in the forms of tags (Davidovice et al., 2016). This creates variation in the satellite data requirements.
There are various quality parameters that can be used to qualify a satellite imagery as fit (Brodeur, Coetzee, Danko, & Hjelmager, 2019). This includes assessing the imagery availability and currentness (Elfadaly & Lasaponara, 2019). Furthermore, it will also help prioritise the areas where high-quality images can improve the mapping which in turn have impact on disaster response.

7.2.1 Quality of satellite imagery

Before moving towards the spatial data requirement, *quality* is again needed to be defined. Quality in this context is how much details can be interpreted, availability of vintage information and how recent the imagery is. This gives the quality standard criteria which can be used to score the satellite imagery that has been used for the mapathon. Now it is important to define each quality criteria and its scoring criteria.

7.2.1.1 C-01 - Level of detail

This criteria is highly context driven due to the fact that satellite images are used for a wide range of purposes and different products give different information (Pabian, 2015). From Battersby (2012) and Jonathan Li (2005) study on the spatial requirements for satellite imagery we came to the following conclusions stated in the **table 7.1**. This table can be translated into what features can be mapped in OSM using open-source satellite imagery with certain spatial resolutions.

Table 7.1: Spatial resolution with interpretable physical features

Spatial resolution (cm)	Interpretable objects
70	Building footprints
50	Roof shapes
30	Cars, residential boundaries

Earth Observing System (EOS), classifies the spatial resolution as: '*Low resolution: over 60m/pixel, Medium resolution: 10 – 30m/pixel and High to very high resolution: 30cm – 5m/pixel'* (EOS, 2019). Scoring is done by combining these classification and table 7.1.

A. Over 60m = 0.0
B. 0.71 - 30m = 0.5
C. 30cm - 70cm = 0.75
D. Less than 30cm = 1.0

7.2.1.2 C-02 - Vintage information

Availability of temporal information is very important to know the reliability of the satellite imagery to be used (Battersby, 2012). Exact date at which the imagery is taken is usually not found in the meta-data of the imagery. Imagery providers usually mention either date range, discrete date or no information in the meta data. For this criteria if the provider states the exact date it will be weighted as 1, if date ranges then 0.5 and if no date then 0. This criteria shows the trustworthiness of the imagery's meta-data.

7.2.1.3 C-03 - Currentness

The more recent the satellite imagery higher is the quality of the satellite imagery. Consideration of what is old depends mainly on the area of interest. If the area of interest is a rapidly growing city then more stricter scoring should be done. For these criteria there should be vintage information in the first place only then this criteria can be assessed. Scoring is as follows:

Table 7.2: Year of acquisition and quality scores for each year.

Vintage year	Score
2020	1
2019	0.9
2018	0.8
2017	0.7
2016	0.6
2015	0.5
2014	0.4

2013	0.3
2012	0.2
2011	0.1
Before 2011	0

7.3 Scoring the satellite images

7.3.1 Introduction

All of the 3 criteria are checked by semi-automated observations. The initial steps include analysing what is available in the OpenStreetMap (OSM) iDeditor and what are the gaps. Then how to improve these gaps. After analysing, a score is given for each criteria based on the satisfaction. Furthermore, how the results of this quality scoring can help in creating the opportunity for mapping. Each criteria has different weights. Bing imagery in iDeditor does not show the date of the imagery but by using the Bing™ Maps REST Services API we get the vintage information. The problem still persists because the meta data gives only the range at which the imagery is taken (see **figure 7.1**). We shall take the upper bound limit as a reference for scoring (VintageEnd).

This XML file does not appear to have any style information associated with it. The document tree is shown below.


```
▼<Response xmlns:xsd="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://schemas.microsoft.com/search/local/ws/rest/v1">
  ▼<Copyright>
     Copyright © 2020 Microsoft and its suppliers. All rights reserved. This API cannot be accessed and the content and any results may not be used, reproduced or transmitted in any manner
     without express written permission from Microsoft Corporation.
   </Copyright>
  ▼<BrandLogoUri>
     http://dev.virtualearth.net/Branding/logo_powered_by.png
   </BrandLogoUri>
   <StatusCode>200</StatusCode>
   <StatusDescription>OK</StatusDescription>
   <AuthenticationResultCode>ValidCredentials</AuthenticationResultCode>
  ▼<TraceId>
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   </TraceId>
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       <EstimatedTotal>1</EstimatedTotal>
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        ▼<ImageryMetadata>
          ▼<ImageUrl>
             http://ecn.t0.tiles.virtualearth.net/tiles/a300112113313202210.jpeg?g-8290
           </ImageUrl>
           <ImageWidth>256</ImageWidth>
           <ImageHeight>256</ImageHeight>
           <ZoomMin>18</ZoomMin>
           <ZoomMax>18</ZoomMax>
           <VintageStart>2017-01-06</VintageStart>
           <VintageEnd>2019-06-30</VintageEnd>
         </ImageryMetadata>
       </Resources>
     </ResourceSet>
   </ResourceSets>
</Response>
```


Figure 7.1: Response from Bing REST service API for a location point in Dar es Salaam.

7.3.2 Criteria for mapping

It can be said that any imagery with a total score of 2.50 to 3.00 according to given criteria. It can be used for mapping features like buildings and roads. As it will enough spatial resolution and the imagery would not be considered as too old. It is always recommended to have as recent satellite imagery as possible especially for rapid growing cities like Dar es Salaam (Kombe E, Email interview, Mar 11, 2020). But due unavailability of free latest satellite imageries, the above-mentioned criteria is sufficient for mapping roads and building in OSM. For the complex tasks such as mapping IDPs (Internally displaced peoples) locations, it is necessary to have up to date and high resolutions satellite imagery (Kranz, Zeug, Tiede, & Clandillon, 2010).

7.3.3 Sample comparison

7.3.3.1 Sample 1a: Dar es Salaam city centre (Esri World Imagery)

Meta data	**Value**
Date	17/03/2019
Spatial resolution	0.31 meters
Quality criteria	**Score**
C-01: Level of detail	0.75
C-02: Vintage information	1.0
C-03: Currentness	0.8
Total	2.55

Figure 7.2: Dar es Salaam, Tanzania imagery by Esiri world imagery

7.3.3.2 Sample 1b: Dar es Salaam city centre (Bing Imagery)

Meta data	**Value**
Date	06/01/2017 to 30/06/2019
Spatial resolution	0.29 meters
Quality criteria	**Score**
C-01: Level of detail	1.0
C-02: Vintage information	0.5
C-03: Currentness	0.8
Total	2.30

Figure 7.3: Dar es Salaam, Tanzania imagery by Bing Microsoft

7.3.3.3 Sample 2a: Tadjoura, Djibouti (Esri world imagery)

Meta data	Value
Date	24/10/2016
Spatial resolution	0.5 meters
Quality criteria	**Score**
C-01: Level of detail	0.75
C-02: Vintage information	1.0
C-03: Currentness	0.6
Total	2.35

Figure 7.4: Tadjoura, Djibouti imagery by Esiri world imagery

7.3.3.4 Sample 2b: Tadjoura, Djibouti (Bing)

Meta data	Value
Date	31/12/2009 to 17/08/2013
Spatial resolution	0.31 meters
Quality criteria	**Score**
C-01: Level of detail	1.0
C-02: Vintage information	0.5
C-03: Currentness	0.3
Total	1.8

Figure 7.5: Tadjoura, Djibouti imagery by Bing

7.4 Comparison results

7.4.1 Trade Offs

Scores for the Esri imagery were higher than Bing imagery with a small margin. Bing imagery does have better resolution, but its reliability is low due to out-of-date satellite imagery and/or less clear information about date of acquisition, but it can help map better than Esri due to higher resolution.

Due to this, there will always be a trade-off between reliability and spatial resolutions with open-source satellite imageries.

7.4.2 Discussion

It is clear by now that Bing provides high resolution imagery which helps the mapper to easily recognise features and map it. On the other hand, Esiri provides comparatively lower resolutions images, but it is more reliable than Bing images. Esiri's images were quite recent as compared to Bing. There are satellite images available that have much higher resolution, but they lack the meta-data requirements such as vintage information (C-03) such as imagery from mapbox. Another such source of collection of satellite images from different providers is SASPlanet which can be used for various applications (Gangaraju, Anitha, Tv, & Ka, 2017). This is an open source tool through which we can download latest satellite imageries from different providers, but it does not provide the meta-data such as date of acquisition.
According to the article "*Should We Always Trust What We See in Satellite Images?"*, there is more to the satellite imagery than spatial resolution to trust the source such as date, validation methods and algorithms used to process (Laituri, 2018). Unavailability of the meta-data can jeopardise the trustworthiness of the satellite imagery (Xie & Shibasaki, 2007). This gives us the conclusion that there are more factors such as temporal aspects that are important for deciding which imagery can be used for mapping.

7.4.3 Limitations

Requirements for spectral resolution are not discussed here which can be important for identifying different features in the OpenStreetMap (OSM) (Wan, Lu, Lu, & Luo, 2017). This comparison is done only for two samples and between two imagery providers. The results can be improved by increasing the number of samples. Furthermore, the number comparable satellite imagery providers can be increased for better insights on different satellite imagery providers and their technical specification for different areas. But analysing the satellite imagery meta-data is very time consuming because extracting of meta-data requires learning of API parameters of the providers and each provider has different.
Nevertheless, this assessment of spatial data requirement of satellite images in iDeditor is also important to increase the self-sufficiency of the OpenStreetMap (OSM). Self-sufficiency will not only improve the OpenStreetMap (OSM), but also the institutional capacities that are using OpenStreetMap (OSM) as a source of information.

7.4.4 Practical implications

Both imagery providers (Esri & Bing) have global coverage with varying quality scores. Moreover, this is also evident from literature review that there are mapping areas in the OpenStreetMap (OSM) are under-mapped. We can use our quality metrics **(QM-1,2,3,4)** to first prioritise the mapping areas and check the scores of the satellite imagery. By scoring we get the idea of what can be mapped and where there is a need for new satellite imagery, if the quality scores are very low (Below 2.0).

Chapter 8: Mapping for enhancing disaster preparedness

8.1 Introduction

After analysing formulating the quality metrics and how it can be implemented using different forms of procedure to be followed. In this mapping event the quality is analysed first according to the quality metrics developed. As mentioned in the section 5.4 mapping strategy, mapping depends on the available resources that can be used for the specific purpose of mapping. After analysing the resources mapping features and modification of features will be the target of this mapathon in relation to box-2 of figure 5.20.

Two areas were selected for two different strategies and for mapping two different features. Area of interest 1 which is Dar es Salaam, is strategized to modify the highway features. Area of interest 2 which is Tadjoura, is strategized to map the building footprints. In this chapter we shall discuss the how the quality metrics are used to prioritise mapping areas and its impact on routing and flood exposure mapping.

8.2 Objectives of the Mapathon

The main objective of the mapathon is to practically see the implication of the main objective of this research. Which is to help the humanitarian organisation to prioritise the mapping areas and to ensure that mapping is done optimally before the disaster. The objective meant to reduce risk of missing information about the measurable components that are required for calculating the disaster risk. In this context two main components are considered that are the building and routing information. Which constitutes this Mapathon as purposeful mapping.

The mapping is specified not only to increase the available information in the OSM but also to increase the reliability of the information. Components that are used to calculate the impact of the mapathon are service area analysis of hospitals in Dar es Salaam and flood exposure map of Tadjoura, Djibouti. Another reason for choosing these features (roads and buildings) is that the network layers are the most dynamic in nature (UN, 2015) and buildings layers are the most essential ones (Ajmar et al., 2015). Furthermore, better classification of the roads improves the reliability of routing algorithms to be used (Chapter 6).

8.3 Mapathon set-up

For this Mapathon mappers from the faculty of ITC are invited, 95% of them were students. At the start of the Mapathon semi-interactive presentation was given covering following points:

1. Research background
2. Background of areas of interest
3. Basics about how to map in OpenStreetMap (OSM)

4. Hierarchy of road classification in Dar es Salaam, Tanzania
5. Training samples for road classification
6. Imagery to be used
7. Impact of this mapping

The presentation was around 15 minutes. The handouts were also given on how to classify roads, training samples and basics of OSM mapping. The presentation and handouts can be found here (https://github.com/MuhammadSaleem056/mapping_future). The coordination during the mapathon was by the author and one of the officials from 510Global. The mapathon took place for three hours in total. All the participants had a background of GIS but still the quality of the data produced was monitored after every hour and requested for correction. The quality is checked by using the overpass API to visualise the edits made by unique users mapping in this mapathon. Mapping coordinated in HOT Tasking manager.

8.4 Area of interest 01 - Dar es Salaam

8.4.1 Introduction

As discussed in the section (spatial data requirements) that the information about critical infrastructure such as hospitals is important but there still remains the problem of accessibility of these services. The information about the healthcare service might be available but in many developing countries the information about the accessibility might not be so reliable (Aftab, Talpur, Napiah, Chandio, & Khahro, 2014).

Dar es Salaam case will be used to modify/edit the highway tags. Objective here is to identify the inadequate highway tags and classify it according to the highway hierarchy discussed in chapter 6. This will improve the reliability of the information about the accessibility of hospitals by using the algorithm developed.

8.4.2 Instructions for mapping

The inadequate highway tags *'unclassified'* will be targeted to classify according to the highway hierarchy. It is possible to do this by identifying first the primary/trunk road and follow the hierarchical order until to reach the selected *'unclassified'* highway tagged feature. This is suggested from the personal experience of the author.

8.4.3 Satellite imagery scores

Using the criteria mentioned in chapter 7, available satellite imagery is scored. Bing imagery was found with the total score of 2.30 and Esri with a total score of 2.55. Both were recommended here due the fact that Bing imagery was of high resolution (see here).

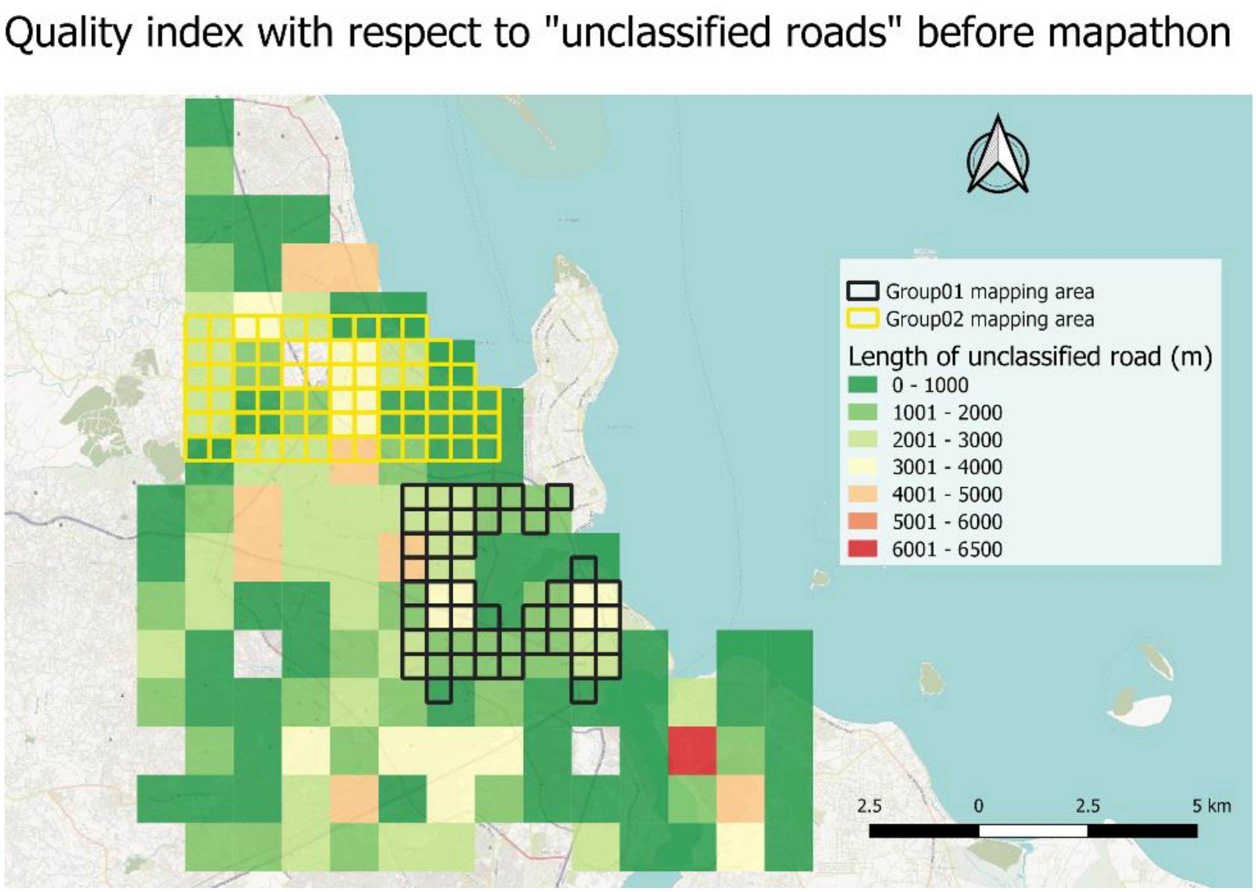

Figure 8.1: Quality index with respect to length (m) of unclassified road tag in Dar es Salaam before mapathon. Red grids show the highest values, which means that they have far the most unclassified roads.

8.4.4 Quality metrics

Quality metrics for tag completeness will be used. Length of highway with *'unclassified'* tag in Dar es Salaam area is calculated and visualise using square grids. **Quality index** here is inversely proportional to the length of *'unclassified'* highway. Square grids are used in order to match it with standard of HOT tasking manager. After the visualisation of results, two mapping group is selected as shown in **figure 8.1**. Group 1 mapping area is selected strictly based on quality metrics and group 2 without strictly following the quality metrics. Idea for dividing into two groups in such fashion is to measure the success of the mapping through quality metrics. Both groups contains near to equal length of unclassified roads to make the results comparable. Group 1 mapping area consists of 30,516 metres of unclassified roads and group 2 consists of 30,860 metres.

Using the algorithm developed in chapter 6, service area analysis is done for all hospitals in Dar es Salaam using network analyst in ArcMap. **Figure 8.2** shows the isochrones of the service areas for all the hospitals in Dar es Salaam before mapathon.

Hospital service area results before Mapathon for all the hospitals in Dar es Salaam, Tanzania

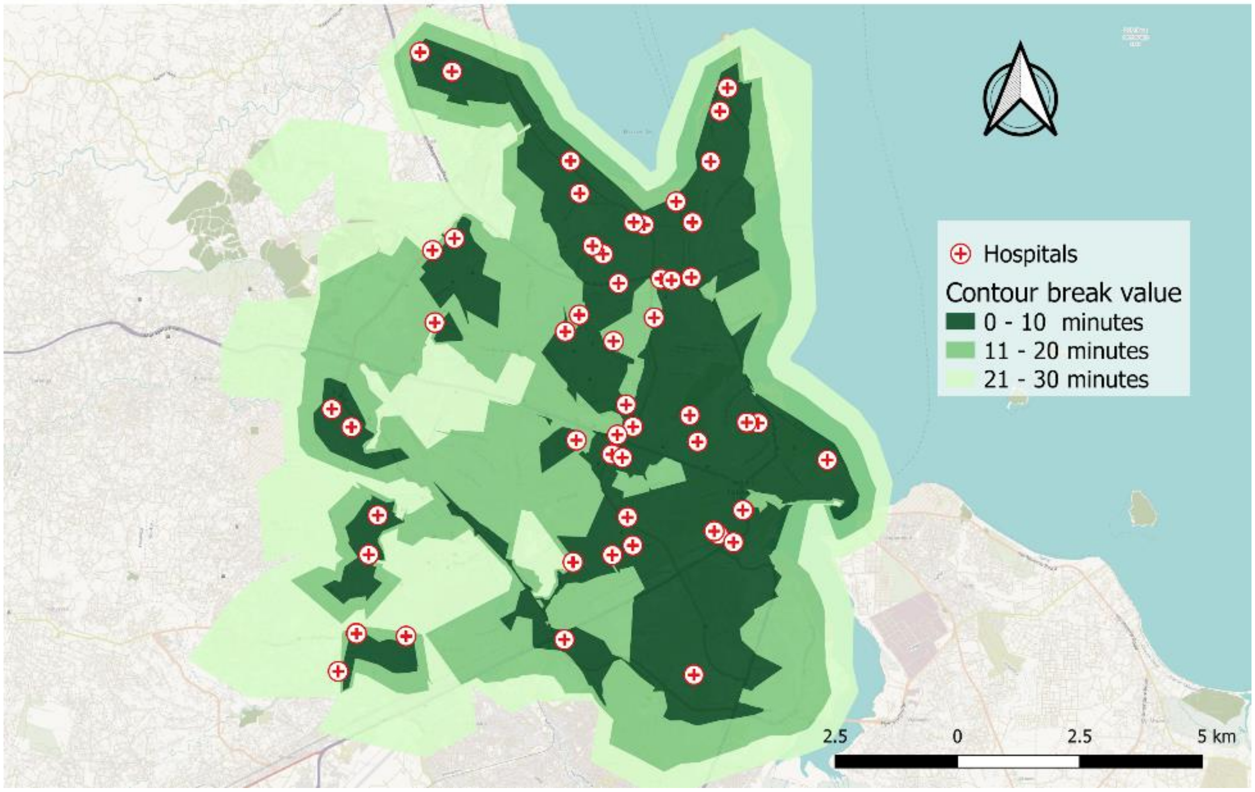

Figure 8.2: Isochrone of service area of all the hospitals combined before the mapathon. Three break values have been taken to visualise with increment of 10, 20 & 30 minutes.

8.5 Area of interest 02 - Tadjoura, Djibouti

8.5.1 Introduction

No risk data is available in the Global Risk Data Platform for Tadjoura, Djibouti. If we correlate this with the recent disaster event in the region which shows major disruption of lives. So, in conclusion there is no openly available and disaster prone with very little information on OSM. The basic objective of mapping in this area will be to map the missing buildings in order produce the data for measuring the flood exposure. Tadjoura is mainly prone to coastal floods. Recently the floods in November 2019 have caused disruption of lives (United Nations Djibouti, 2019).

8.5.2 Satellite imagery scores

According to the criteria mentioned in Chapter 7, available satellite imagery is scored. Bing imagery found with a total score of 1.8 and Esri with 2.35 (see here). Esri imagery was recommended for this AOI.

8.5.3 Instructions for mapping

Main instructions include to adjust the contrast and brightness of the satellite imagery. This is because the available imagery has scores below 2.5. Basic tag combination used here is building=yes because no other information can be traced with this low scoring satellite imagery.

8.5.4 Flood exposure

One of the risk components that is highly dependent on availability of information is the extent of exposed buildings (Naso, Chen, & Aronica, 2016). The most basic information that is required for the flood exposure mapping are the number of buildings in the flood prone area. After analysing the area manually using available satellite imagery in iDeditor it was found that there were several buildings unmapped in the OpenStreetMap (OSM). This creates the underestimation of the number of exposed houses which in turn leads to underestimation of the number of inhabitants in need of relief aid.

8.5.5 Quality metrics

Combination of two quality metrics was used to prioritise the mapping areas. First quality metric is experienced mappers and the second one is application specific. Here the application is derived from the objective of this mapping, which is mapping the missing buildings. It is important to find out which areas in our area of interest are considered as incomplete. Our urban environment is made-up of different patterns which are the strategies and/or concepts we used to create our built-up environment (Park, 2015). These patterns relate to each other in different forms. Typical example is the occurrence of residential areas following the existence of roads or streets (Trim Tab, 2016). Various urban growth models have predicted this pattern (Aithal, 2014). This pattern is used for developing these quality metrics which is *where there are roads, there are buildings*.
For quantification, highways are taken as reference to know if there are buildings mapped or missing. The basic concept is if there is a closed-way for highway then there is assumed to be building(s) enclosed in it and if there is none then this area should be prioritized for mapping. Example shown in **figure 8.3 and 8.4**. Because the streets represent the movement of people and goods (Trim Tab, 2016). The roads represent different urban development patterns and eventually represent geographical regions of settlement.

Figure 8.3: Closed way of roads with buildings enclosed inside.

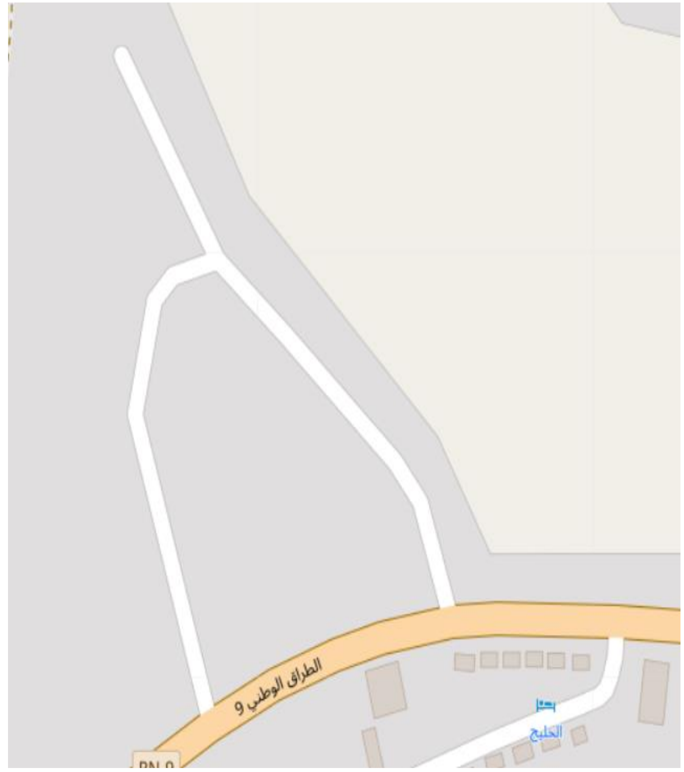

Figure 8.4: Closed way without building enclosed in it. This area has probability that there exists buildings that are not mapped in OSM.

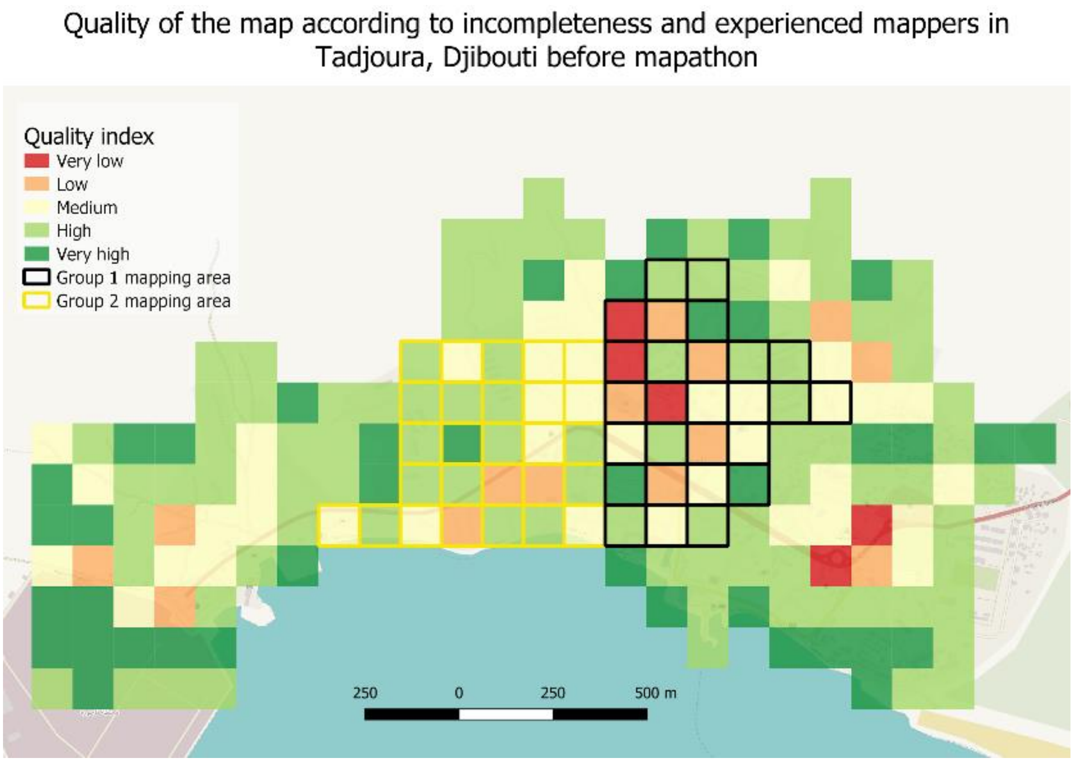

Figure 8.5: Quality index with respect to QM-03 before mapathon. Scale used here is Very low=0; Low=0.01-0.25; medium=0.26-0.50; high=0.51-0.99 & very high=1.0

Overpass API is used for analysing both quality metrics. First all the features that are mapped by inexperience mappers which are not lying in the top 20 experienced mappers are extracted. Quality index (QI(e)) for inexperienced mapper is visualised using square grids (100x100) and created by using this formula:

$$QI(e) = 1 - \frac{A}{B}$$

Where **A** is the total number of features added by an inexperienced mapper and **B** is the total number of features in a square grid. Incompleteness is analysed first by extracting the roads (using overpass API) with no building adjacent to it. These closed ways will give geographical regions which then can be visualised by square grids (100x100) and Quality index (QI(i)) for incompleteness is calculated by using this formula:

$$QI(i) = 1 - \frac{C}{D}$$

Where **C** is the length of the roads in a square grid with no buildings adjacent to it and **D** is the length of the roads in a square grid with buildings adjacent to it. Final quality index is calculated by combining 0.65xQI(e) and 0.35xQI(i). Experience mappers quality metric is weight 0.65 and feature completeness 0.35. This is because there is more literature backing the mapper experience quality metric as compared to feature completeness. **Figure 8.5** shows the result of this combination. Where the scale used in this

8.6 Impact of mapathon

8.6.1 Mapping roads in AOI - 1

Quality index is visualised after mapathon which shows the improvement in group 02 mapping area is more than group 01 **(see figure 8.6)**. This is also evident from the mapping statistics as well. Service area analysis is done again for all hospitals in Dar es Salaam **(see figure 8.7)**. After that to visualise the difference better one hospital is taken, and difference of complete isochrone is visualised. Finally, a deep difference is also calculated for each hospital by analysing the difference between isochrones before and after mapathon for every contour interval that is 10 minutes. We name this hospital as hospital#1. This deep difference will help to see how much impact this mapathon had on travel time while the general difference only visualises the difference in extent.

Now, towards the practical information that humanitarian organisations are interested in knowing which is the reliable accessibility information. They are interested in knowing how many hospitals are accessible to how many houses with reliable time travel information (Krijnders K, Personal Interview, Jan 14, 2020). Number of houses within the service area before the mapathon and after were calculated (**See table 8.1**). Difference is then discussed for both mapping groups and for hospital #1.

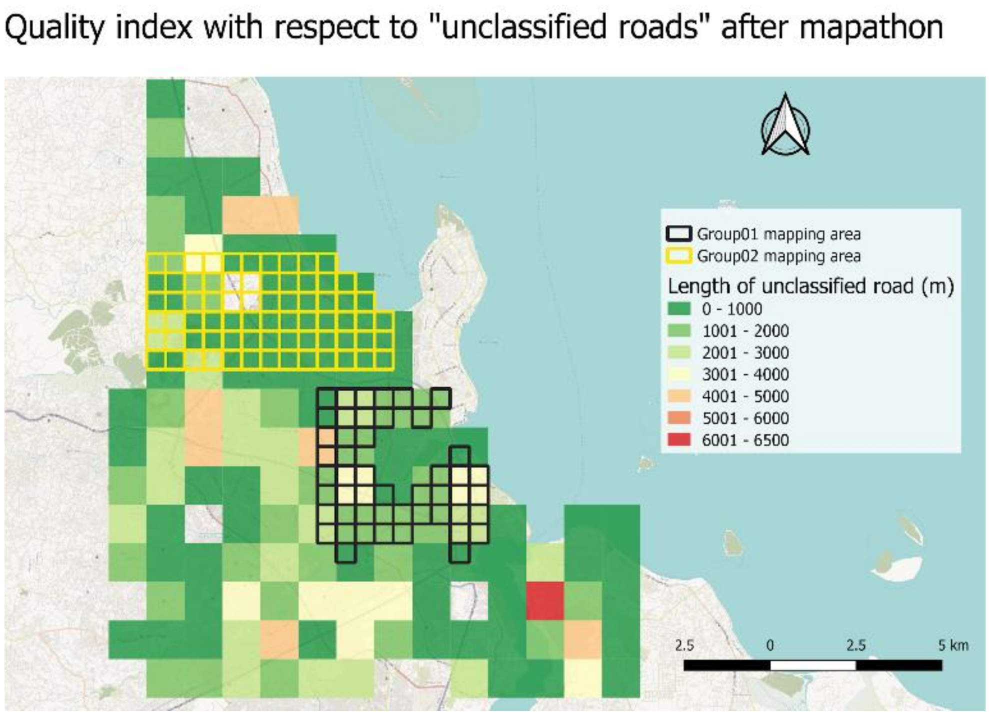

Figure 8.6: Quality index with respect to length (m) of unclassified road tag in Dar es Salaam after mapathon. Red grids show the highest values, which means that they have far the most unclassified roads.

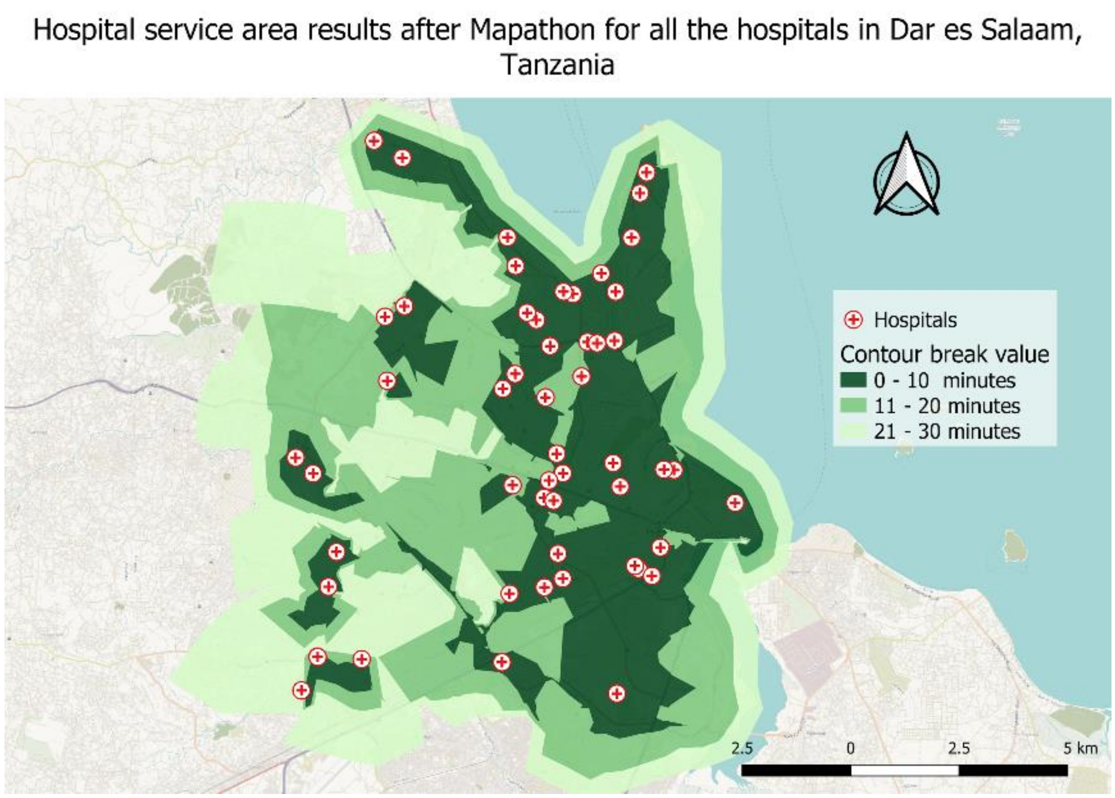

Figure 8.7: Isochrone of service area of all the hospitals combined after the mapathon. Three break values have been taken to visualise with increment of 10, 20 & 30 minutes.

Table 8.1: Number of houses inside the isochrone service areas with reliable time-travel estimation. This is results by intersecting isochrones in figure 8.2 and 8.7 with number of houses in each mapping area (group 1 & 2).

Group Number	Before Mapathon	After Mapathon
One	48252	49377
Two	10685	11561

8.6.1.1 Mapping statistics

Both mapping groups shows changes, but the modification rate was found to be higher in group02 mapping area than group01. Percentage decrease in unclassified tag is shown in **figure 8.8**. This also evident that more grids in the tasking manager has been completed in group02 mapping area than group01 mapping area. This is because the group01 mapping area found to be congested in terms of feature density than group02. After reviewing the feedback from the mappers, it was also found that the group01 area was also difficult to classify because many roads do not follow the hierarchy that was provided to the mappers.

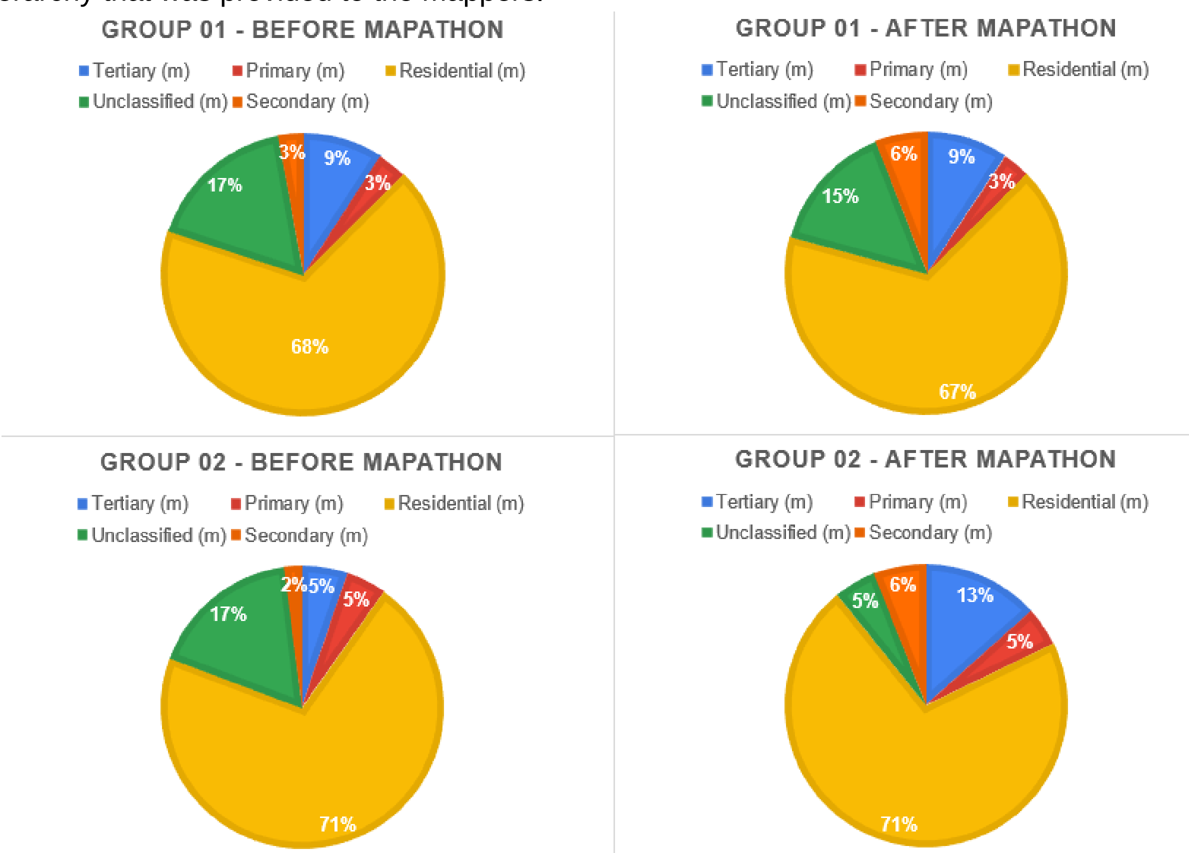

Figure 8.8: Division of different classification of roads before and after mapathon (both groups). Bottom left and right pie charts for group 2 mapping area shows 12% decrease in unclassified road. While top right and left pie charts for group 1 shows only 2% decrease in unclassified roads.

In any case, there is an increase in total mapped roads and decrease in unclassified roads. Which has an impact on the service area coverage. It must be noted here that mappers are suggested not to modify primary roads because it has been used as a reference to follow road hierarchy.

8.6.1.2 General difference in service area

Hospital#1 is considered for better visualisation of the impact on reliable accessibility information. **Figure 8.9** shows the results of service area analysis before the mapathon. Darker green represents high proximity with respect time (10 minutes) and lighter green represents lower proximities (20 and 30 minutes).

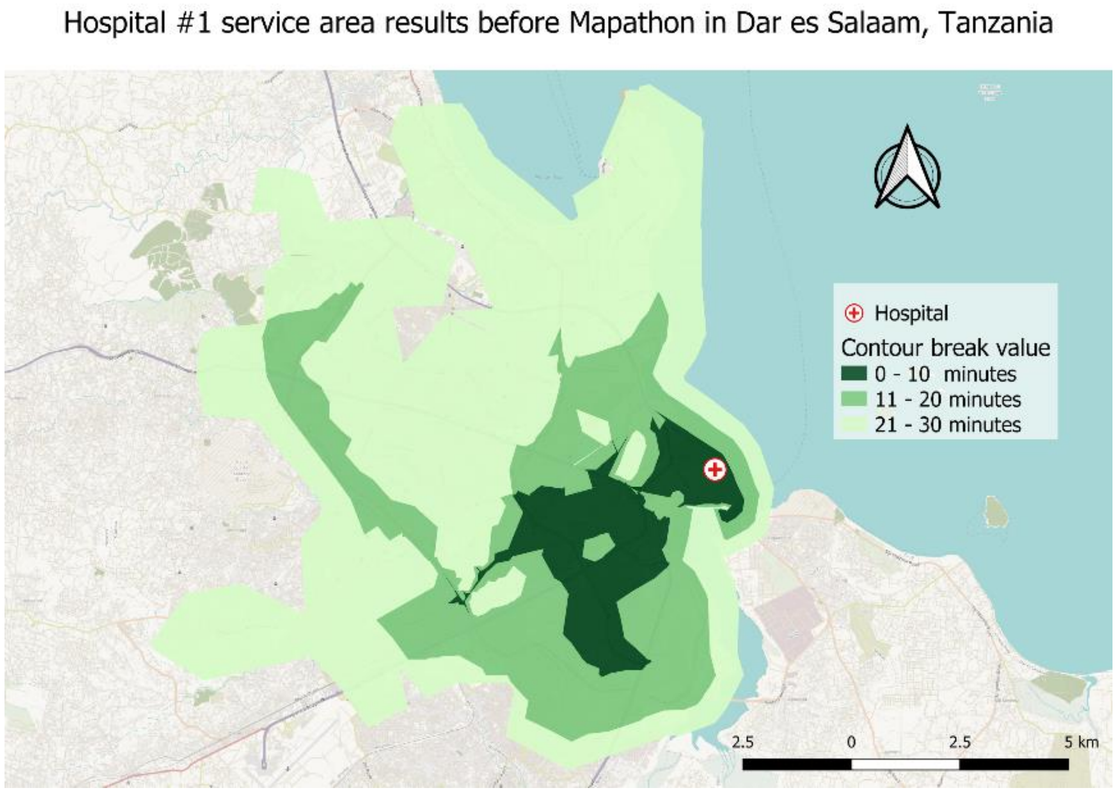

Figure 8.9: Service area iso-chromes of hospital #1 before the mapathon.

Difference is visualised using a difference map using the symmetrical difference calculation in Q-GIS. **Figure 8.11** shows the difference between the service area before and after the mapathon. ‘Red’ areas in the map represent where there is difference between two isochrones. Difference in real terms means how much area is covered by these isochrones gives reliable time-travel information about the accessibility to the hospital#1 to the households. This will be discussed while calculating deep differences.

Hospital #1 service area results after Mapathon in Dar es Salaam, Tanzania

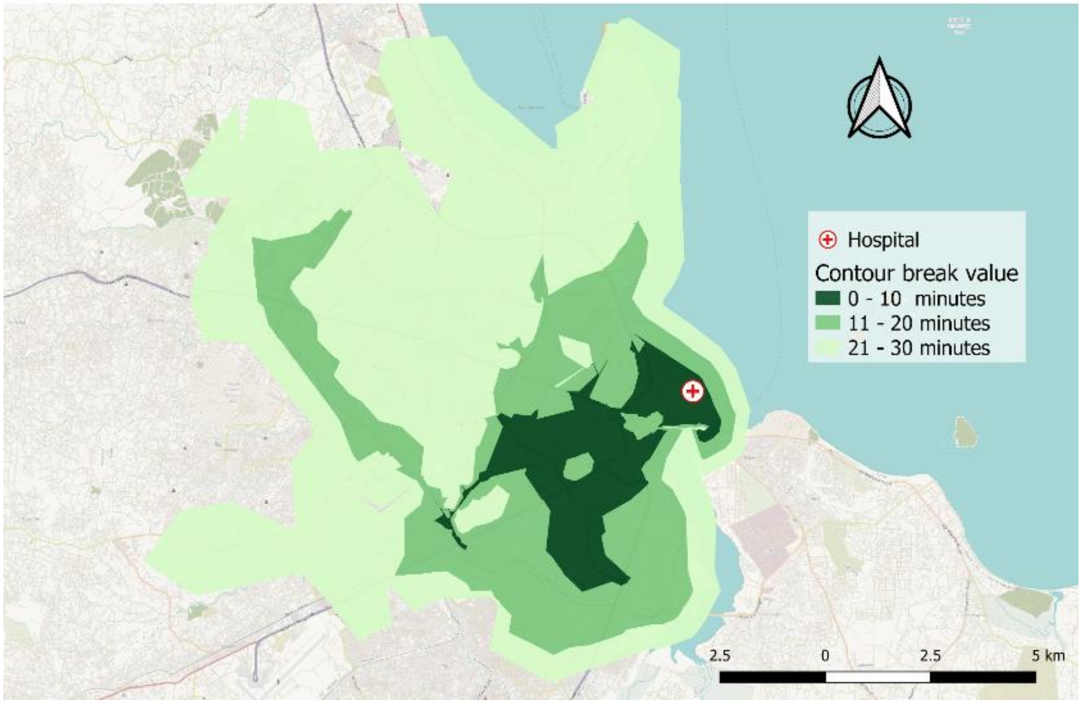

Figure 8.10: Service area iso-chromes of hospital #1 after the mapathon.

Hospital #1 general difference of service area before and after Mapathon in Dar es Salaam, Tanzania

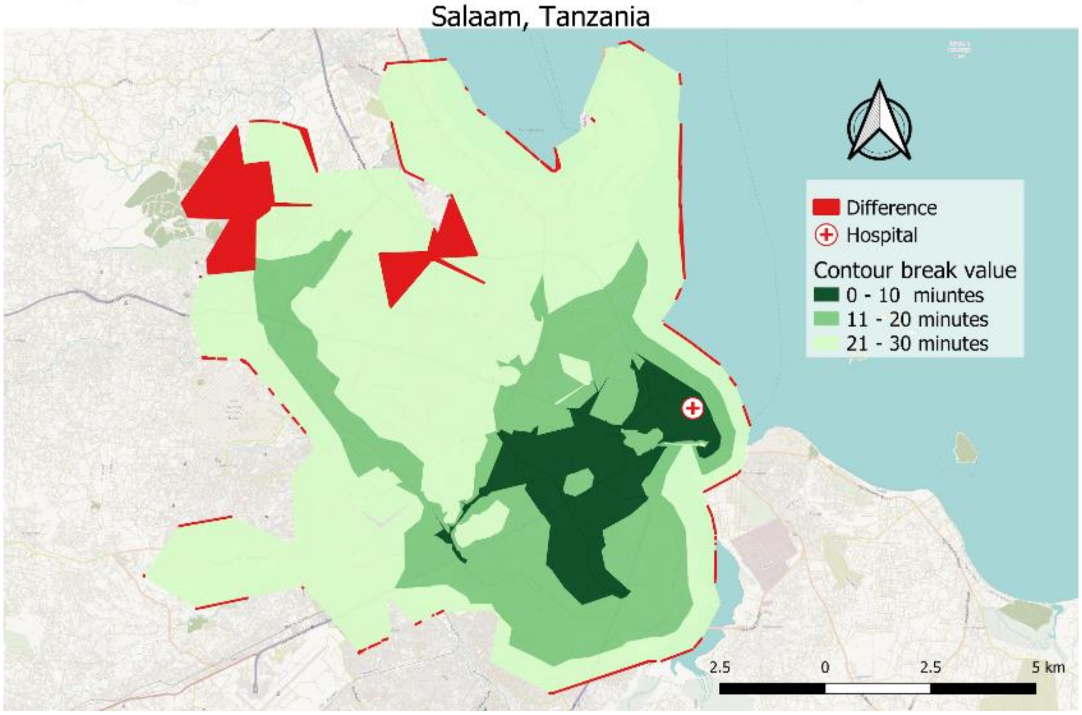

Figure 8.11: Visualisation of spatial difference between isochrone of service area before and after mapathon.

8.6.1.3 Deep difference

This is analysed to see the difference in service area with each changing contour values in figure 8.10 and 8.9. From **figure 8.12 to 8.14** visualise this difference and 'red' areas represent the existence of difference in service areas for each time interval (10, 20, 30 minutes), before and after the mapathon. The important part of this deep difference is how reliable is the information regarding the travel-time for the residents of this test service area isochrones. This is done by intersecting the buildings underlying in each of the contours time interval and counted. **Table 8.2** shows the results of this counting. In figure 8.12 to 8.14 the isochrones shows some sharp corners, this is because there are single highway edges that are classified as higher speed highway classification. Such as primary or secondary.

Table 8.2: number of buildings lying in the service area of hospital #1 before and after the mapathon. Break values represent the time-travel interval used to generate isochrones.

Hospital No. 1	**Number of buildings**		
Break value (Minutes)	**Before Mapathon**	**After Mapathon**	**Difference**
0 - 10	29043	29423	380
0 - 20	101071	92143	-8928
0 - 30	302725	306650	3925

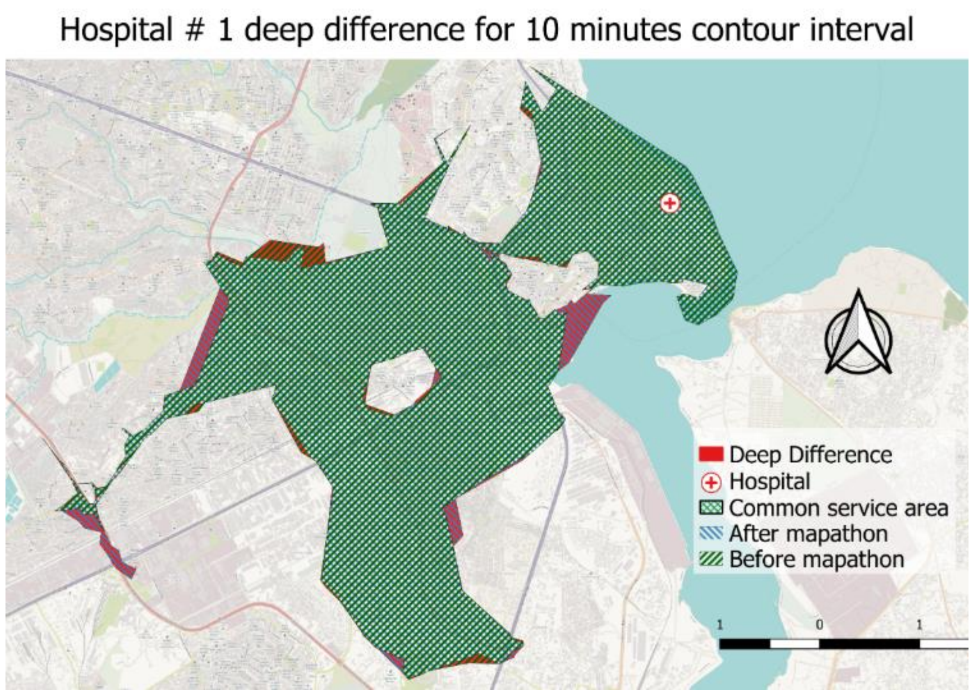

Figure 8.12: Difference between isochrones representing 10 minutes time-travel to the hospital#1 before and after the mapathon

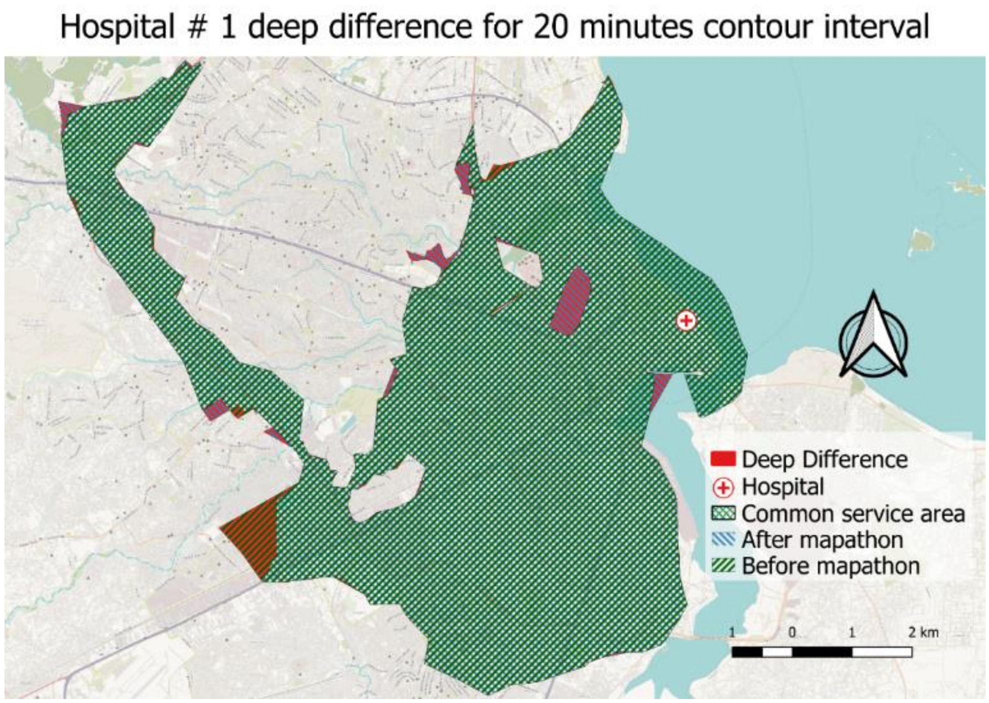

Figure 8.13: Difference between isochrones representing 20 minutes time-travel to the hospital#1 before and after the mapathon**.**

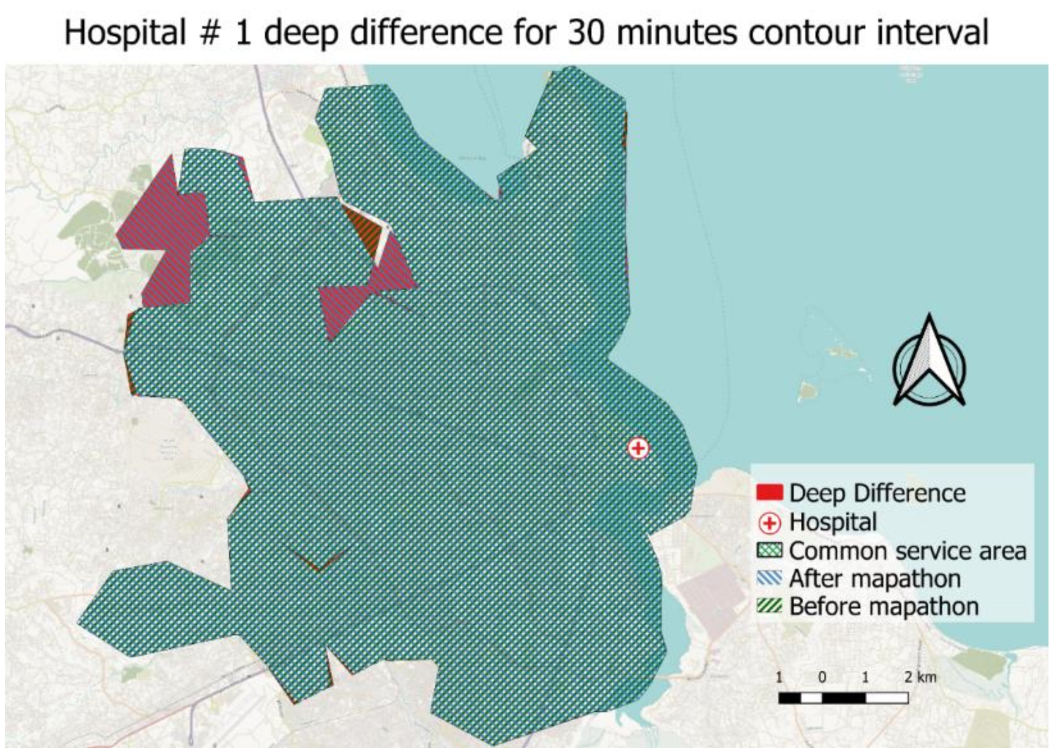

Figure 8.14: Difference between isochrones representing 30 minutes time-travel to the hospital#1 before and after the mapathon

8.6.1.4 Critical findings

It is very interesting to compare the number of houses inside the service area of hospital # 01. The results show that the number of the building and service area does not only increase but also decreases. It is important to do the deep difference to analyse the results and to assess the travel time carefully. **Table 8.2** shows the summary of the results. If we look at the results of the break value of 0-20 minutes the number of buildings decreased, which is because some roads have gone down in the hierarchy (for example from secondary to tertiary or tertiary to residential). This is because, as a result not only unclassified roads are classified but highway tags that are not classified according to the hierarchy were also improved. Furthermore, to make the routing reliable better training samples for classification of roads should be given so the mappers can map it accurately. The limitation of this mapping in this area was the roads of Dar es Salaam don't follow hierarchical order perfectly. Some roads can be classified as 'residential' that are adjacent to 'primary' roads.

8.6.1.5 What can be added to the routing model?

This routing model has rather limited dynamic behaviour due to the fact that it only takes type of the road as a variable. This can further improve by adding different variables and to visualise using these variables. According to UN report on geospatial science and technology for development (2012) the following information is necessary for sustainable urban transportation:

1. *Infrastructure information*
2. *Movement information*
3. *Physical, social and environmental contextual information*

This information can add value to the routing model in different ways. There are many tags available in OpenStreetMap (OSM) (except for social contextual information) that can be used to add this information but this needs local knowledge.

8.6.2 Mapping buildings in AOI - 2

Task for this area was to map the building footprints. To quantify the impact of the exposure map is created by using two factors that is DEM and distance from the river. **Figure 8.15** shows the increase in quality index with respect to the quality index before the mapathon.

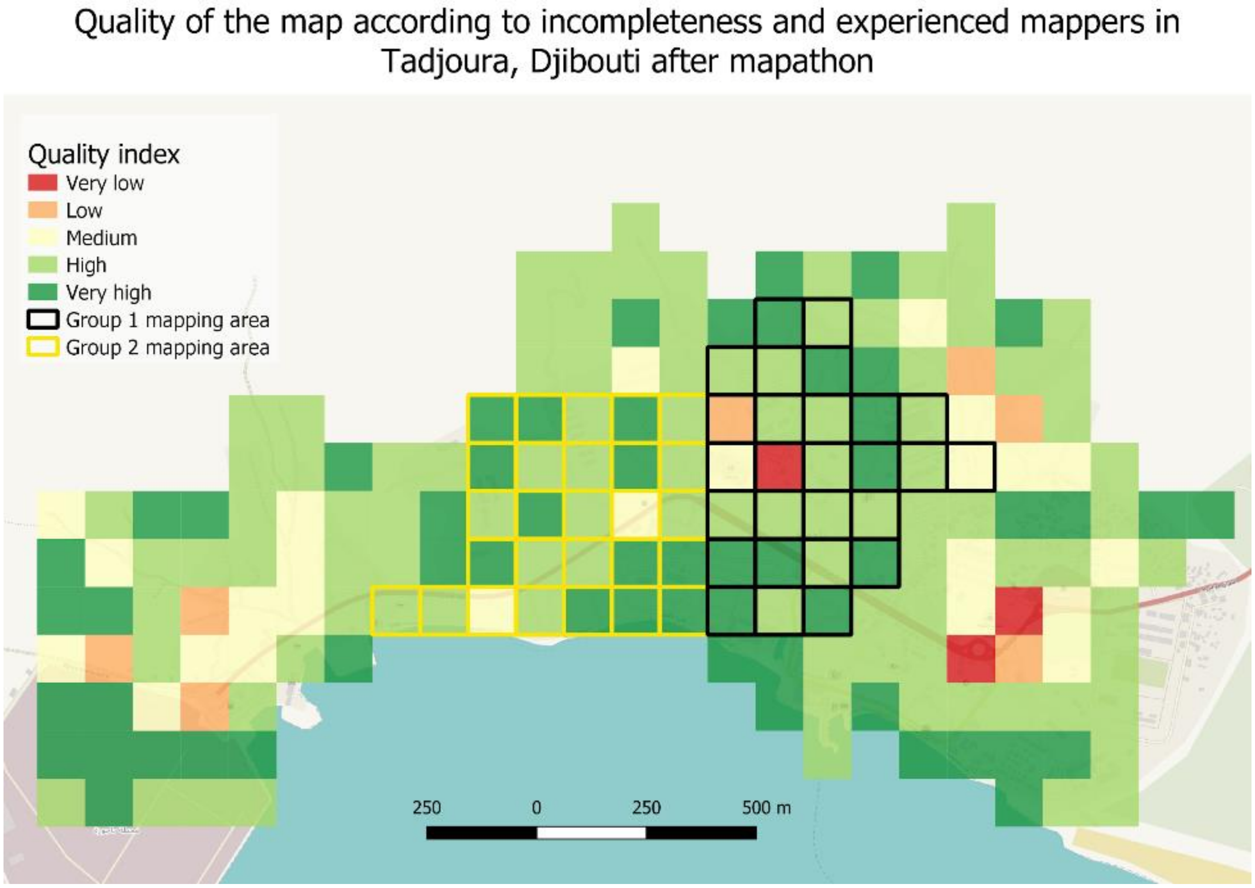

Figure 8.15: Quality index with respect to QM-03 and QM-04 for Tadjoura, Djibouti to find out the areas to be mapped. This figure shows the quality index after the mapathon. Scale used here is Very low=0; Low=0.01-0.25; medium=0.26-0.50; high=0.51-0.99 & very high=1.0.

8.6.2.1 Mapping flood for exposure

We had limited data to include in our exposure model. Digital elevation model (DEM) from 1 to 20 m above the sea-level is used to normalise and 0-500meters proximity to the river is normalised. These normalised values are added and again normalised (equally weighted). The results in **figure 8.16 and 8.17** shows the increase of exposed buildings which is alarming because if this mapping area have not been targeted for mapping there might remain a lot of buildings which underestimates the population that could be caught up in floods. Mapping with this approach decreases the risk of missing information.

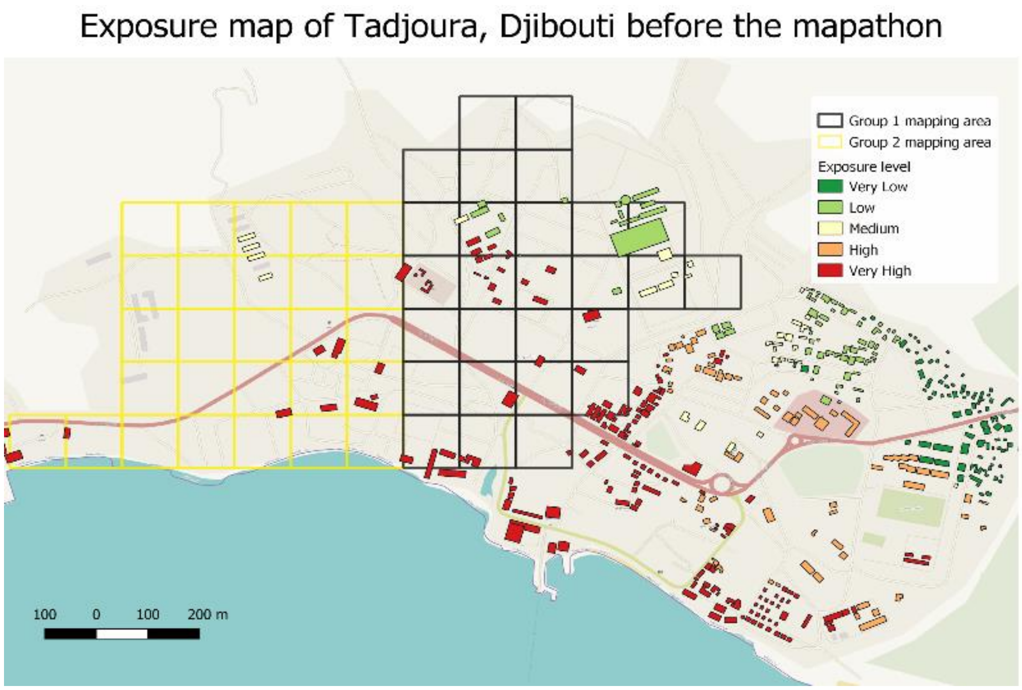

Figure 8.16: Flood exposure map before mapathon.

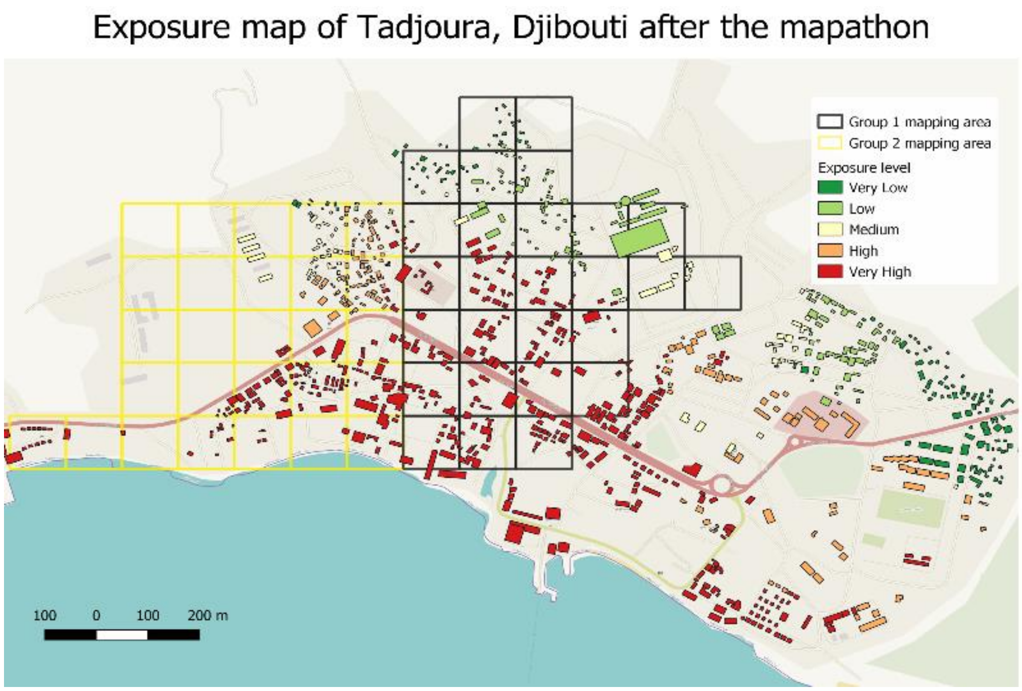

Figure 8.17: Flood exposure map after the mapathon.

8.6.2.2 Critical findings

The percentage increase in the mapped buildings for group 2 is more than that of group 1. This can be explained in two different ways, first is the mapper that was mapping in the group 2 area was very experienced in mapping in OSM. Second is that it might be possible that quality metrics we were using was underestimating the scores in the group 2 area. Underestimation is because there were far too few buildings mapped before the mapathon. This leads to unintended the limitations of the comparison method. **Table 8.3** shows the number of buildings before and after the mapathon with percentage increase for each group.

Table 8.3: Mapped building before and after the mapathon.

Number of buildings	**Before Mapathon**	**After Mapathon**	**Percent increase**
Group 1	77	368	378 %
Group 2	20	319	1500 %

8.6.2.3 Limitation of exposure model

This flood exposure model takes only 2 indicators, which is not enough to carry this type of sensitive analysis (Verlaan, Winsemius, Aerts, Ward, & Muis, 2016). Furthermore, according to thinkhazard.org Tadjoura is also prone to extreme heat, wildfire and volcanic eruption (http://thinkhazard.org/en/report/15282-djibouti-tadjourah-tadjourah/VA). So, a multi-hazard approach should be taken into account while calculating exposure and risk (Van Westen, 2013). The multi-hazard approach will increase the spatial data requirements, quality standards and thus increase the number of indicators. Quality assessment used for this AOI has also not been tested before, but it gives good results.

8.6.2.4 What can be added to the exposure model?

Data that at least can be added is the purpose of the building tag in the OpenStreetMap (OSM). This task can easily be added using iDeditor. This addition can further help in decreasing the abstraction of the exposure map by prioritising the critical infrastructure. Below **table 8.4** shows what kind of information can be added in the OpenStreetMap (OSM) and what impact it can have in disaster preparedness. In the point for assets management it is also important to know and define infrastructure categories (UN, 2015).

Table 8.4: Information required for mapping exposure with respect to floods and how it can be integrated into OSM.

Information	**OSM format**	**Impact on exposure mapping**
Location	building=yes; footprints	Building footprints can yield
Type	building=residential; building=detached; building=apartments; amenity=hospital;	Weighting buildings exposure with respect to the type of the building
Number of floor	building:floor; buildings:floor; floor; floors; floor_nr;	Better estimation of population
Floor area	floor_area	Estimation of the area

8.7 Lessons learnt

8.7.1 Measuring success

Measuring the success for this approach was indeed challenging. We tried to compare different areas by dividing into two groups. Group 1 for both areas of interest was selected strictly following the quality metrics. While group 2 for both areas of interest were not strictly following the quality metric criteria for selecting the mapping area. This was found to be an ineffective way for measuring the success of this mapping approach. This is due to the fact that both of the groups have different areas to be mapped, and different areas have different built-up patterns (He et al., 2018). Taking an example of group 1 and 2 mapping areas of Dar es Salaam. Group 1 is lying in the city centre of Dar es Salaam while the group 2 is lying in outskirts of Dar es Salaam. This makes both groups mapping area incomparable because the built-up area in the city centre in Dar es Salaam is more compacted as compared to the north of the city (UNISDR, 2012).

8.7.2 Comparison between the mapper groups

It is difficult to quantify the impact of this mapping approach. Because comparison is only possible if we have the same area. This arises the issue of time and resources. If we were to employ the same volunteers then there is a chance that they will already recognize the due to spatial cognition because the former mapping has an influence over the knowledge of the participant (Epstein et al., 2019). So, more volunteers would have required a strong conclusion in comparison. Then applying different mappers would raise an issue of their background, because different mappers have different speeds and experiences. Ultimately, the solution would be applying the same mappers on different areas that are very similar. Which arose the challenge of *what is similar?, what constitutes similarity?* And *do it have the same intensity of disaster?*. These are the challenges that will be faced during the mapping events that can objectively justify this study.

8.7.3 Selection of quality metrics

There should be reasonable selection criteria of quality metrics to be used for selecting the mapping area(s). The quality metric used will define which parts of the areas should be mapped and if quality metrics are not studied carefully it can lead to inefficient results. Taking example of quality metrics used Dar es Salaam case in which there is significant increase of quality index increase after the mapathon in group 2 as compare to group 1. This can also be justified by overlaying the results from quality metrics 3 (experienced mappers) from chapter 5 over the mapping area selected (see **figure 8.18**). Results in **figure 8.18** shows that the group 2 mapping area lies in the area with low percent of edits by experienced mapper and group 1 lies in area with high percent of edits by experienced mappers. Meaning that inadequate highway tags in group 2 can easily be identified and classified according to the highway hierarchy because of edits in that area is made by inexperienced mapper. This was unintentionally not considered by the author and realised later. Moreover, the combination of two quality metrics found more effective in mapping as a result from mapping in AOI-1.

Mapping area overlayed over quality index with respect to the percentage of edits made by experienced mappers.

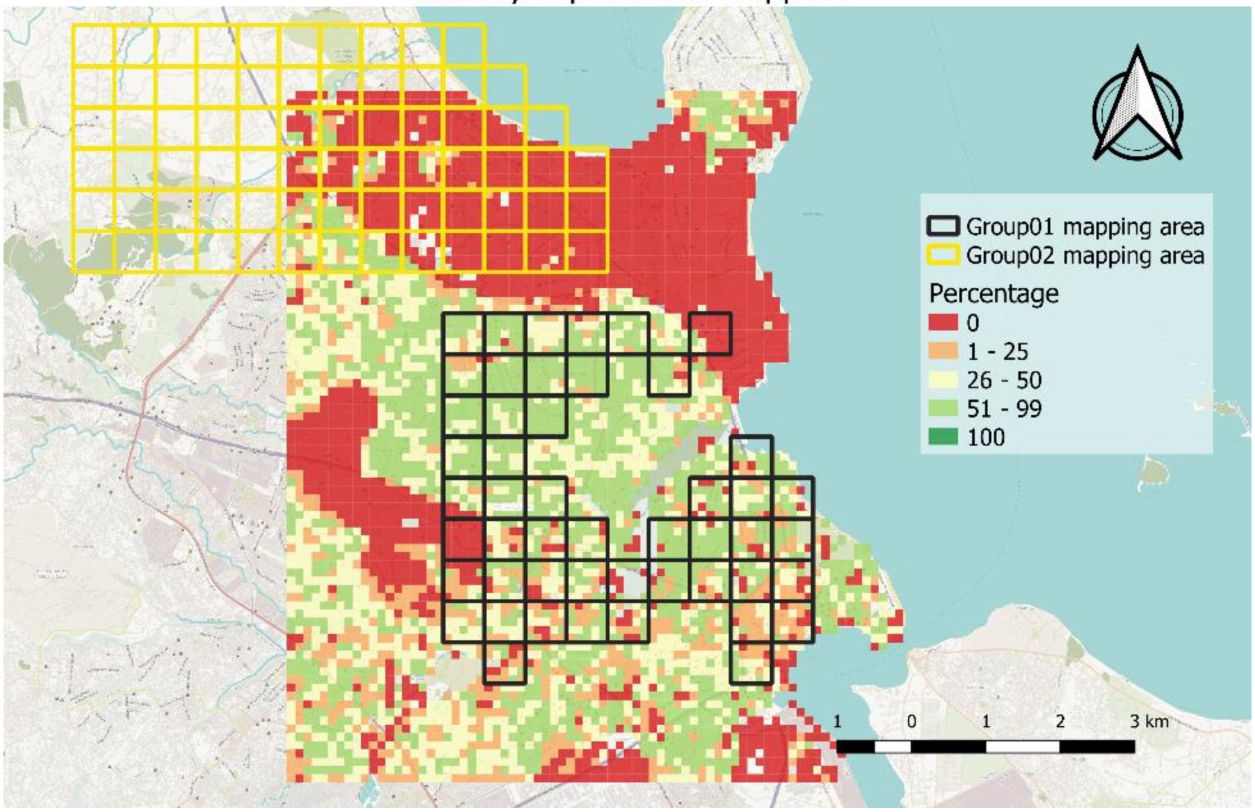

Figure 8.18: Overlaying of both mapping area over QM-3 results from figure 5.17.

Another interesting realisation is that too strict criteria for selecting the mapping area should be avoided. There should be spatial tolerance and degrees of freedom with respect to the number of grids selected. Which is in correlation with the fact that the quality metric is selected based on limited justifiable mapping requirements. This can give more space to the mappers to map and get the idea surrounding area more precisely. Furthermore, this will be discussed in the next chapter.

8.7.4 Identifying routing features

Feedback from the mappers shows that the training samples for classifying the road types were very less and it was difficult for them to recognize the type of roads. Perhaps increasing the number of training samples for the mappers should be increased and should be depended on the context of the area.

8.8 Conclusion

8.8.1 AOI-1 Dar es Salaam

Routing is done using OpenStreetMap (OSM) data which is easy and free to access. Advantage of the algorithm developed is that it is suited for raw OpenStreetMap (OSM) data and works directly with the information in the form of tags in OSM. This makes the algorithm stand-alone and can be easily transferable for almost worldwide with little modification. As you can add and remove costs by just modifying information in OSM this makes easy for the disaster managers get the real idea of geographical accessibility of certain location. Of-course it comes up with the challenge of information completeness in OSM which was the main objective of this mapathon. The algorithm is indeed limited in many ways, because it should be suited for tools like OpenRoutingService (OSR). Integration of such algorithms ORS is recommended because not many countries have access to tools like ArcMap. This algorithm only considers speed of automobile (car) while in reality it should be multi-modal.

8.8.2 AOI-2 Tadjoura, Djibouti

This mapping using quality metrics results in increasing quality of spatial information that is required to enhance the disaster preparedness. One way or another, the study of assessing the quality according to the user requirements is found helpful for many reasons. Such as the incompleteness metrics that was used for mapping the buildings in the second area of interest (AOI-2). Impacts are clear from the figures and numbers, irrespective of which group performed well. Both groups showed progress in lowering the quality index. This means that the quality metric is effective in nature in improving the number of buildings exposed to flood. Exposure model is indeed not extensive nor limited as well. This exposure model is no way meant for risk management decisions. It is only meant for showing how the component of exposure can be affected by non-availability of information. Like for example, design discharge which is needed for flood modelling cannot be calculated with only rain data.

Chapter 9: Discussion and conclusion

9.1 Introduction

In this chapter, the outcomes of this research and critically review on how the applied approach can be implemented will be discussed. Before that a hypothetical mapathon is designed based on the lesson learnt from the previous mapathon. This hypothetical mapathon can further quantify the success of this mapping approach of using quality metric. After that conclusion with respect to each research question be discussed and the main conclusion is given.

9.2 Objectives

In previous mapathon two different groups with different areas are used to comparisons because group 1 area was prioritised using quality metrics and group 2 not. This hypothetical mapathon is designed because previous mapathon failed to measure the success of the quality metrics approach for prioritising mapping areas. In this mapathon, mapping is divided into two mapping tasks in the same area instead of two groups in different areas. Because different mapping area have different built-up patterns (He et al., 2018). This makes the comparison unsuccessful between the two groups.

Mapping area for first mapping task for this mapathon is prioritise by strictly following the quality metrics approach. Mapping area for second mapping task is selected without following the quality metrics approach. It should be noted that the mapping area for the second mapping task will be the same geographical area as first mapping task and be done after deleting the features mapped by the first mapping task. These two mapped areas are then comparable because of similarity in built-up patterns and mapping complexity. This mapathon remains theoretical and did not take place due to the current restrictions imposed as a result of spread of COVID-19.

9.3 Mapathon design

The objective of this mapathon would be to better test the mapping approach that has been applied in this research. Assume a geographical area of interest (AOI) - A. We shall propose to do mapping in this area with and without applying quality metric methods. After this we can compare the results.

9.3.1 Step-1: Mapping with quality metrics methods

Figure 9.1 shows the workflow that should be followed for this step. Assume map-1a represents the area before the mapathon. After applying a quality metric method and prioritising the mapping area strictly with respect to quality index which results in (say) map-1b. Combination of quality metrics for [tag completeness]() and [application specific]() is preferred for prioritising the mapping areas. Now map-1b represents the AOI-A after the mapathon. All the quantifiable components such as mapped features, time and complexity required for mapping should be calculated for comparison.

9.3.2 Step-2: Setting-up for second mapping

Now for setting the stage for the second mapathon we shall delete all the features that were mapped in map-1b. This will give (say) map-2a. It should be noted that ideally only those features should be deleted that are mapped in step-1. Now the map should be the same as map-1a. It should also be noted that the number of mappers should remain the same, but the mappers should be different.

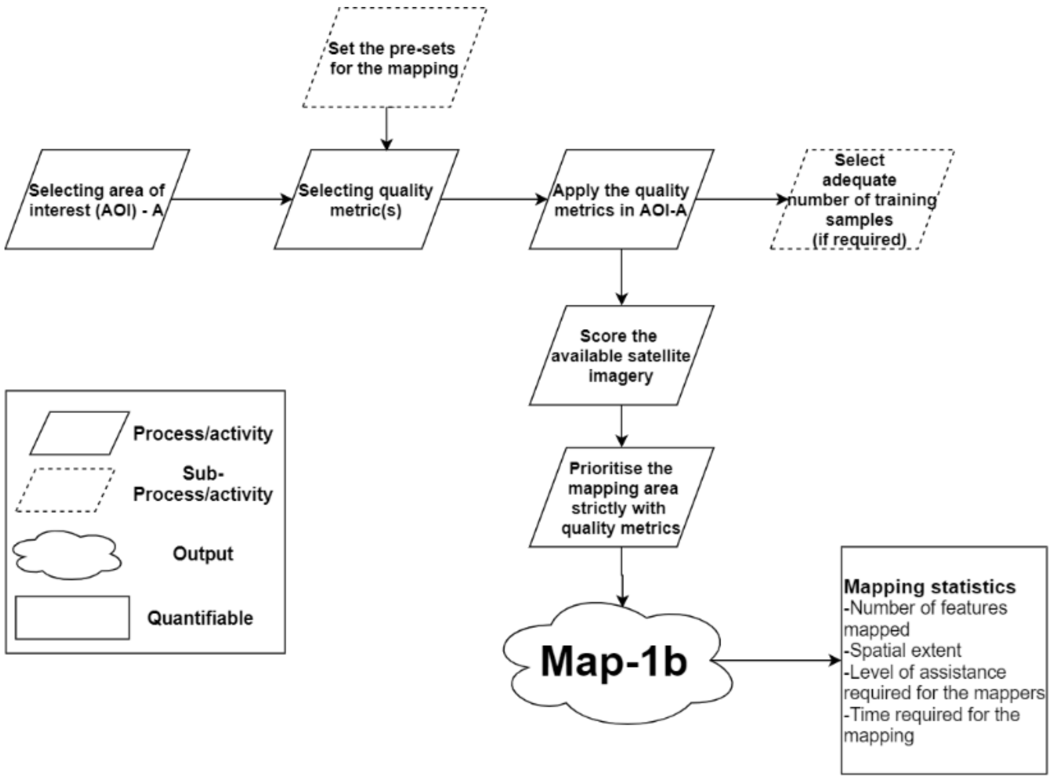

Figure 9.1: Workflow for mapping by strictly following the quality metric methods

9.3.3 Step-3: Mapping without quality metrics methods

Figure 9.2 shows the workflow that should be followed for this step. Assume map-2a represents the area before the mapathon. After applying a quality metric method and prioritising the mapping area with some degree of freedom with respect to quality index which results in (say) map-2b. Now map-2b represents the AOI-A after the mapathon. All the quantifiable components such as mapped features, time and complexity required for mapping should be calculated for comparison.

9.3.4 Step 4: Comparison

After calculating all the quantifiable components of map-1a, map-1b, map-2a and map-2b now we can compare and conclude the findings. **Table 9.1** shows how this mapathon can be compared to measure the success of the quality metrics approach. Comparison of number of features mapped, spatial extent of the features mapped, time and assistance required for mapping gives the overview on how the mapping areas using quality metrics is helpful. This comparison results is not only useful in measuring the success of the mapping approach but also identifying the resources required for mapping such as time and level of assistance required for certain mapping tasks.

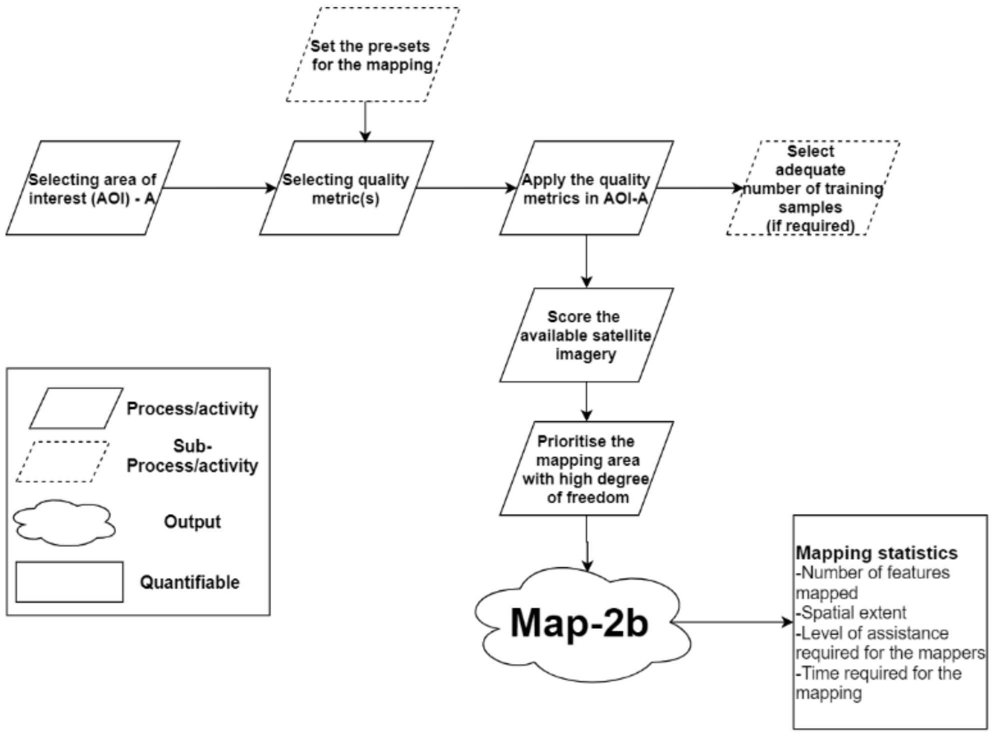

Figure 9.2: Workflow for mapping without strictly following the quality metric methods

Table 9.1: Comparison format for the designed mapathon

Scenario	**With quality metric method**	**Without quality metric method**
Before Mapathon	Map-1a	Map-2a
After Mapathon	Map-1b	Map-2b

9.4 Conclusion per research question

Sub Obj 1. Evaluate methods to determine and visualize the quality of OpenStreetMap (OSM)

Q1.1: What type of quality heterogeneity exists in OSM and what is the influence on specific applications?

1. In OSM heterogeneity exists in the form of incomplete, non-reliable and non-trustworthy information. Due to the application of OSM in rescue operation this heterogeneity can cause time-delays during the disaster response.
2. Heterogeneity in the OSM data is due to inexperienced mappers, non-local mappers and inactivity of mapping activity in the region. This heterogeneity increases the risk due to underestimation or overestimation of measurable disaster risk components. Results from mapping events shows that (a) there were too few exposed buildings in Tadjoura, Djibouti (see: section 8.6.2.2 critical finding) and (b) non-reliable accessibility measurement due to incomplete and in-adequate tags in Dar es Salaam (see: section 8.6.1.4 critical finding) .
3. The results from (b) shows that often reliable information is the result of completed information as well. Which means different quality metrics compliments each other and in many cases integration of two or more quality metrics can give outputs that are more impeccable than if single quality metrics are used. Mapping in Tadjoura, Djibouti clearly shows a remarkable increase in the mapped features, as this mapping area has been prioritized by combining two quality metrics. The Dar es Salaam case was prioritised using only one quality metric.

Q1.2: What type of quality attribute(s) can be used for OSM quality assessment?

4. In addition to incomplete information, date of edit, frequency of edits in OSM defines the credibility of the mapped features. Date and frequency of edits shows how operational the mapping activity is in the region. Furthermore, as evidence from outcome of reliability quality metric that in our study area of Dar es Salaam more is the edit frequency for hospital features, more is the level of details as compared to the less edited features. Moreover, the date of edit is also found to be correlated to the level of detail.
5. Mappers that have more edits in the same region represent more local knowledge. Outcome of quality metric 4 shows that hospital features that are mapped by experienced (top 20) mappers have more completed tags but the selected criteria is bias (see note #1 and note#2 in appendix A). Nevertheless, this has found useful in mapping missing buildings in Tadjoura, Djibouti.

Q1.3: Which element of the OSM quality can be emphasised for specific purposes?

6. The quality metrics developed emphasize the important mapping areas first for the specific types of disaster. As evident from application specific quality metrics for flood disaster, prioritising mapping areas for the areas lying in flood plain gives insight about what to map first. As seen in figure 5.19 which reduces the prioritised mapping area which helps in reducing the mapping tasks while keeping the impact of mapping on disaster risk

calculation. Application specific quality metrics found to be useful for the Tadjoura case for mapping the missing building footprints. As the number of mapped buildings lying in exposed areas increased by more than 200%.

7. For the reason mentioned in (4) information or tag completeness has the most impact on the rescue operation and reliability, trustworthiness compliments the information completeness. Furthermore, results of the mapathon also show that specific information such as classification of the type of the road can lead to dynamic routing.

Sub Obj 2. Evaluate the impact of the quality of map related to disaster response routing with respect to the requirements.

Q2.1: What constitutes a suitable disaster response routes model and how can the features related to disaster response routes be identified using satellite images with respect to user requirements?

8. A dynamic algorithm based on different road classification with varying speed is considered as adequate routing algorithms. This algorithm is fit-for-use as it is dynamic with varying speed for the edges representing different road class and can be implemented using OSM data.
9. As observed during mapping roads in Dar es Salaam, highway or road classes can be identified using satellite imagery by selecting the highest class in the hierarchy which is primary road as a reference. Meaning that this reference is used to classify the other road classes below in the hierarchy using **figure 6.2**. From the mapper's feedback this needs more experience in mapping roads as it caused confusion in the areas like Dar es Salaam. It is due to that fact that from observation from satellite imagery the roads in Dar es Salaam does not follow the hierarchical order of roads classes. Increased coordination during the mapathon has shown the improvement of mappers experience and of the map itself as well.

Q2.2: How can the quality of OSM and its content affect the disaster response routing model?

10. If the tagging of the highways in OSM is done accurately, then the routing algorithm can give reliable results. Households can have more reliable time-travel information if the quality criteria of highway tags are met. Time-travel information found to be different if highway tags are not according to the ground condition as observed from table 8.4. Which shows different number of buildings lying inside the accessibility isochrones of hospital # 1 before and after mapathon.

Sub Obj 3. Develop an integrated approach to ensure that the mapping is done systematically and meticulously.

Q3.1: How can we evaluate if the satellite imagery is fit-for-purpose?

11. Three criteria developed for studying the quality of satellite imagery available in iD editor: level of detail, vintage information and currentness. These criteria can therefore determine

which imagery to be used for which purposes. For mapping building in Tadjoura (AOI-2) imagery with total quality score below 2.5 is used and was adequate because mapping building footprints don't need very high spatial resolution. As compare to mapping roads in Dar es Salaam AOI-1 where satellite imagery with total quality score above 2.5 was used and found to be adequate for classifying roads in Dar es Salaam.

Q3.2: How can the combination of quality assessment methods, disaster escape route application and satellite image quality assessment methods help in defining metadata and presets for prioritising the mapping areas for organising the mapping events?

12. Quality metrics gives us the areas to map, satellite imagery quality criteria gives the fitness of the images and routing can be effectively done if the highways can be classified accurately provided that mappers are given training about classification of the roads. This gives other information that is useful for defining the routing algorithms in a more realistic way. This helps in putting emphasis on classifying the roads by observing the local conditions.
13. Combination of application specific and experience mapper quality metrics helped in prioritising the mapping area in Tadjoura for improving the calculation of flood exposed buildings. This model only uses the footprints for scoring the buildings in areas with DEM lower than 20 meters from the STRM data. This can also be combined by scoring of satellite imagery. This can also be used to propose satellite imagery providers to provide with high quality satellite imagery and thus mapping beyond just footprints of buildings. Which in turn decreases the limitation of the flood exposure model.

Q3.3: How much of this integrated approach can help disaster managers in prioritising the mapping areas?

14. The main goal was to develop an approach to make the mapping which has an impact on reducing risk and enhance disaster preparedness using OpenStreetMap (OSM). The mapping using a quality metrics approach not only increases the possibility of measuring risk but also made disaster routing as well. Different components of risk like calculation of exposure require spatial data that can be produced during mapping events more efficiently using quality metrics with regards to time and skills required.
15. Using this approach can help humanitarian organisations to start mapping tasks using OpenStreetMap (OSM) and provide the information to the disaster responder on-ground. The advantage of using OSM is its availability and wide range of editable information can be added.

9.5 Conclusion and recommendations

In this study we First analyse which stakeholder can be of our interest, meaning the actor that has high interest and has some level of influence on mapping in different phases of disaster. Secondly, we explored what kind of data is required and what type of heterogeneity in the OpenStreetMap (OSM) hinders the operation of the humanitarian organisations. Thirdly, we developed quality gates which are termed as quality metrics. We tested these quality metrics by implementing the same procedure as it is done by our major stakeholder which is a humanitarian organisation to match the success of this approach. That's why we HOT tasking manager is used for mapathon. Furthermore, we also analyse the available satellite imagery and what can be mapped using the available satellite imagery.

Building footprints and road networks are the two most essential data requirements that are needed to be on the map irrespective of the type of the disaster. If this data is produced before the disaster it saves time in reducing the efforts and time required to produce basic data to help rescue operation. Most developing countries lacks this data. Using this quality metric approach encourages the improvement of data quality for buildings and road networks while using OpenStreetMap (OSM) as a source of information. This increases the potential of OSM and disaster responders in countries like Djibouti or Tanzania can use the high quality spatial information using this mapping strategy to produce high quality information with less cost.

There are indeed challenges and struggles to this approach in which we try to generalise the spatial data requirements for the floods. Furthermore, this is also not limited, and it can be used to set the quality standards for the satellite imagery as well. Important thing that we learn from the literature is that a self-reliable tool for crisis management is the best solution for handling mash-ups and big data such as in disaster management (Lijnse, 2019). This can be achieved for open source tools like OSM by developing methods to assess the quality and to prioritise with respect to the specific spatial data requirements for the disaster scenarios.

Adding to the limitation of this study is that many online data sources were not given attention to explore which could validate the approach. Furthermore, this has only been applied to limited number of cases and spatial features. For example, tag completeness is only implemented for hospitals, schools and building features only. While analysis for other features such as government offices and place of worship can give relevant completion and reliability criteria.

This study gives insights from chapter 1 to chapter 9 about different quality gateway that can be used to produce specific spatial information in OSM. Main results are that the **information completion** is the most important aspect for enhancing disaster preparedness. As evident from outcomes from QM-2 & QM-3, which shows that the experience and reliability has correlation with tag completeness. In-depth study can give more insight about regional correlation of QM-2 & QM-3 with tag completeness. This can result in step towards standardised approach in mapping in OSM. Furthermore, the completeness studies should be conducted in *'leave nothing behind'*. Meaning that all features representing critical infrastructure necessary for certain disaster should be studied for quality assessment with regional context. Furthermore, the quality metrics should be designed for multi-hazard not just single type of disaster. Moreover, this study applies semi-automated approach which in future should be completely automated.

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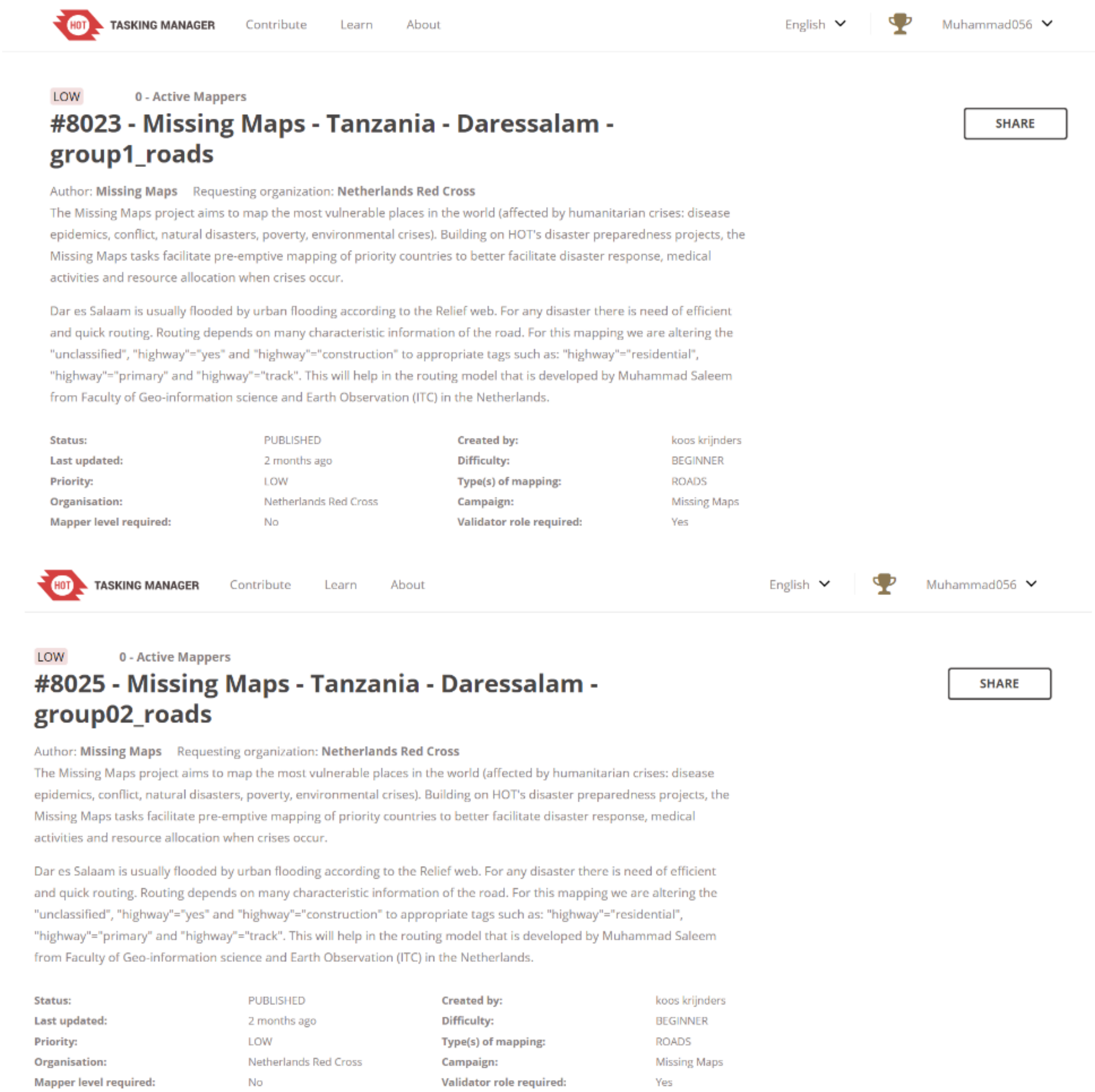
Appendix A

A.1 Mapathon set-up



TASKING MANAGER Contribute Learn About English Muhammad056

LOW 0 - Active Mappers

#8023 - Missing Maps - Tanzania - Daressalam - group1_roads

SHARE

Author: **Missing Maps** Requesting organization: **Netherlands Red Cross**

The Missing Maps project aims to map the most vulnerable places in the world (affected by humanitarian crises: disease epidemics, conflict, natural disasters, poverty, environmental crises). Building on HOT's disaster preparedness projects, the Missing Maps tasks facilitate pre-emptive mapping of priority countries to better facilitate disaster response, medical activities and resource allocation when crises occur.

Dar es Salaam is usually flooded by urban flooding according to the Relief web. For any disaster there is need of efficient and quick routing. Routing depends on many characteristic information of the road. For this mapping we are altering the "unclassified", "highway"="yes" and "highway"="construction" to appropriate tags such as: "highway"="residential", "highway"="primary" and "highway"="track". This will help in the routing model that is developed by Muhammad Saleem from Faculty of Geo-information science and Earth Observation (ITC) in the Netherlands.

Status:	PUBLISHED	**Created by:**	koos krijnders
Last updated:	2 months ago	**Difficulty:**	BEGINNER
Priority:	LOW	**Type(s) of mapping:**	ROADS
Organisation:	Netherlands Red Cross	**Campaign:**	Missing Maps
Mapper level required:	No	**Validator role required:**	Yes

TASKING MANAGER Contribute Learn About English Muhammad056

LOW 0 - Active Mappers

#8025 - Missing Maps - Tanzania - Daressalam - group02_roads

SHARE

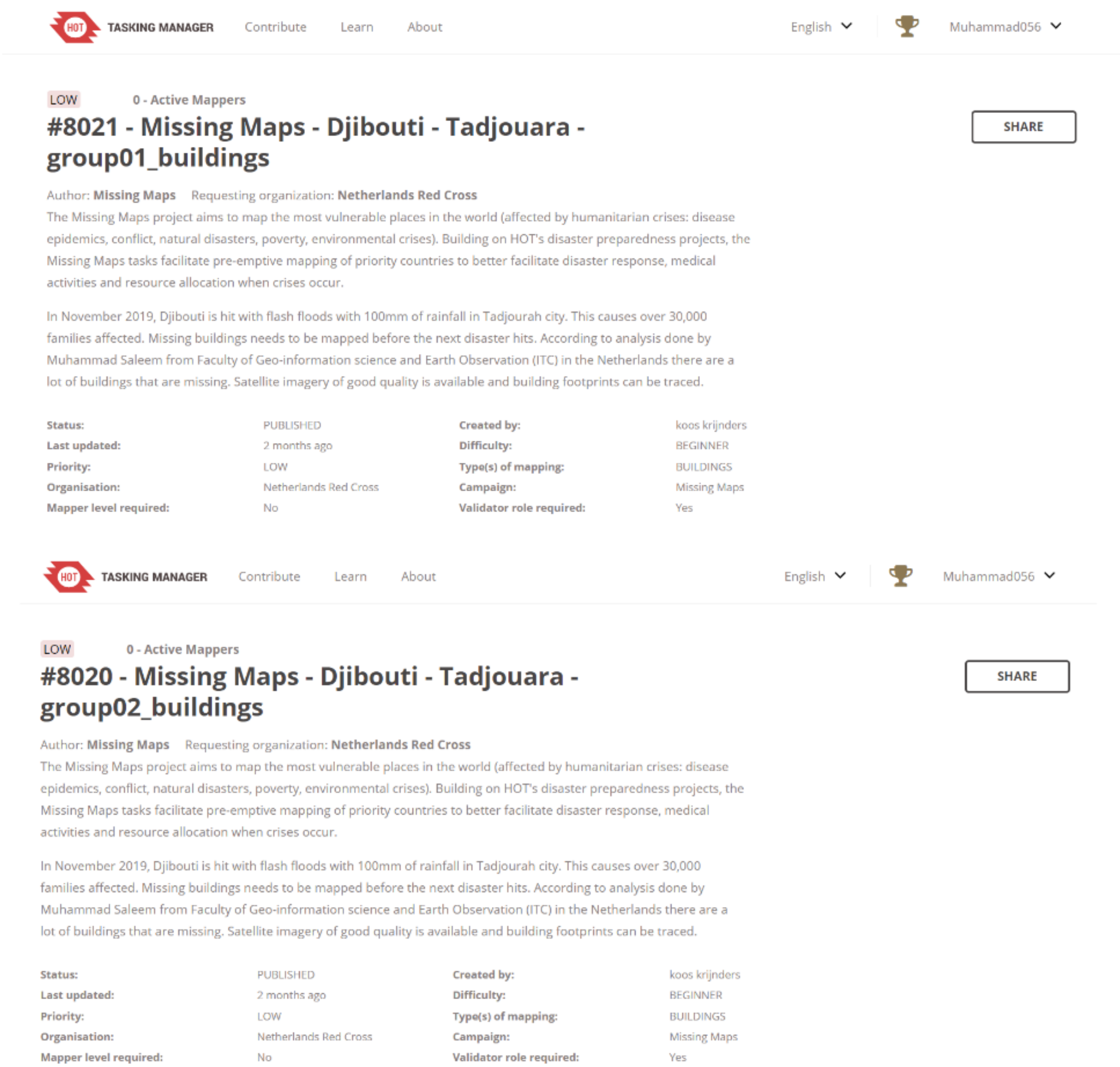
Author: **Missing Maps** Requesting organization: **Netherlands Red Cross**

The Missing Maps project aims to map the most vulnerable places in the world (affected by humanitarian crises: disease epidemics, conflict, natural disasters, poverty, environmental crises). Building on HOT's disaster preparedness projects, the Missing Maps tasks facilitate pre-emptive mapping of priority countries to better facilitate disaster response, medical activities and resource allocation when crises occur.

Dar es Salaam is usually flooded by urban flooding according to the Relief web. For any disaster there is need of efficient and quick routing. Routing depends on many characteristic information of the road. For this mapping we are altering the "unclassified", "highway"="yes" and "highway"="construction" to appropriate tags such as: "highway"="residential", "highway"="primary" and "highway"="track". This will help in the routing model that is developed by Muhammad Saleem from Faculty of Geo-information science and Earth Observation (ITC) in the Netherlands.

Status:	PUBLISHED	**Created by:**	koos krijnders
Last updated:	2 months ago	**Difficulty:**	BEGINNER
Priority:	LOW	**Type(s) of mapping:**	ROADS
Organisation:	Netherlands Red Cross	**Campaign:**	Missing Maps
Mapper level required:	No	**Validator role required:**	Yes

Figure A.1: Area of Interest (AOI-1) mapping tasks in tasking manager



HOT TASKING MANAGER Contribute Learn About English Muhammad056

LOW 0 - Active Mappers

#8021 - Missing Maps - Djibouti - Tadjouara - group01_buildings

SHARE

Author: **Missing Maps** Requesting organization: **Netherlands Red Cross**

The Missing Maps project aims to map the most vulnerable places in the world (affected by humanitarian crises: disease epidemics, conflict, natural disasters, poverty, environmental crises). Building on HOT's disaster preparedness projects, the Missing Maps tasks facilitate pre-emptive mapping of priority countries to better facilitate disaster response, medical activities and resource allocation when crises occur.

In November 2019, Djibouti is hit with flash floods with 100mm of rainfall in Tadjourah city. This causes over 30,000 families affected. Missing buildings needs to be mapped before the next disaster hits. According to analysis done by Muhammad Saleem from Faculty of Geo-information science and Earth Observation (ITC) in the Netherlands there are a lot of buildings that are missing. Satellite imagery of good quality is available and building footprints can be traced.

Status:	PUBLISHED	**Created by:**	koos krijnders
Last updated:	2 months ago	**Difficulty:**	BEGINNER
Priority:	LOW	**Type(s) of mapping:**	BUILDINGS
Organisation:	Netherlands Red Cross	**Campaign:**	Missing Maps
Mapper level required:	No	**Validator role required:**	Yes

HOT TASKING MANAGER Contribute Learn About English Muhammad056

LOW 0 - Active Mappers

#8020 - Missing Maps - Djibouti - Tadjouara - group02_buildings

SHARE

Author: **Missing Maps** Requesting organization: **Netherlands Red Cross**

The Missing Maps project aims to map the most vulnerable places in the world (affected by humanitarian crises: disease epidemics, conflict, natural disasters, poverty, environmental crises). Building on HOT's disaster preparedness projects, the Missing Maps tasks facilitate pre-emptive mapping of priority countries to better facilitate disaster response, medical activities and resource allocation when crises occur.

In November 2019, Djibouti is hit with flash floods with 100mm of rainfall in Tadjourah city. This causes over 30,000 families affected. Missing buildings needs to be mapped before the next disaster hits. According to analysis done by Muhammad Saleem from Faculty of Geo-information science and Earth Observation (ITC) in the Netherlands there are a lot of buildings that are missing. Satellite imagery of good quality is available and building footprints can be traced.

Status:	PUBLISHED	**Created by:**	koos krijnders
Last updated:	2 months ago	**Difficulty:**	BEGINNER
Priority:	LOW	**Type(s) of mapping:**	BUILDINGS
Organisation:	Netherlands Red Cross	**Campaign:**	Missing Maps
Mapper level required:	No	**Validator role required:**	Yes

Figure A.2: Area of Interest (AOI-2) mapping tasks in tasking manager

Contributions: #8025 - Missing Maps - Tanzania - Daressalam - group02_roads

	USER	MAPPED	VALIDATED
1.	Sarah Joey Salgado	17	0
2.	Else-linda	10	0
3.	Ranzrz	6	0
4.	xeeshui	4	0
5.	naomiberkhout	2	0

Contributions: #8023 - Missing Maps - Tanzania - Daressalam - group1_roads

	USER	MAPPED	VALIDATED
1.	Swati_rameez	4	0
2.	thom10	3	0

Contributions: #8020 - Missing Maps - Djibouti - Tadjouara - group02_buildings

	USER	MAPPED	VALIDATED
1.	koos krijnders	18	0
2.	Sarah Joey Salgado	3	0
3.	ranzrz	2	0
4.	MamuLMC18	2	0
5.	Muhammad056	1	0
6.	Else-linda	1	0

Note: here user koos krijnders is a professional OSM mapper.

Contributions: #8021 - Missing Maps - Djibouti - Tadjouara - group01_buildings

	USER	MAPPED	VALIDATED
1.	MamuLMC18	10	0
2.	aalhajeri	7	0
3.	Muhammad056	4	0
4.	Arun Balaji	3	0
5.	golnarcivil	1	0

A.2 SQL queries for routing algorithm

```
case
when "highway" = 'primary' or "highway" = 'primary_link' then 60
WHEN "highway" =  'secondary'  THEN 50
WHEN "highway" =   'road'  THEN 20
WHEN "highway" =   'secondary_link'  or "highway" =   'residential'   THEN 20
WHEN "highway" =   'tertiary' or "highway" = 'tertiary_link'   THEN 30
WHEN "highway" =   'service'  OR  "highway" = 'track' OR "highway" ='trunk' OR "highway"
='trunk_link' OR "highway" =  'path' THEN 10
WHEN "highway" =   'cycleway' or  "highway" ='cycleway' or  "highway" = 'footway' or  "highway"
= 'steps' or  "highway" ='construction' or  "highway" =  'unclassified' or  "highway" = 'yes' THEN
0.5

ELSE 0
END
```

A.3 Tag completeness supplements

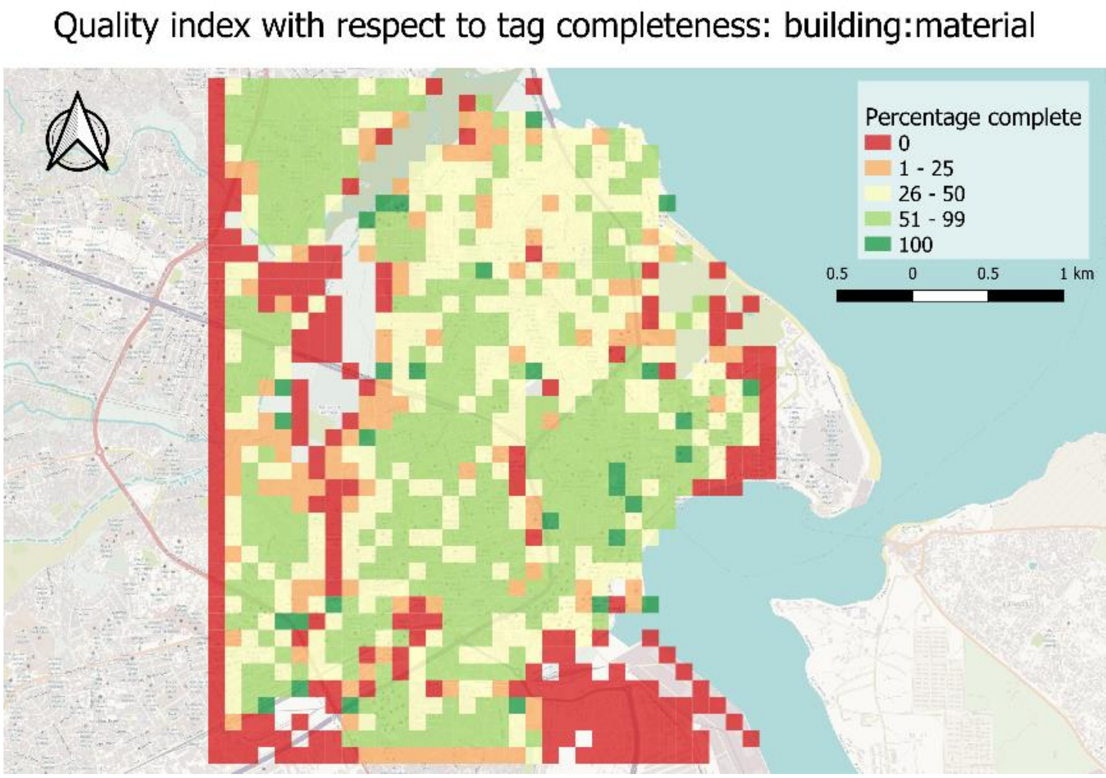


Figure A.3: Square grid map of tag combination building material with edging effect

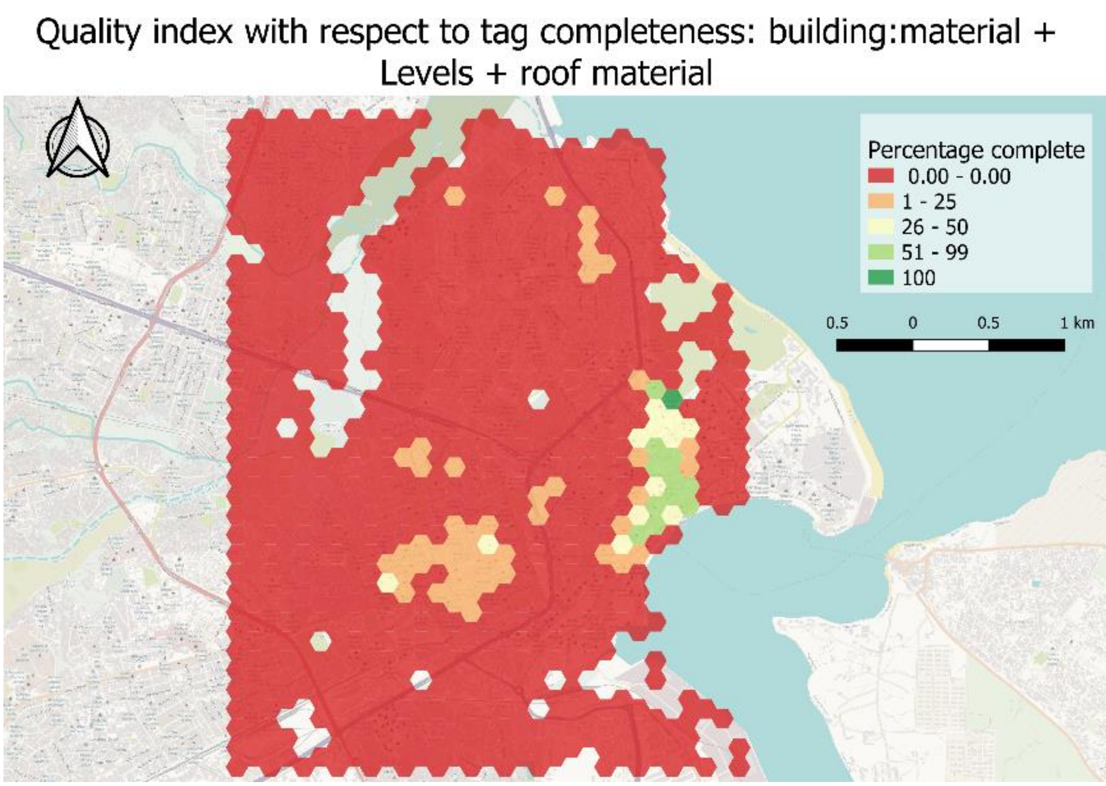


Figure A.4: Quality index for building features with respect to level 3 tag completion

Quality index with respect to tag completeness: building:material + Levels + roof material + age

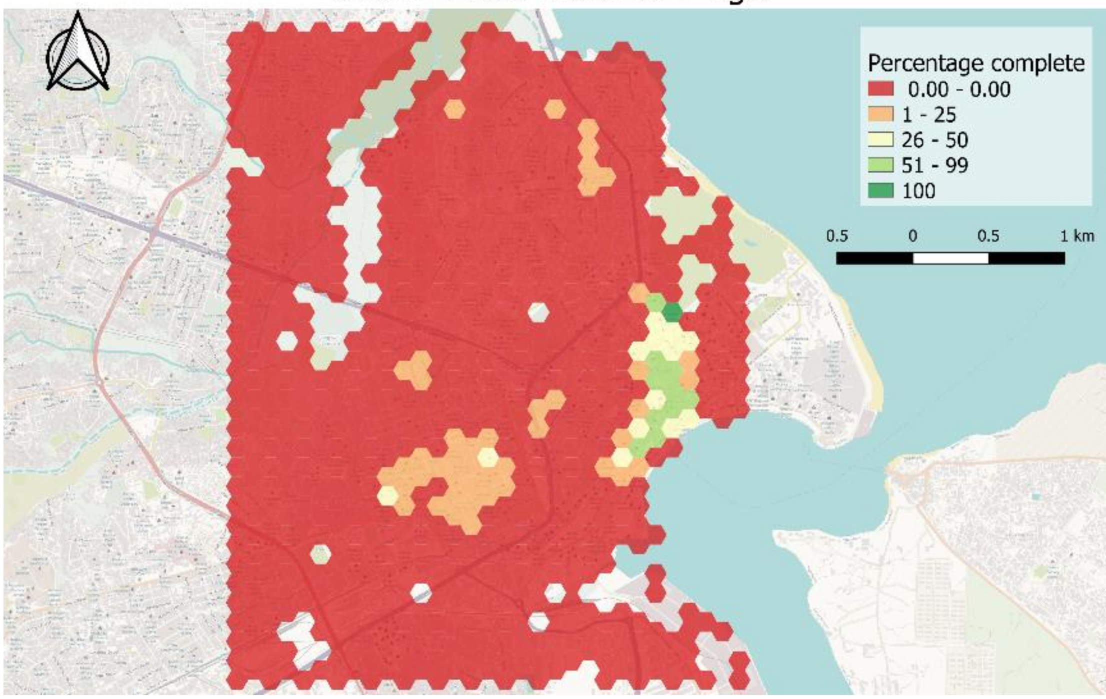


Figure A.5: Quality index for building features with respect to level 4 tag completion

Quality index with respect to tag completeness: building:material + Levels + roof material + age + condition

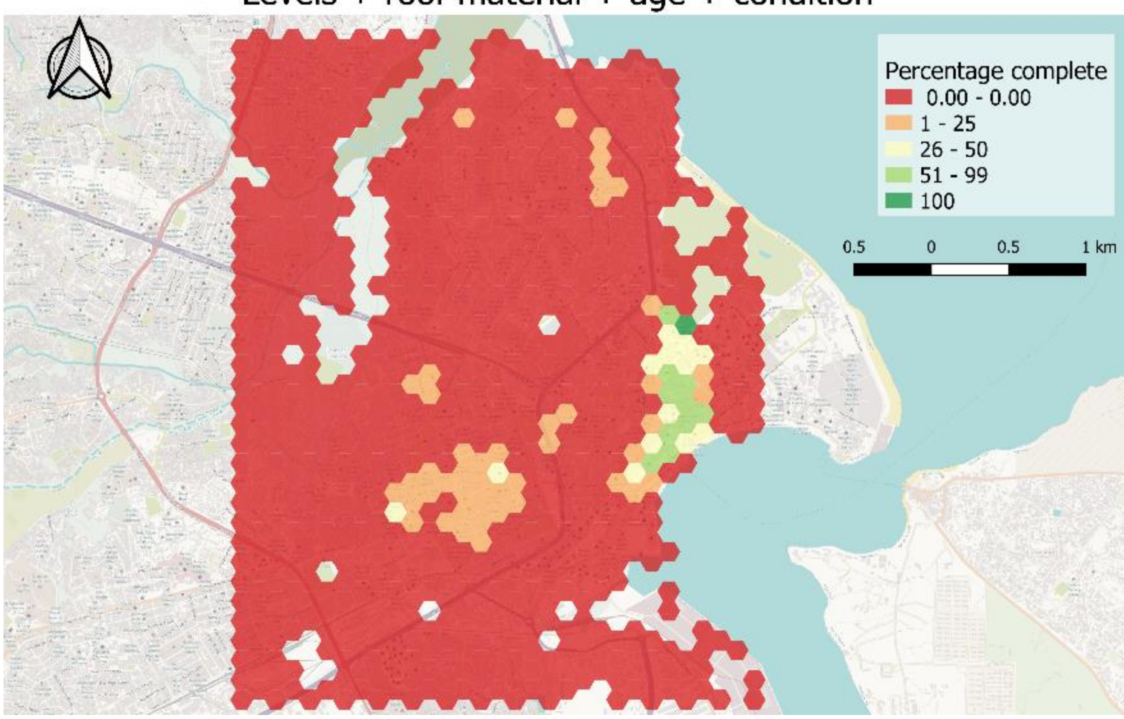


Figure A.6: Quality index for building features with respect to level 5 tag completion

A.4 Experienced mapper supplements

Top 20 user editing in Dar es Salaam

	user	**Nodes edited**
1.	kombe1207	111778
2.	charles Frank	101558
3.	Abou kachongo jr	99660
4.	Samwel Kyando	99191
5.	amour_nyl	96916
6.	JAMAL AMANI	94336
7.	janeth mlinga	91061
8.	Damon Monyo	87940
9.	Godfrey Faustine	85229
10.	AronMartin	83961
11.	lovenes	70419
12.	Charles Massawe	67175
13.	NURU ATHUMANI	66914
14.	Hawa Adinani	62386
15.	dorica_mugusi	59485
16.	tonny john	59459
17.	asibwene	56527
18.	mwanaharusi ngaluma	54886
19.	jackson pascal hombo	54762
20.	Furaha L Mrema	53764

Note#1

Number 5 user: '*amour_nyl*' has edited two of the hospital features in figure 5.16 with tag combination hospital:specialisation.

@version	@changeset	@user
2	54593332	thetornado76
3	56724241	amour_nyl
3	56411985	amour_nyl
2	54593332	thetornado76
1	70357762	mbadwe
2	58349885	thetornado76
2	54593332	thetornado76

Figure A.6: User edited the hospitals in figure 5.16

Note #2

Other users that made the edits in figure 5.16 as shown in **figure A.6** do not lies in top20 but user *'thetornado76'* have **476** edits inside Dar es Salaam, which states that this mapper is not a beginner mapper. **Figure A.7** we extracted the edits made by user *'thetornado76'*. While the other user *'mbadwe'* has only one edit in the region. This shows how bias the quantification of experienced mapper quality metrics can be.

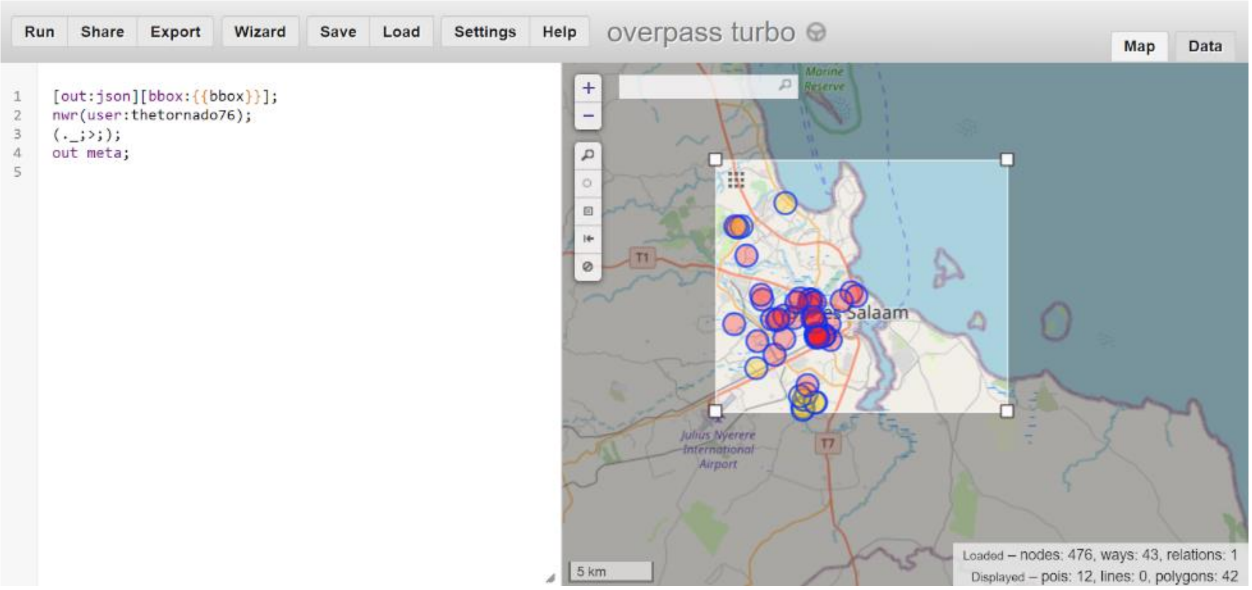


Figure A.7: Total edits made by user *'thetornado76'* in Dar es Salaam