METEOR: Protocols for Crowd-Sourcing Regional Exposure Data. Report M4.3/P

METEOR
Modelling Exposure Through Earth Observation Routines

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Glossary

BGS	British Geological Survey: An organisation providing expert advice in all areas of geosciences to the UK government and internationally
DE	Data Entry; the inputting of data or information into a computer, here it is often used to describe 'data entry specialists' who collect data in the field using mobile devices
DMD	Disaster Management Department, Prime Minister's Office of Tanzania, focused on disaster risk
DRM	Disaster Risk Management; the application of disaster risk reduction policies and/or strategies
DRR	Disaster Risk Reduction; disaster risk reduction is aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development
EO	Earth Observation; the gathering of information about Earth's physical, chemical and biological systems via remote sensing technologies, usually involving satellites carrying imaging devices
FATHOM	Provides innovative flood modelling and analytics, based on extensive flood risk research
GED4ALL	Global Exposure Database for All; an open global database for hosting exposure information for multiple-hazard impact assessment
GEM	Global Earthquake Model, non-profit organisation focused on the pursuit of earthquake resilience worldwide
GFDRR	Global Facility for Disaster Risk Reduction and Recovery; a global partnership that helps developing countries better understand and reduce their vulnerability to natural hazards and climate change
GIS	Geographic Information System; a conceptualised framework that provides the ability to capture and analyse spatial and geographic data
GPS	Global Positioning System; a satellite-based radio navigation system owned by the United States government and operated by the United States Space Force
HOT	Humanitarian OpenStreetMap Team, a global non-profit organisation that uses collaborative technology to create OSM maps for areas affected by disasters
InaSAFE	Free open software that produces realistic natural hazard impact scenarios for better planning, preparedness and response activities
ImageCat	International risk management innovation company supporting the global risk and catastrophe management needs of the insurance industry, governments and NGOs
IPP	International Partnership Programme; the UK Space Agency's International Partnership Programme (IPP) is a £30M per year programme, which uses expertise in space-based solutions, applications and capability to provide a sustainable economic or societal benefit to emerging nations and developing economies
JOSM	Java OpenStreetMap; free Java software desktop editing tool for OSM data
KLL	Kathmandu Living Labs; a living lab and non-profit civic technology company based in Kathmandu, Nepal that primarily works on mobile technology and mapping
LDC	Least Developed Country on the Organisation for Economic Co-operation and Development's (OECD) Development Assistance Committee (DAC) list
M	Milestone, related to work package deliverable
Mapathon	Coordinated mapping event where individuals learn about OSM, and make edits to the map through remote digitising of satellite imagery

METEOR	Modelling Exposure Through Earth Observation Routines; a three-year project funded by the UK Space Agency to develop innovative application of Earth Observation (EO) technologies to improve understanding of exposure and multihazards impact with a specific focus on the countries of Nepal and Tanzania
NGO	Non-Governmental Organisation; organisations which are independent of government involvement
NSET	National Society for Earthquake Technology, non-governmental organisation working on reducing earthquake risk in Nepal and abroad
OCHA	UN Office for the Coordination of Humanitarian Affairs
ODA	Official Development Assistance; government aid that promotes and specifically targets the economic development and welfare of developing countries
ODbl	Open Database License; a copyleft license agreement intended to allow users to freely share, modify, and use a database while maintaining this same freedom for others
ODK	OpenDataKit; mobile application questionnaire form for collecting data
OFDA	USAID Office of United States Foreign Disaster Assistance
OMK	OpenMapKit; mobile application that works with ODK to collect data in OSM
OPM	Oxford Policy Management, organisation focused on sustainable project design and implementation for reducing social and economic disadvantage in low-income countries
OSM	OpenStreetMap, a collaborative project to create a free and open editable map database of the world
OSMCha	OpenStreetMap Changeset Analyzer; a web tool to help mappers analyse and review data changes to OSM. The objective of the tool is to help detect vandalism and act on bad changes to the map data
OSMF	OpenStreetMap Foundation; a not-for-profit organisation that supports the OpenStreetMap Project
Osmose	OpenStreetMap Oversight Search Engine; one of many quality assurance tools available to detect issues in OpenStreetMap data. It detects a very wide range of issue types
PDC	Pacific Data Center; an applied research centre managed by the University of Hawaii, PDC is continuously developing new technologies and best practices to help our many global partners effectively mitigate, prepare for, respond to, and recover from disasters
POSM	Portable OpenStreetMap; project to bring together assorted OpenStreetMap tools onto a portable device which works without an internet connection
QA	Quality Assurance specialist; people who ensure that the data is being collected correctly and to a high standard, often reviewing data after collection
QGIS	Free open source desktop geographic information system
Ramani Huria	A community mapping project based in Dar Es Salaam, Tanzania; Swahili for "open map"
SDGs	Sustainable Development Goals; these goals were set up in 2015 by the United Nations General Assembly and are intended to be achieved by the year 2030
TS	Team Supervisor; person responsible for managing and supervising teams, they possess high degrees of technical proficiency
UAV	Unmanned Aerial Vehicle; an aircraft without a human pilot on board, often simply referred to as 'drones'
UKSA	United Kingdom Space Agency; an executive agency of the Government of the United Kingdom, responsible for the United Kingdom's civil space programme

UN	United Nations
USAID	United States Agency for International Development
WASH	Water, Sanitation and Hygiene; universal, affordable and sustainable access to WASH is a key public health issue within international development and is the focus of Sustainable Development Goal 6
WP	Work Package; discrete sets of activities within the METEOR Project, each work package is led by a different partner and has specific objectives

Foreword

This report is the published product of a study by Humanitarian OpenStreetMap Team (HOT) as part of the Modelling Exposure Through Earth Observation Routines (METEOR) project led by British Geological Survey (BGS).

The objective of this report is to outline the protocols for crowd-sourcing of exposure data for OpenStreetMap for use in Kathmandu (Nepal) and Dar es Salaam (Tanzania) within the METEOR project.

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Summary

This report describes a specific piece of work conducted by Humanitarian OpenStreetMap Team (HOT) as part of the METEOR (Modelling Exposure Through Earth Observation Routines) project, led by British Geological Survey (BGS) with collaborative partners Oxford Policy Management Limited (OPM), SSBN Limited, The Disaster Management Department, Office of the Prime Minister – Tanzania (DMD), The Global Earthquake Model Foundation (GEM), The Humanitarian OpenStreetMap Team (HOT), ImageCat and the National Society for Earthquake Technology (NSET) – Nepal.

The 3-year project was funded by UK Space Agency through their International Partnership Programme, details of which can be located in the Foreword, and was completed in 2021.

The project aimed to provide an innovative solution to disaster risk reduction, through development of an innovative methodology of creating exposure data from Earth Observation (EO) imagery to identify development patterns throughout a country and provide detailed information when combined with population information. Level 1 exposure was developed for all 47 least developed countries on the OECD DAC list, referred to as ODA least-developed countries in the METEOR documentation, with open access to data and protocols for their development. New national detailed exposure and hazard datasets were also generated for the focus countries of Nepal and Tanzania and the impact of multiple hazards assessed for the countries. Training on product development and potential use for Disaster Risk Reduction was performed within these countries with all data made openly available on data platforms for wider use both within country and worldwide.

This report (M4.3/P) is the third report generated by HOT for the work package on Inputs and Validation (WP4) led by HOT. The other 7 METEOR work packages included, Project Management (WP1 – led by BGS), Monitoring and Evaluation (WP2 – led by OPM), EO data for exposure development (WP3 - led by ImageCat), Vulnerability and Uncertainty (WP5 - led by GEM), Multiple hazard impact (WP6 – led by BGS), Knowledge sharing (WP7 – led by GEM) and Sustainability and capacity building (WP8 – led by ImageCat).

1. METEOR Project

1.1. PROJECT SUMMARY

Project Title	Modelling Exposure Through Earth Observation Routines (METEOR): EO-based Exposure, Nepal and Tanzania
Starting Date	08/02/2018
Duration	36 months
Partners	UK Partners: The British Geological Survey (BGS) (Lead), Oxford Policy Management Limited (OPM), SSBN Limited
	International Partners: The Disaster Management Department, Office of the Prime Minister – Tanzania, The Global Earthquake Model (GEM) Foundation, The Humanitarian OpenStreetMap Team (HOT), ImageCat, National Society for Earthquake Technology (NSET) – Nepal
Target Countries	Nepal and Tanzania for "level 2" results and all 47 Least Developed ODA countries for "level 1" data
IPP Project	IPPC2_07_BGS_METEOR

Table 1: METEOR Project Summary

1.2. PROJECT OVERVIEW

At present, there is a poor understanding of population exposure in some Official Development Assistance (ODA) countries, which causes major challenges when making Disaster Risk Management decisions. Modelling Exposure Through Earth Observation Routines (METEOR) takes a step-change in the application of Earth Observation exposure data by developing and delivering more accurate levels of population exposure to natural hazards. METEOR is delivering calibrated exposure data for Nepal and Tanzania, plus 'Level-1' exposure for the remaining Least developed Countries (LDCs) ODA countries. Moreover, we are: (i) developing and delivering national hazard footprints for Nepal and Tanzania; (ii) producing new vulnerability data for the impacts of hazards on exposure; and (iii) characterising how multi-hazards interact and impact upon exposure. The provision of METEOR's consistent data to governments, town planners and insurance providers will promote welfare and economic development and better enable them to respond to the hazards when they do occur.

METEOR is co-funded through the second iteration of the UK Space Agency's (UKSA) International Partnership Programme (IPP), which uses space expertise to develop and deliver innovative solutions to real world problems across the globe. The funding helps to build sustainable development while building effective partnerships that can lead to growth opportunities for British companies.

1.3. PROJECT OBJECTIVES

METEOR aims to formulate an innovative methodology of creating exposure data through the use of EO-based imagery to identify development patterns throughout a country. Stratified sampling technique harnessing traditional land use interpretation methods modified to characterise building patterns can be combined with EO and in-field building characteristics to capture the distribution of building types. These protocols and standards will be developed for broad application to ODA countries and will be tested and validated for both Nepal and Tanzania to assure they are fit-for-purpose.

Detailed building data collected on the ground for the cities of Kathmandu (Nepal) and Dar es Salaam (Tanzania) will be used to compare and validate the EO generated exposure datasets.

Objectives of the project look to: deliver exposure data for 47 of the least developed ODA countries, including Nepal and Tanzania; create hazard footprints for the specific countries; create open protocol; to develop critical exposure information from EO data; and capacity-building of local decision makers to apply data and assess hazard exposure. The eight work packages (WP) that make up the METEOR project are outlined below in section 1.4.

1.4. WORK PACKAGES

Outlined below are the eight work packages that make up the METEOR project, which are led by various partners. Table 2 provides an overview of the work packages together with a brief description of what each of the work packages cover.

Work Package	Title	Lead	Overview
WP.1	Project Management	BGS	Project management, meetings with UKSA, quarterly reporting and the provision of feedback on project deliverables and direction across primary stakeholders.
WP.2	Monitoring and Evaluation	OPM	Monitoring and evaluation of the project and its impact, using a theory of change approach to assess whether the associated activities are leading to the desired outcome.
WP.3	EO Data for Exposure Development	ImageCat	EO-based data for exposure development, methods and protocols of segmenting/classifying building patterns for stratified sampling of building characteristics.
WP.4	Inputs and Validation	HOT	Collect exposure data in Kathmandu and Dar es Salaam to help validate and calibrate the data derived from the classification of building patterns from EO-based imagery.
WP.5	Vulnerability and Uncertainty	GEM	Investigate how assumptions, limitations, scale and accuracy of exposure data, as well as decisions in data development process lead to modelled uncertainty.
WP.6	Multiple Hazard Impact	BGS	Multiple hazard impacts on exposure and how they may be addressed in disaster risk management by a range of stakeholders.
WP.7	Knowledge Sharing	GEM	Disseminate to the wider space and development sectors through dedicated web-portals and use of the Challenge Fund open databases.
WP.8	Sustainability and Capacity-Building	ImageCat	Sustainability and capacity-building, with the launch of the databases for Nepal and Tanzania while working with in-country experts.

Table 2: Overview of METEOR Work Packages

1.5. IN-SITU INPUTS AND VALIDATION

The project WP led by HOT is broken down into six deliverables, which are focused on the mapping of exposure data for the cities of Kathmandu and Dar es Salaam in OpenStreetMap (OSM). These involve importing existing data into OSM, the remote mapping of building footprints and road networks, drafting protocols for crowdsourcing exposure data, collecting detailed attribute information on the ground and producing a final report (Table 3).

| Deliverable	Title	Overview
M4.1	Import Existing Data into OSM	Review and assess the suitability of existing open datasets for import into OSM for Kathmandu and Dar es Salaam.
M4.2	EO Mapping of Exposure Data	Remote mapping of building footprints and road networks in OSM for Kathmandu and Dar es Salaam.
M4.3	Protocols for Crowdsourcing Exposure Data	Draft protocols for the crowdsourcing of exposure data in OSM, covering data imports, remote mapping and ground data collection.
M4.4	Ground Data Collection using Protocols I	Collect exposure data on the ground for Kathmandu using a data model developed in line with the requirements for WP.3
M4.5	Ground Data Collection using Protocols II	Collect exposure data on the ground for Dar es Salaam using a data model developed in line with the requirements for WP.3
M4.6	Final Report	Deliver a final version of M4.3 along with the resulting data from M4.4. and M4.5.

Table 3: Overview of HOT Work Package
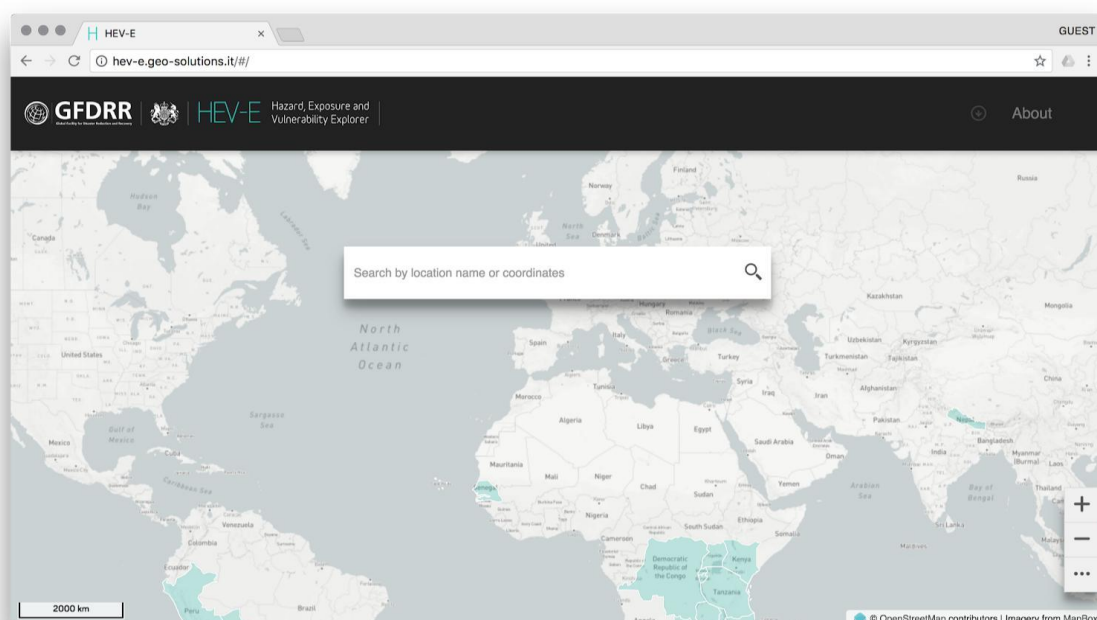
Figure 1: GFDRR Challenge Fund HEV-E Data Platform (Hazard, Exposure and Vulnerability Explorer, http://hev-e.geo-solutions.it/). Layers displayed © OpenStreetMap contributors and Imagery from MapBox

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2. OpenStreetMap

2.1. WHAT IS IT?

OSM is a crowdsourced geospatial database of the world built largely by volunteers and professionals digitising aerial imagery, collecting attribute information on the ground and liberating existing public sources of geospatial data. Known as the 'Wikipedia' of maps, the data is freely accessible to all under the Open Database License (ODbL)[1], meaning that it can be queried, used, manipulated, contributed to and redistributed in any form. OSM is the ideal database for humanitarian efforts and disaster management, as it is a great source of geographic baseline data for many cities around the globe, especially in countries with emerging economies that are not always on the map.

2.2. OPEN DATA

The ODbL license is a copyleft ("share alike") agreement intended to allow users to freely share, modify, and use a database while maintaining this same freedom for others. Published by Open Data Commons, part of the Open Knowledge Foundation[2], the ODbL license enables OSM to be a source of powerful geospatial data to make change, particularly in ODA countries where a potential lack of internal funds and skill sets make it difficult to create up-to-date exposure data themselves. Such data is necessary to conduct hazard impact risk assessments and carry out informed appropriate disaster management decisions. One project may focus on creating data in OSM for a specific purpose, but this data can then be used by anyone for their area of interest. This freedom of use is outlined on the ODbL website (Open Data Commons, 2018):

You are free:

- ❖ To Share: To copy, distribute and use the database
- ❖ To Create: To produce works from the database
- ❖ To Adapt: To modify, transform and build upon the database

As long as you:

- ❖ Attribute: You must attribute any public use of the database, or works produced from the database, in the manner specified in the ODbL. For any use or redistribution of the database, or works produced from it, you must make clear to others the license of the database and keep intact any notices on the original database
- ❖ Share-Alike: If you publicly use any adapted version of this database, or works produced from an adapted database, you must also offer that adapted database under the ODbL
- ❖ Keep open: If you redistribute the database, or an adapted version of it, then you may use technological measures that restrict the work (such as DRM) as long as you also redistribute a version without such measures

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[1] https://opendatacommons.org/licenses/odbl/

[2] https://okfn.org/

2.3. DATA STRUCTURE

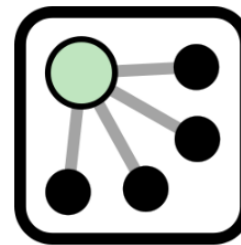Geospatial data is stored in OSM as vectors, with three types of elements:

1. **Nodes**, which represent a point on the surface of the earth
2. **Ways**, which are sets of ordered nodes that can form lines or polygons
3. **Relations**, which are sets of nodes, ways and/or relations as members that are used to define logical or geographic relationships between other elements
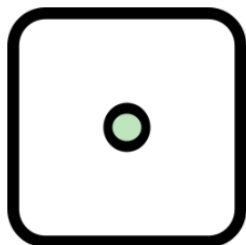
| Nodes | Ways | Relations |

Each of these elements can have any number of `key=value` tags, that represents the attribute information for a given feature. For example, a post office may be represented by a way with the tags `building=yes` and `amenity=post_office,` to help identify the purpose of the building.

2.4. WHY USE IT?

The most common question people ask is: *Why would you use OpenStreetMap if there is Google Maps?[3]* These platforms have many similarities and address the same basic human of spatially knowing where things are. In short, OSM represents an open approach to how data is collected and distributed, which makes it fast, free, flexible and widespread; an ideal combination for development application among others.

In the case of Haiti, the OSM community needed just a few hours to remotely digitise earthquake affected areas from satellite imagery, in contrast to commercial maps that had no way of responding in such a short period. The thousands of active volunteers around the globe are what made this possible, and the fact that every update is immediately visible to all other users, and is also version controlled. In many cases, the OSM community has been able to achieve even higher detail than any other map source.

The very idea behind OSM was to solve the problem of data restriction by using a Wikipedia model. Each edit made in OSM is owned by the community, whereas each change made in commercial map is owned by the providers. Data in commercial maps is copyrighted and so it can be subject to licensing fees and contractual restrictions. OSM is, and always will be, available for free. This open access to geospatial data makes it easy for researchers, governments, disaster management agencies and policy implementers to work collectively from the same database.

OSM is also ready for any kind of operation. Many major organisations are choosing OSM for their maps because it allows for customisation based on need. It has been used to collect functioning and non-functioning water facilities in northern Uganda, to mapping hundreds of thousands of shelters in Bangladesh, to planning logistics for a Yellow Fever campaign in the Democratic Republic of Congo and mapping the exposure information of infrastructure for

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[3] https://welcome.openstreetmap.org/

hazard impact. It allows access to all of the map offline and can be formatted in local languages, transcending national boundaries.

Most importantly, OSM emphasises local knowledge across the globe. The barrier to entry is low, and there are many ways to contribute that do not require access to the latest technology. The result is a map made by local experts. OSM provides global map data in a unified tagging schema, although there are some local variations, this allows for consistency from country to country, for a truly global map.

3. Participatory Mapping

Participatory mapping a phrase commonly used in the OSM community. It is the creation of maps by local communities. They are visual representations of what a community perceives as its environment and the significant features within it. Participatory mapping is based on the premise that local communities possess expert knowledge of their surroundings.

Often this process is supported by organisations, with a target goal and funds to assist with the research and direction, depending on the purpose of the data creation. The emphasis, however, is always on providing skills for the community to create the maps themselves in order to represent the spatial knowledge of local citizens. Participatory mapping is at the core of HOT and their work, where local teams are the experts to create the necessary data in OSM.

Participatory mapping relates to fostering a collaborative approach. The primary ingredient in the success of an open mapping project is the cultivation and care of a strong network of partners across the range of communities and institutions that have a stake in the project. These partnerships are critical for the implementation, uptake, and sustainability of open mapping projects. They can lead to shared investment of resources and technical expertise, innovative use cases for open data, increased legitimacy for the project, and stability over time. Because the open mapping ecosystem is a global phenomenon, it is likely that at the start of any project, there will be a pre-existing group of individuals and organisations already mapping in the target area. With proper outreach and engagement, these groups can be a powerful resource. Including them early in the planning and design phases of a project will help increase their sense of ownership and improve the likelihood of successful collaboration.

Government agencies responsible for areas as diverse as national statistics, urban planning, transportation, public health, environment and natural resource management, and disaster response have all benefited from working with open mapping and can bring valuable resources, expertise, and authority to a mapping project. The OSM community is active globally and will, in many cases have a local presence with experience mapping in the area, technical knowledge about mapping, and a group of passionate volunteers who may be willing to participate.

As is the case for crowd-sourcing the regional exposure data in the cities of Kathmandu and Dar es Salaam for the METEOR project. Kathmandu Living Labs (KLL) is a local company who has been involved with the OSM community for years, having worked on numerous projects with the Nepalese government. While Ramani Huria is a community-based mapping initiative that began in Dar es Salaam training university students and local community members to create OSM maps of the most flood-prone areas of the city, in an effort to help combat the impact.

The OSM community often uses mailing lists, Facebook or Meetup groups, or the OSM wiki[4] to communicate and plan activities. Table 4 below lists other potential groups and how they participate in an open mapping project.

Potential Group	How they participate in an open mapping project
Universities	Universities and colleges are great potential collaborators. Participation in a mapping project offers students and faculty an opportunity to learn about cutting-edge open-source methodologies, ideas, and software. Students are often technically minded and have flexible time commitments and enthusiasm to learn new things. Mapping projects that involve academia may also evolve into a permanent part of the university's curriculum or even a course by itself.
Scientific communities	Local scientific communities, whether involved in university research or in civil society organisations, can be called upon to support an open mapping project in several important ways. First, these are important groups to involve in the data modelling process. Civil engineers, planners, and others have experience with relevant data and analysis, so they may be able to provide suggestions as well as important local context. Second, data quality assessment throughout the project, particularly at the end of the data collection period, is critical, and these groups may be well placed to support it.
Technical communities	Open-source software communities (user groups and private companies) are often closely linked with OSM communities. Freelance software developers, GIS specialists, and private software companies may be interested in providing software that assists the project as well as services for the community. The technical community also can share its collective professional expertise when hosting a skills workshop, and service providers can rent office space or equipment. For example, the widespread Open Source Geospatial Foundation (OSGeo, at osgeo.org) is closely related to OSM.
Civil society organisations	The advantages that collaborating with a civil society organisation or local NGO can bring to projects include in-depth understanding of local context and important issues, data-sharing and collection, youth outreach, and well-developed networks in the local community.
International organisations	Many development projects are funded by international organisations that have significant datasets from previous projects. Their interests focus on a variety of areas and potential synergies may exist. Offices such as the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) often have existing mapping capacity and already have knowledge of the local context and existing data.
Youth and adult community groups	Community groups, by their nature, attract members of society who are interested in volunteering their time for the benefit of the community. A great example comes from Indonesia, where Humanitarian OpenStreetMap Team (HOT) worked with the Scouts to map thousands of buildings in the Bengawan Solo River Valley.
Private sector corporations	In recent years, corporations have contributed greatly to open mapping initiatives through provision of financial resources, in-kind donations of services, and donation of employee time to work on mapping projects. Corporate social responsibility (CSR) and philanthropy initiatives often lead corporations to sponsor mapping and mapping technology development projects aligned with their geographic areas of operation and expertise

Table 4: Types of Open Mapping Participation by various groups

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[4] https://wiki.openstreetmap.org/

4. Data Creation

The terms participatory mapping and crowd-sourcing can be used interchangeable, as they both refer to the creation of data in OSM by local communities. HOT generally follows three mapping stages to help guide local communities with their data creation process:

1. Import Existing Open Datasets
2. Remote Mapping of Exposure Feature Footprints
3. Ground Data Collection of Detailed Information

4.1. IMPORT EXISTING DATA

The first stage of creating data in OSM is the importing of existing open datasets. This involves a fair amount of research into the availability of suitable datasets, taking into account the area of interest, the type of feature, data completeness, data accuracy, whether the data is up to date and if it has the correct licensing to match the OSM ODbL license.

The main tools used for importing existing datasets into OSM is the Tasking Manager[5] and JOSM[6], but more important than the tools used, is the way in which the whole process is planned and executed. This must be carried out with more care and sensitivity than other edits in OSM, as it can have significant impacts on both existing data and the local mapping community.

A methodology must be developed and strictly followed for datasets that will be imported. There are various Import Guidelines[7] created by the OSM community, which must be taken into account while developing the import methodology:

A. Prerequisites
B. Community Buy-in
C. License Approval
D. Documentation
E. Import Review
F. Uploading

The first part of the import guidelines is very important, as this includes reviewing what can go wrong with an import, as well as identifying which datasets to import. In many cases the import process will stop here. Recent HOT projects have found that the datasets initially nominated for import are in face not suitable, and this step has not been carried out. This can be attributed to a number of factors, such as the lack of completeness, poor quality and incompatible licensing.

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[5] https://tasks.hotosm.org/

[6] https://josm.openstreetmap.de/

[7] https://wiki.openstreetmap.org/wiki/Import/Guidelines

4.2. REMOTE DIGITISATION

The second stage of creating data in OSM is through remote mapping, which is the process of modifying or adding data from a distance. In OSM this usually involves the tracing of features from satellite imagery or other earth observation material such as drone footage.

Once the features are mapped into vectors, the data is uploaded straight to the OSM database so that the results instantly form part of the global map and is available to everyone. Using imagery to draw points, lines and shapes on the ground is also called 'digitising', and is generally done remotely. This means it does not have to physically be done in the same area.

The objective of remote mapping is to cover a large area quickly, obtaining a high-level overview of what is actually on the ground. It allows people to directly contribute to projects even if they cannot be physically present in the field and greatly speeds up the mapping progress.

Aerial Imagery © HOT   Digitise Footprints   Upload Data
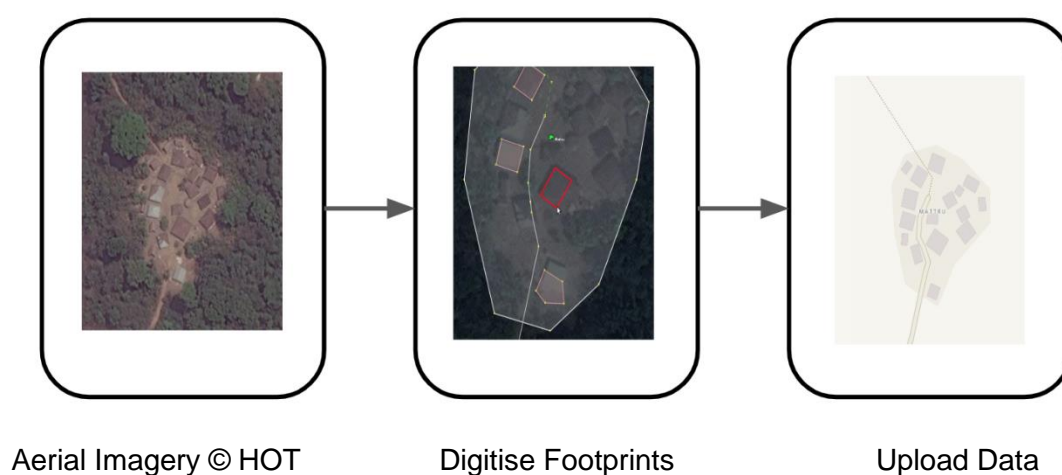
The main tools used for remotely digitising data in OSM is also the Tasking Manager and JOSM. The area of interest is divided into sections by a grid, known as tasks which can then be selected by individual remote mappers who each map a part of the overall area. This helps to avoid data conflicts, and allows for the sections to be checked by a second remote mapper who makes sure it is correct, a process called 'validation'. While there are many advantages to remote mapping, there are also some disadvantages. Data accuracy tends to be lower when users do not physically visit the places they are mapping, hence the emphasis on local mappers.

4.3. GROUND DATA COLLECTION

The third and final stage of creating data in OSM is the collection of information on the ground. This is the process of adding detailed attribute information to the digitised features, such as building footprints and road networks. There are several ways to collect data in the field and it will vary by context, but it will generally include the following:

- ❖ Development of an OSM data model
- ❖ Recruiting a mapping team and providing training
- ❖ Preparing the relevant data collection tools
- ❖ Allocating appropriate transport for the area
- ❖ Authorisation from district officials to survey the area of interest
- ❖ Producing field maps to help guide the team on the ground

- ❖ Managing data being collected on the ground
- ❖ Data validation and spot checks, followed by a
- ❖ Final round of validation before uploading the data into OSM

The main tools used for the collection of detailed information on the ground include OpenDataKit, OpenMapKit, Field Papers, GPS units and OMK Server. Customised survey forms, based on a project data model are created for OpenDataKit through a simple spreadsheet. The use of customised forms ensures that the data collected by the mappers during the survey is consistent, with a set of standardised tags for each map feature. This makes the data collection workflow much more streamlined and greatly helps reduce the potential for error.

5. Crowd-Sourcing Exposure Data

5.1. OVERVIEW

Collecting exposure data on the ground through crowd-sourcing or participatory mapping, is a surveying technique that focuses on local communities capturing information associated with key features in their environment. This generally involves going out in person to map a level of detail that cannot be seen from aerial imagery. This is necessary for creating a detailed and accurate map. By going in person, they are 'ground truthing' the data by directly observing it and ensuring its accuracy.

In addition to identifying and collaborating with the local OSM community, it is very important to ensure that the correct preparations are carried out and the mapping team have all the tools and training required. This section will outline the key components of crowd-sourcing exposure data in OSM, from developing a data model, to the importance of team structure, tools used for collecting data on the ground, managing data and validating the information before uploading it into the database.

5.2. DATA MODEL

A data model in OSM refers to a set of features, their geometries and associated attribute tags. The OSM data model used for surveying in Kathmandu and Dar es Salaam as part of the METEOR project was initially developed through the second round of the GFDRR Challenge Fund.[8]

The Challenge Fund aims to decrease disaster risk management costs and increase resilience by developing a framework that facilitates a multi-hazard view of risk. The second round focused on developing three open databases, which included hazard footprints, exposure data and vulnerability models. The Global Earthquake Model (GEM), ImageCat and HOT made up the consortium that created the schema for a 'Global Exposure Database for Multi-Hazard Risk Analysis'.

One of the key outputs for our consortium was the development of an open exposure database and corresponding data model for multi-hazard risk analysis. The Global Exposure Database for All (GED4ALL) taxonomy was created while taking into account the effects of volcanoes, floods, tsunamis, storms and cyclones on the structural integrity of a building. HOT assisted with the

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[8] https://www.gfdrr.org/en/challenge-fund

integration of OSM data into GED4ALL at the building level, by aligning the appropriate data tags in OSM to the taxonomy attributes. A full review of the existing tags in OSM was conducted to help identify which tags, also known as keys, matched the outlined attributes of the building, lifeline, crop, livestock, forestry and socio-economic taxonomy.

When conducting a review of tags in OSM, it is advised to use the Map Features[9] OSM wiki page, as well as Taginfo[10] to assess the most commonly used tags. The Map Features page contains a list of features and their associated attributes which are represented in OSM as `key=value` tags. This page provides examples of tag usage, suggestions for tag combinations, and accompanying images, but is not exhaustive, which is why a tag review requires the use of Taginfo as well. Taginfo collects information about tags from several sources to help users understand what they mean and how they are used (Figure 2).
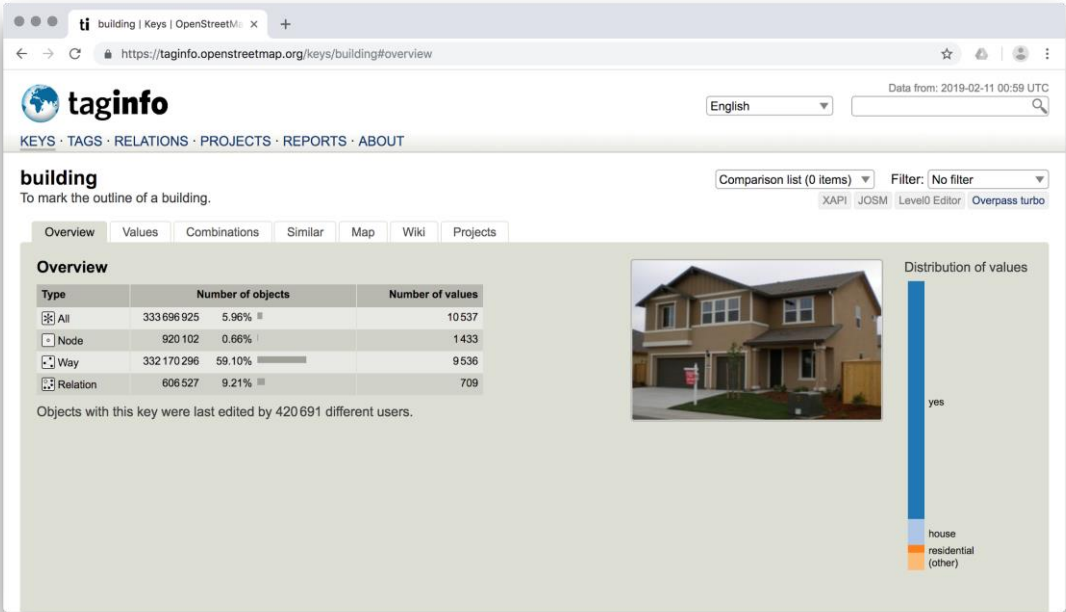

Figure 2: Taginfo, as accessed on 11 February 2019. Data © OSM contributors (ODbL)

Most of the GED4ALL taxonomy aligned with existing tags in OSM, but in some cases a new key had to be proposed, which is highlighted in red within the table below (Table 5). As the data collection in METEOR focuses on buildings, this report solely focuses on the use of the GED4ALL building taxonomy. Please visit the Challenge Fund page on the OSM wiki for more information on lifeline, crop, livestock, forestry and socio-economic taxonomy.[11]

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[9] https://wiki.openstreetmap.org/wiki/Map_features

[10] https://taginfo.openstreetmap.org/

[11] https://wiki.openstreetmap.org/wiki/GED4ALL

BUILDING TAXONOMY			
No.	GED4ALL	OSM Key	OSM Description and Values
2	Material of the Lateral Load Resisting System	building:lateral:material=*	Proposed lateral load resisting material tag (concrete_reinforced, concrete, concrete_steel, metal, masonary_reinforced, masonry, masonry_confined, earth, earth_reinforced, wood, other, unknown)
3	Lateral Load Resisting System	building:lateral:system=*	Identify structural system of buildings (moment_frame, infilled_frame, braced_frame, post_beam, wall, dual_framewall, flat_slab, waffle_slab ,infill_flatslab, infill_waffleslab, hybrid, unknown)
4	Height	building:levels=*	Number of above-ground levels of a building
		building:levels:underground=*	Proposed tag for number of below-ground levels of a building
		building:slope=*	Proposed tag for describing the slope of the building in degrees
5	Date of Construction or Retrofit	building:age=*	Proposed age tag, associated with buildings (pre_2000, post_2000, unknown)
		building:condition=*	Describe the condition of the building (good, average, poor, unknown)
6	Occupancy	building=*	Describe the building purpose (residential, commercial, public, mixed_use, industrial, agriculture, assembly, government, educational, unknown)
		capacity:persons=*	Describe the number of people a building can support
9	Ground Floor Hydrodynamics	ground_floor:openings=*	Proposed openings tag, associated with building ground floors (yes, no, unknown)
		ground_floor:height=*	Proposed height tag in meters, associated with building ground floors
11	Roof	roof:shape=*	Well known roof shapes (flat, pitched, monopitch, sawtooth, curved, complex_regular, complex_irregular, unknown)
		roof:material=*	Outer material for the building roof (masonry, earth, concrete, metal, wood, fabric, slate, stone, clay, unknown)

Table 5: GED4ALL Simplified Building Taxonomy with related OSM key, description and values

It should be noted that the building taxonomy in the table above is a simplified set of attributes, that are key structural influences to the performance of a building. An analysis of the most common, relevant and easy to define features used in building inventory development, guided the creation of the simplified taxonomy list. These were selected to help reduce the comprehensive multi-hazard risk assessment taxonomy for less experienced users, as it is important to consider where the data is coming from and who is collecting the information. From the perspective of the OSM community, which is largely crowdsourced through volunteered efforts, GED4ALL needs to not only be understood by hazard specialists who are utilising the data, but also by the general public.

For this very reason, the creation of a simplified building taxonomy was designed for GED4ALL, that can be shared with the OSM community for data collection and is being applied by Kathmandu Living Labs (KLL) in Kathmandu and Ramani Huria in Dar es Salaam. As the GED4ALL building taxonomy is designed to work globally, the corresponding OSM values to the attributes in the table are merely guidelines to commonly used entries to the listed OSM keys. These values, however, will need to localised for the area of interest it is being applied to. This should involve the revision and adjustment of the GED4ALL building taxonomy to create a suitable OSM data model for collecting detailed attribute information on the ground for Kathmandu and another one for Dar es Salaam.

5.3. TEAM STRUCTURE

The structure of the data collection team is very important and will greatly influence the management, efficiency, quality and overall success of surveying on the ground, especially when working with large amounts of information. One of the biggest mapping efforts carried out by HOT took place in Indonesia, as part of the InAWARE project[12] in collaboration with the Pacific Disaster Center[13] and PetaBencana.[14] The initiative is funded through the USAID Office of U.S. Foreign Disaster Assistance (OFDA)[15] and is successfully continuing today, looking to scale up for the rest of Indonesia and Southeast Asia.

The project focused on the data collection of key lifeline infrastructure in Surabaya, Jakarta and Semarang, the three largest cities in Indonesia. With an extensive OSM data model looking to collect comprehensive geospatial data for baseline information that can be used for disaster risk assessment. The data included administrative boundaries, building footprints, road networks, waterways and disaster vulnerability characteristics.

With such a large task at hand it was imperative that the mapping team had a solid structure so that the data collection could be carried out systematically, in tiered order, to ensure the line of responsibility and guidance was clear. As data collection is crowdsourced through in OSM, the surveying teams are composed of local citizens who understand their surroundings, but might not necessarily have the technical background and skills required to conduct the work. This is why it is important to ensure that a tiered order is presence, so that every member of the team has someone to report to and receives guidance, through training, feedback and validation of their work.

For example, the mapping team in Surabaya consisted of 16 data entry specialists (Table 6), who would go out on the ground in groups of two to survey their environment and collect detailed attribute information of the features specified in the data model. There were also 4 quality assurance specialists, each of who oversee 4 data entry specialists, and delegate the work, collect and review the surveyed data at the end of the day and who would go out at times with their respective data entry teams to help guide them through feedback, as well as conduct random spot checks.

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[12] https://www.hotosm.org/projects/disaster-early-warning-and-capacity-building-inaware

[13] https://www.pdc.org/

[14] https://petabencana.id/

[15] https://www.usaid.gov/

Supervisor	QA	Team	Data Entry	
Dewi	Aming	A	Aris	Irma
		B	Awal	Desta
	Lukman	C	Endang	Galang
		D	Danang	Ficky
Wulan	Kiara	E	Robi	Dinar
		F	Agit	Iwan
	Ramadyan	G	Anjar	Yudha
		H	Dedy	Tyas

Table 6: Ground Data Collection Team Structure

And finally, there were two team supervisors, Dewi Sulistioningrum and Wulansari Khairunisa (Figure 3), each of who would oversee 2 of the quality assurance specialists. They were in charge of planning the whole mapping approach, from developing the workflow, setting up the tools, hiring the team, conducting the training and strategically dividing up the city. Once the work was delegated down the line, the team supervisors and quality assurance specialists could focus on ensuring that the data was being collected correctly and to a high standard, while providing feedback both down the line to the data entry specialists, as well as to the project manager for reporting to the donor and the rest of the HOT team.

Figure 3: InAWARE Team Supervisors. Images © HOT 2019

The team structure was not only important for efficiency, which is key when surveying cities as large as Jakarta, with a population of 30 million, but also for ensuring that the data collected was checked and validated during several stages of the mapping, by different individuals looking and assessing at different scales.

5.4. DATA COLLECTION

Collecting data on the ground is an integral part of editing OSM. This data is typically richer in detail and more accurate than map data that is generated solely by remote digitisation. Mappers can choose from a number of free and open tools that facilitate on-the-ground data collection in both online and offline settings. The tools generally used in a HOT led data collection effort include but are not are not limited to OpenDataKit, OpenMapKit, Field Papers, a Global Positioning System unit and Maps.me. OpenMapKit Server is also used to help manage questionnaires and submitted data out on the ground, which is covered in the section 5.6 Data Management.

5.4.1. OpenDataKit

OpenDataKit[16] (ODK) is a free and open source set of tools that help organisations author, field, and manage mobile data collection solutions. ODK Collect is part of ODK, which is an Android application that replaces paper forms used in survey-based data gathering. It supports a wide range of question and answer types, that can be managed by a set of rules in order to help reduce the occurrence of errors during data collection (Figure 4). It is also designed to work well without network connectivity.

ODK Collect is very versatile and can be used in almost any setting. Once forms have been downloaded, it does not depend on the internet again until the collected data needs to be uploaded to a server, or not at all if the data is transmitted directly to a desktop. The guidelines below briefly outline the key steps for setting up ODK:

1. Install ODK Collect on an Android phone – this can be downloaded from the Google Play Store
* For OSM compatibility, install OpenMapKit from the Google Play Store

2. Generally organisations first fill out a form and then upload it to a server - such as OpenMapKit Server
*One way to do this is by creating a form online with ODK Build, though you can also build a form with a spreadsheet

3. To download the form, open ODK on the phone and go to **General Settings**, then click **Server**.

4. Enter in the server information, return to the home screen and select **Get Blank Form**, then select the form of interest.

5. In order to begin filling out the selected survey, click **Fill Blank Form** - now the attribute information can be completed following the questionnaire.
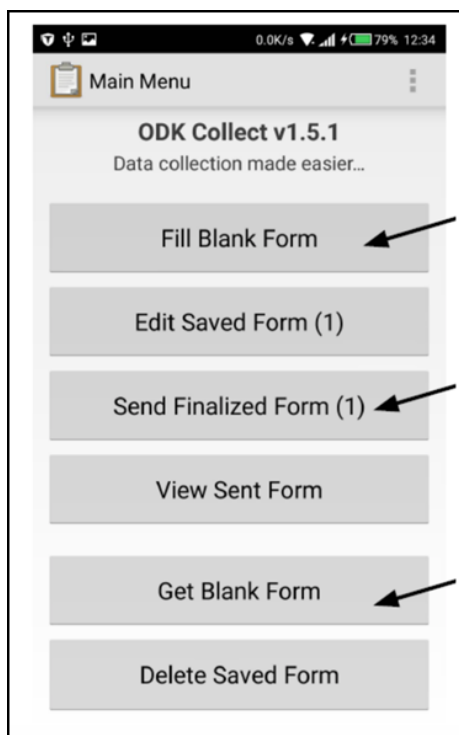
Figure 4: OpenDataKit Interface, ODK is a free and open source mobile application questionnaire form for collecting data

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[16] https://opendatakit.org

Reference	Link
OpenDataKit Docs	https://docs.opendatakit.org/
ODK Guide	https://docs.opendatakit.org/collect-intro
ODK Build	https://build.opendatakit.org or http://xlsform.org/en

Table 7: OpenDataKit References

5.4.2. OpenMapKit

OpenMapKit[17] (OMK) is a free and an open source tool that is used to create professional quality mobile data collection surveys on the ground in OSM. OMK launches directly from ODK and allows users to add points of interests and attribute information in the form of tags for OSM (Figure 5), following a customised survey questionnaire. This detailed information can be securely collected, saved, and uploaded to the server of choice or directly to OSM, although it is recommended that the data is validated before being sent to OSM.

OMK is an extension that launches directly from within ODK Collect, when the OSM question type is enabled in a standard survey. It allows the user to browse OSM features, and to create and edit OSM tags. Therefore, ODK Collect must also be installed on the Android phone in order to use OMK to collect and edit data in OSM.
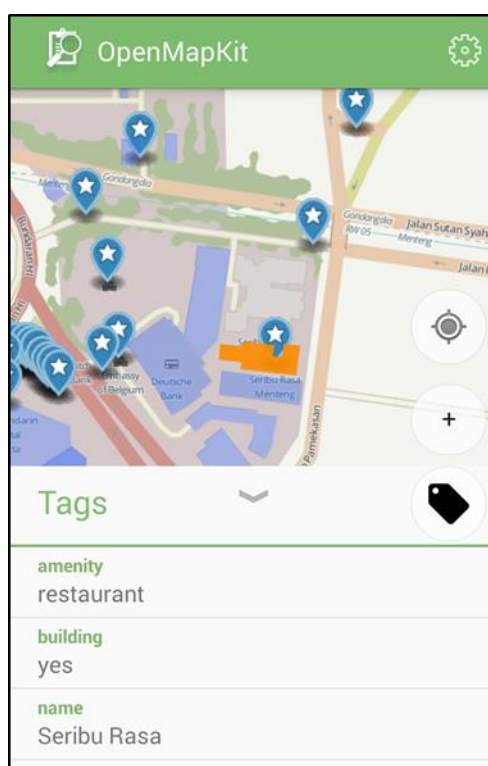
Figure 5: OpenMapKit Interface, OMK is a free and open source mobile application that works with ODK to collect data in OSM

Reference	Link
OpenMapKit Documentation	http://openmapkit.org/docs.html

Table 8: OpenMapKit References

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[17] http://openmapkit.org

5.4.3. Field Papers

Field Papers[18] enables mappers to create a printable atlas of the OSM view of an area of interest, in order to conduct pen-and-paper street mapping. Mappers can walk the streets of their community or area of interest and add attribute information by labelling features such as buildings and roads, as well as add geometries by sketching directly onto the printed Field Papers map (Figure 6).

The labels and sketches can then be directly edited into OSM by referencing the completed Field Papers. This is done by scanning or photographing the Field Papers and uploading it back to their site once there is internet access. This way the labels are added as tags and the sketches are digitised as geometries in OSM. Field Papers does not require a GPS or the user to learn complicated GIS software to help contribute to OSM, which makes it an excellent tool for individuals who perhaps do not have the necessary equipment or the skills to do so.
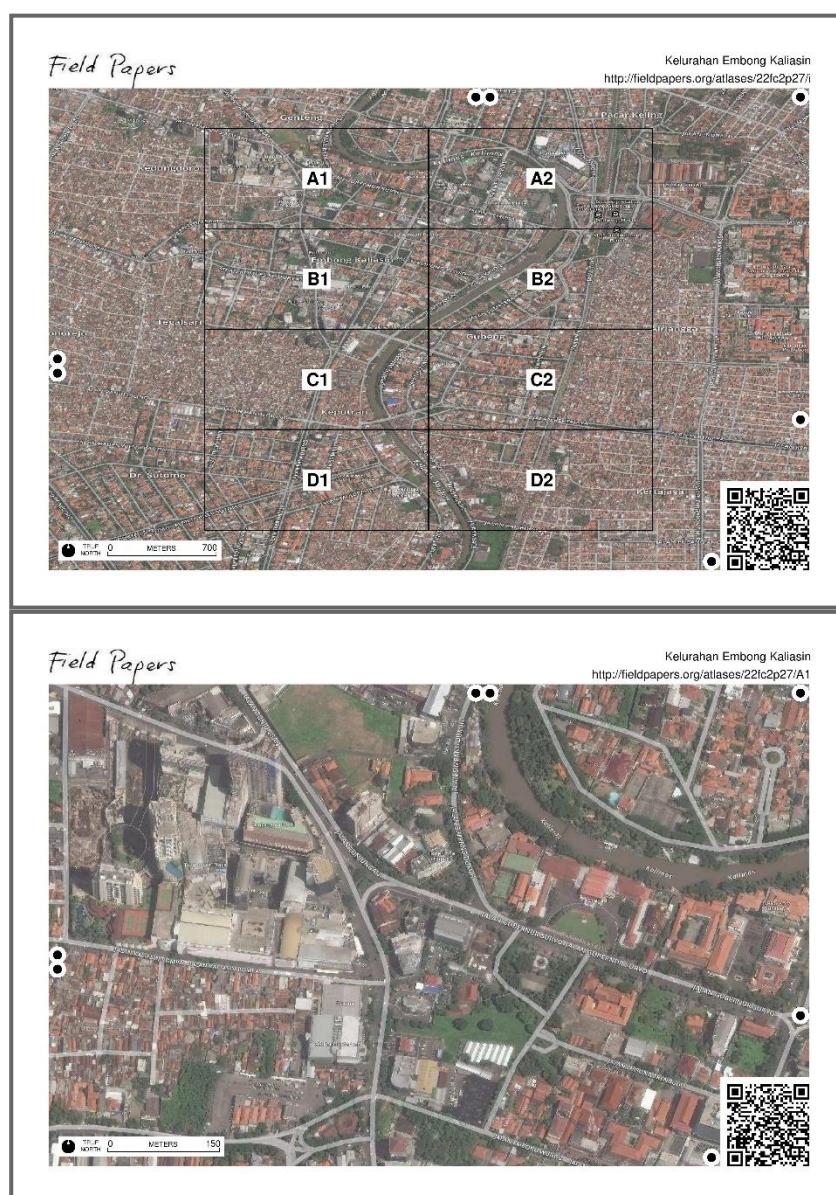
Figure 6: Field Papers, an open project of OSM for creation of a printable atlas of the OSM view of an area of interest. Images © OpenStreetMap

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[18] http://fieldpapers.org

Field Papers is generally used as a reference guide for mappers on the ground, so that they know what area they are meant to cover in addition to the survey boundaries that are brought into OMK as a vector layer. It also works as a valuable tool to capture additional notes or as a backup for collecting data in the rare, but not unheard of case, where the mobile phone or the data collection software runs into some errors and does not work as expected.

Reference	Link
Field Papers About	http://fieldpapers.org/about

Table 9: Field Paper References

5.4.4. GPS Units

The use of a Global Positioning System (GPS) unit is also advised when conducting data collection on the ground, as it allows a user to orientate themselves by displaying their current location on a basemap. This basemap can be derived from OSM and added to the GPS unit. The mobile application OMK can also do this, but the accuracy is dependent on the capabilities of the mobile phone being used and can be off by several metres, while a GPS unit provides a much higher accuracy.

GPS units used in previous HOT led crowd-sourcing data collection projects, include the Garmin etrex 20, Garmin etrex 30[19], Garmin GPSmap 62s and Garmin GPSmap 64s[20] (Figure 7). These units were selected for use based on a balance between their capabilities and costs, as costs are attempted to be kept at a minimum in order to make our procedures more realistic to replicate around the world, in all environments and with as many communities as possible.

Figure 7: Garmin GPSMAP® 64 unit. Image © Garmin

GPS units can also be used to collect coordinates and take notes for features being surveyed on the ground. Once the survey is complete, the data can be loaded into an editor and digitised into OSM. For example, the inbrowser iD editor[21] tool for OSM makes it easy to upload a GPX file for tracing. Mappers can also choose to make their GPS layers public, by adding their data to the OSM GPS database, which is one of the largest collections of GPS data in the world.

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[19] https://buy.garmin.com/en-US/US/c12521-p1.html?series=BRAND472&sorter=featuredProducts-desc

[20] https://buy.garmin.com/en-US/US/c12521-p1.html?series=BRAND563&sorter=featuredProducts-desc

[21] http://ideditor.com/

Reference	Link
OSM GPS Unit Reviews	https://wiki.openstreetmap.org/wiki/GPS_device_reviews
OSM Public GPS Traces	https://www.openstreetmap.org/traces
OSM Upload GPS Tracks	https://wiki.openstreetmap.org/wiki/Upload_GPS_tracks

Table 10: OSM GPS Database References

5.4.5. Maps.Me

Another way to help mappers on the ground orientate themselves and navigate to their area of interest is with the use of Maps.Me, which is a free and open source mobile application that can be used with both Android and iOS operating systems. Based on OSM data, the application provides offline maps, which is especially useful for navigating in areas with no network coverage. All that is needed is the GPS in the mobile device and the map data downloaded for the area of interest, prior to heading out on the ground for mapping.

In situations with low levels of internet these can be especially useful offline maps. The simple interface (Figure 8) also means Maps.Me is easy for anyone to learn and use. Because they are user-friendly, they can be used for crowd-sourced data collection, expanding humanitarian mapping beyond the staff of any project into the wider community. Maps.Me also has the capability to add new OSM features and edit existing ones, which are outlined below in the brief guidelines for setting up the application:

1. First download Maps.Me from the Google Play Store

2. Maps.Me has maps for every country in the world. There are at least three different ways these can be download:

 Zoom in to the area of interested until a **Download** button appears

 Tap on the country or city name on the world map and then tap the download icon

Find a map in the list of countries by selecting **Menu → Download Maps**

3. Now the map will be accessible offline. To zoom in, use your fingers or double tap the screen. To see information about a feature simply tap its icon. If the map is upside down just tap the compass icon. To determine your current location, tap the geolocation button in the lower left corner.
* Make sure location services are enabled on your device first

4. To search for something on the map simply tap the search icon and then type the name into the search bar. A keyword or exact coordinate can also be used to search (Ex. 43.9775, 15.3854)

5. To create a route choose the destination, then tap the route icon at the bottom of the screen. A pedestrian route or a car route can be selected - followed by clicking **Start**

6. Perhaps one of the most useful features of Maps.Me is the built-in map editor. New places can be added to the map or existing ones edited. In order to have these changes available to others, open the app settings, go to **Profile,** and log in with your OSM account

7. To add a new place to the map, go to the menu and then press **Add a place to the map**. Select the correct location of the object and then press **Done** in the top right-hand corner. You can then fill in other details. These will then be automatically uploaded to OSM within a few hours.
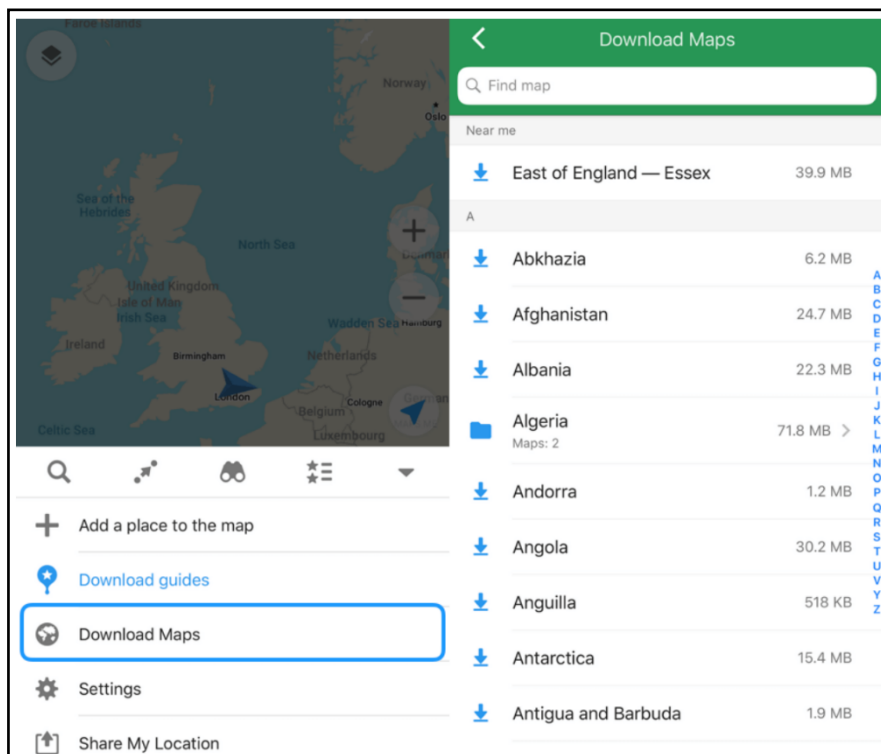
Figure 8: Maps.Me Interface, Maps.Me is a free and open source mobile application

Reference	Link
Maps.Me	https://support.maps.me/hc/en-us
OSM Wiki Maps.ME	https://wiki.openstreetmap.org/wiki/MAPS.ME

Table 11: Maps.Me References

5.5. DIVIDING THE AREA

How the area of interest is divided up and delegated to the mapping team is key to successfully and efficiently collecting data on the ground. This is dependent on the type of mapping initiative, whether it is looking at a whole city or simply targeted portions. The former generally is broken down by administrative boundaries, while the latter is dependent on the targeted area. It should also be kept in mind that it might not make sense to simply split the area between the teams equally. There may be other factors to take into consideration, such as the density of features within an area, how far apart features are from one another and what kind of transport will be used. It is also advisable to be flexible with the plan and adapt it along the way, as there may be some unforeseen blocks that can slow down the mapping for one team, such as restrictions to areas, poor weather conditions and faulty equipment.

For the METEOR project, both the cities of Kathmandu in Nepal and Dar es Salaam in Tanzania are the focus, but only targeted areas. These areas have been broken down into homogenous sampling zones determined by ImageCat based on classified development patterns. There are 7 such identified homogenous zone types in Kathmandu (Figure 9) and 6 in Dar es Salaam (Figure 10).
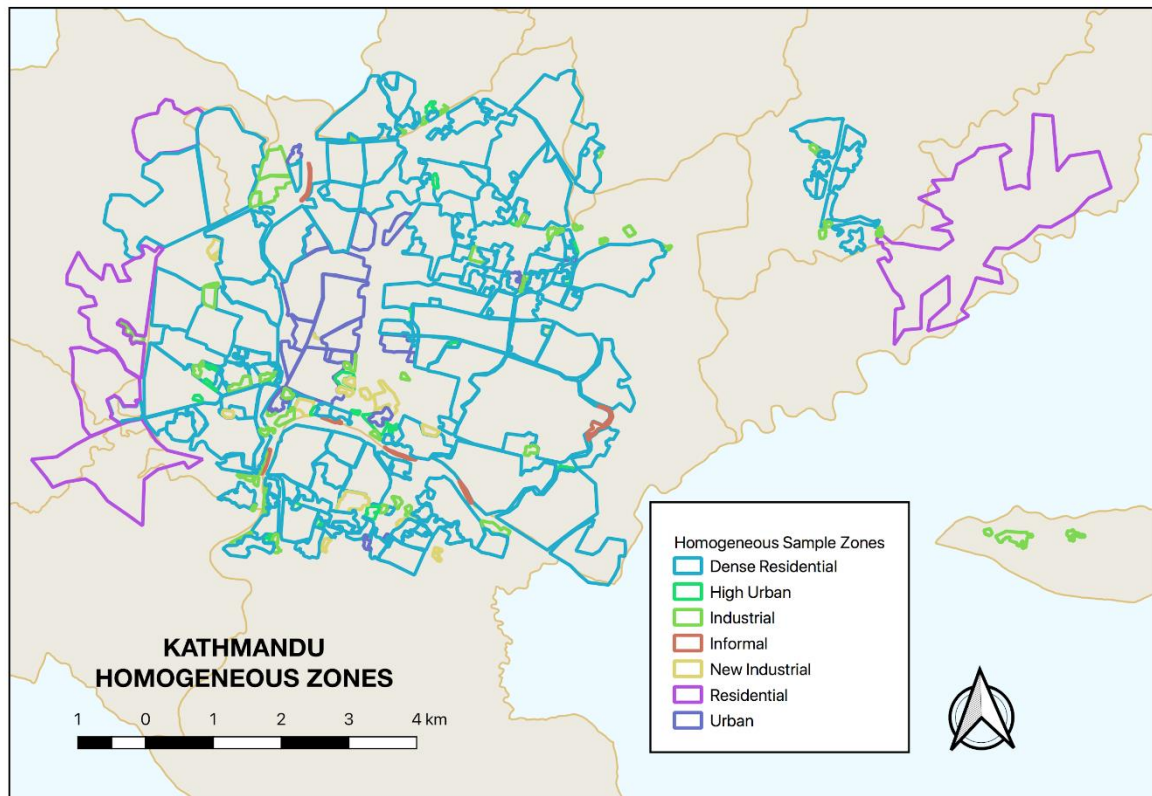
Figure 9: Kathmandu Homogeneous Zones © ImageCat, inc., zones defined by ImageCat as part of the METEOR project. Data displayed within OSM © OpenStreetMap contributors, licensed under ODbL

Homogenous Zone Type	No Zones Identified
Dense Residential	143
High Urban	23
Industrial	51
Informal	7
New Industrial	13
Residential	5
Urban	19
Total	**261**

Table 12: Kathmandu Homogeneous Zones
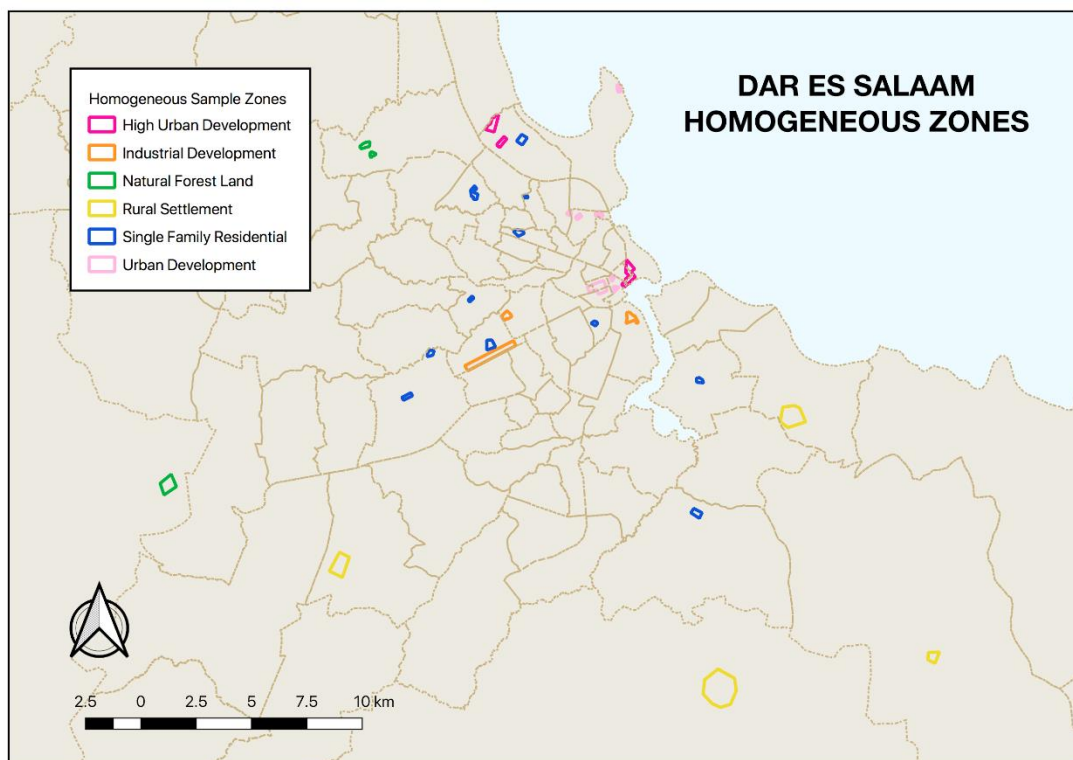
Figure 10: Dar es Salaam Homogeneous Zones © ImageCat, inc., zones defined by ImageCat as part of the METEOR project. Data displayed within OSM © OpenStreetMap contributors, licensed under ODbL

Homogenous Zone Type	No Zones Identified
High Urban Development	3
Industrial Development	3
Natural Forest Land	3
Rural Settlement	4
Single Family Residential	11
Urban Development	7
Total	**31**

Table 13: Dar es Salaam Homogeneous Zones

ImageCat requested that a randomised sampling strategy is applied to the homogenous zone types, so that there are 40 randomised points in each development type, with 10 buildings surveyed around each point. These points will be used as coordinates on the ground, from which the mappers will select 10 buildings to survey and collect data for, following the project data model.

As there are 7 homogenous zone types in Kathmandu, there will be a total of 2,800 buildings surveyed. While in Dar es Salaam there are 6 homogenous zone types, one of which is classified as 'Natural Forest Land' and does not contain any buildings, so there will be a total of

2,000 buildings surveyed. It should be noted that the 40 randomised points only need to be generated for one of the polygons for a homogenous zone type.

The random sampling will be generated by KLL for Kathmandu and by Ramani Huria for Dar es Salaam. It will also be up to the respective teams, how they decide to divide the areas that need to be covered and surveyed. This is where it is key for members of the community to determine this, as they will have local knowledge of the area and can estimate how easy or difficult it will be to survey, how much time is needed, and if there are any potential blocks or delays that may arise.

5.6. DATA MANAGEMENT

After collecting data, the data needs to be retrieved from the devices. Sometimes, it works to simply to manually copy and process the data directly from the data collection mobile devices. However, this does not scale well, when there are large numbers of people collecting data. It also means the data is not backed up, and if the device is lost, then all the data collected during the survey is also lost. Prior to collecting data on the ground, it is important to have a data management strategy that is fit for purpose. One of the data management strategies utilised during a HOT led crowd-sourcing survey is the use of a server.

A server is a central repository that manages the access to data in a physical (offline) or cloud (online) location. Servers can ease operations with higher numbers of data collectors and reduces the risk of losing data. Using a data collection server also allows for better management of questionnaire forms and deployments, collection and aggregation of responses, and can offer additional features for viewing, analysing and exporting data.

OMK Server is commonly used by HOT, although there are other great options as well, such as ODK Aggregate, Kobo Toolbox and Portable OSM. POSM is a physical server that contains a set of OSM tools, including OMK Server. POSM allows multiple users to connect and upload data from surveying devices to a central location without the need for internet access. This data can then be aggregated using the OMK Server and synced with OSM directly or downloaded for analysis and processing (Figure 11).

Figure 11: OpenMapKit Server, data for METEOR project collection in Kathmandu © HOT 2019

Using OMK Server on its own is a lighter solution, which sits online in the cloud and therefore requires internet connectivity. If the mapping teams have internet access while they are surveying on the ground, than this option is preferred, so that the completed questionnaire forms can be submitted directly from the field and backed up by the server. In addition to the deployment of forms to ODK, overall data management and automatic backing up of submitted forms, OMK Server also provides the ability to view all the surveyed features on a map, as well as filter and export selected data.

Reference	Link
POSM	https://github.com/posm/posm
OpenMapKit Server	https://github.com/hotosm/OpenMapKitServer
ODK Aggregate	https://docs.opendatakit.org/ aggregate-intro/
KoBo Toolbox	https://kobo.humanitarianresponse.info

Table 14: Server Resources

5.7. DATA WORKFLOW

Having the data model, the team, the tools and a data management system in place is key to a successful crowd-sourcing data collection effort, but it is also imperative that there is a systematic workflow for all the data, beginning in the office, to the field, from the server and back to the office for several rounds of validation before being submitted to OSM (Figure 12). There is no one way to set up a data workflow, but the following methodology has worked well in the past:

1. Data entry specialists: pull in team survey boundaries into OMK as a vector file
* survey boundaries can be administrative or in METEOR's case homogeneous zones

2. Data entry specialists: pull in background aerial imagery for the survey area into OMK as a raster file

3. Data entry specialists: use the same boundary and aerial imagery in the Tasking Manager
* the Tasking Manager projects were used to remotely digitise the building footprints from the aerial imagery into OSM as vector data

4. Data entry specialists: pull in the digitised building footprints into OMK as a layer

5. Data entry specialists: pull in the survey questionnaire into OMK with ODK through the OMK server

6. Data entry specialists: collect attribute information for the features listed in the data model

7. Data entry specialists: submit the completed questionnaire forms to the OMK server

8. Data entry specialists: copy the raw data over to a desktop for the first round of validation with JOSM

9. Data entry specialists: upload the validated data to OSM through JOSM

10. Quality assurance specialist: conduct a second round of validation through the Tasking Manager based on boundary

11. Team supervisors: conduct a third and final round of validation of all the data for the project area of interest
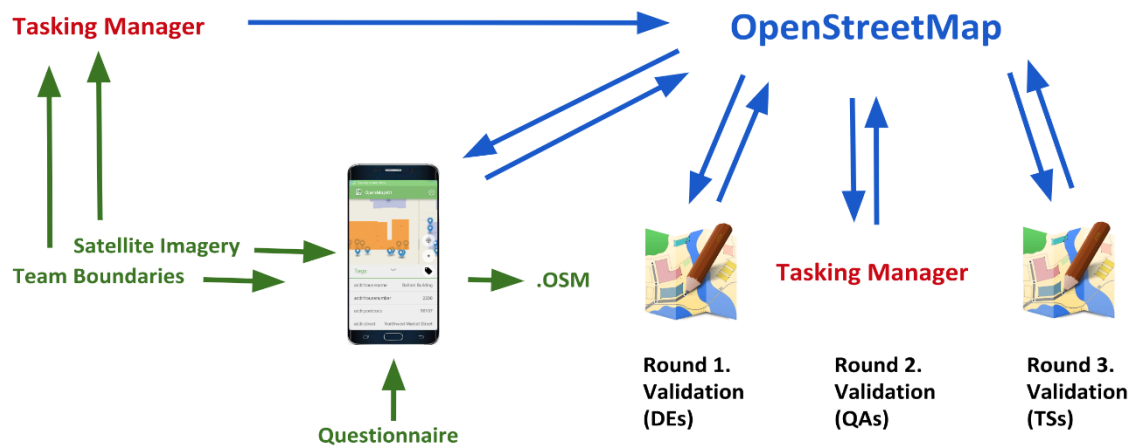
Figure 12: Data Workflow for OSM data acquisition, validation and submission

5.8. DATA VALIDATION

Validating the data collected is the process of going through the features one by one and checking for any errors. It is a key part of HOT mapping, ensuring that the OSM data is complete and correct so that anyone using the information in their own projects can feel confident about the quality. Validation should be performed at all stages of mapping, including the importing of datasets into OSM, remote digitisation of features from aerial imagery and detailed data collection on the ground.

The main objective is to catch any mistakes in the data before uploading it to OSM or using it for any maps. In the same way that there is no one way to set out a workflow for data collection, there is also no correct way to perform validation and quality control. There are, however, several tools that assist with this process while digitising in OSM, such as the 'Validation' tool in JOSM, OpenStreetMap Changeset Analyzer (OSMCha)[22] from Mapbox and the OpenStreetMap Oversight Search Engine (Osmose)[23].

The validation tool helps highlight any errors and warnings in all of the data loaded as a layer file in JOSM (Figure 13). Geospatial errors detected include intersecting geometries and unconnected nodes, while attribute information errors include missing tags, misspelled tags, and incorrectly assigned tags. The 'TODO' tool, which is also available in JOSM, allows the user to select all the features in a layer and organise them so that they can be reviewed systematically one by one, so that none of them are missed.

Another great tool is OSMCha, an online tool designed to review uploads and changes to OSM data. This tool is largely used to prevent bad edits and vandalism to map data, but also works great as a project management tool for carrying out data validation. This tool allows users to filter by username, location, dates of upload, and other metadata features. OSMCha is useful for monitoring the progress of data cleaning and uploads by teams.

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[22] https://osmcha.mapbox.com/

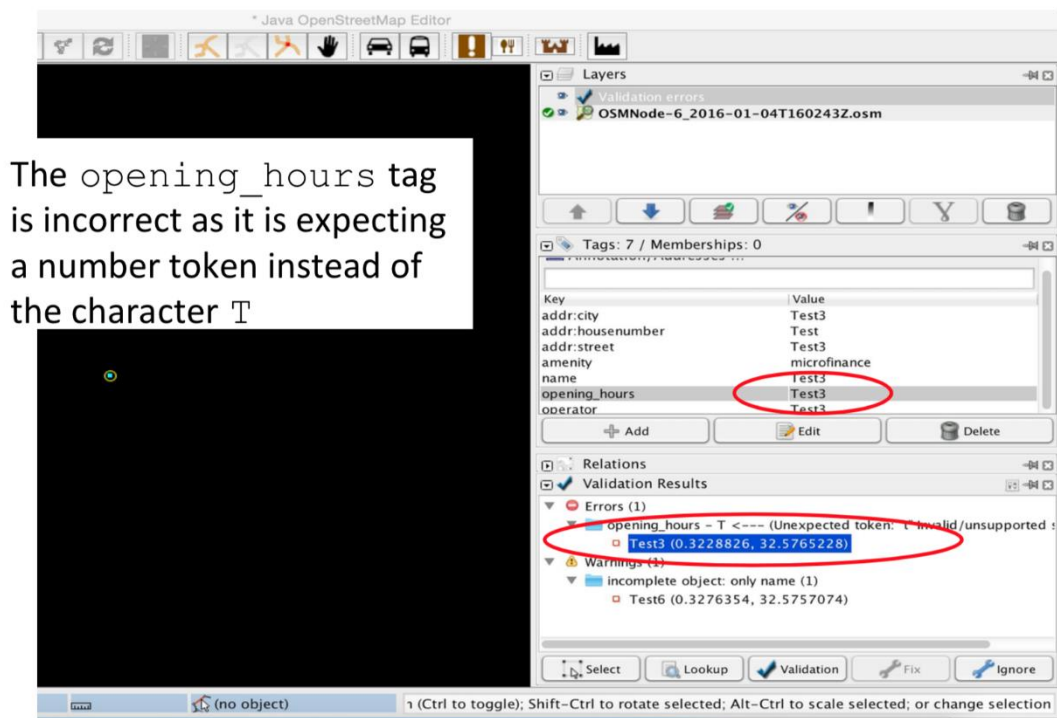[23] http://osmose.openstreetmap.fr

Figure 13: JOSM (Java OpenStreetMap) Validation Tool for quality assurance of digitised data in OSM. JOSM is a free Java software desktop editing tool for OSM data

While errors and bad data should be caught prior to uploading to OSM, these mistakes happen. OSMCha allows managers to check the contributions of others for any missed errors and to provide feedback on their data quality checks. This feedback is especially important for mappers new to using JOSM so that mistakes are caught early and mappers can improve their quality assurance skills. OSMCha provides an additional opportunity to ensure no sensitive information is wrongly uploaded to OSM.

Osmose is another one of the many quality assurance tools available to detect issues in OSM data. It detects a very wide range of issue types[24]. Please see the Appendix for more details about common errors found in OSM data. There are many tools freely available to assist with the data validation and data quality in OSM, but it is important to keep in mind that users should only fix real errors which are fully understood and can be improved correctly.

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[24] https://wiki.openstreetmap.org/wiki/Osmose/issues
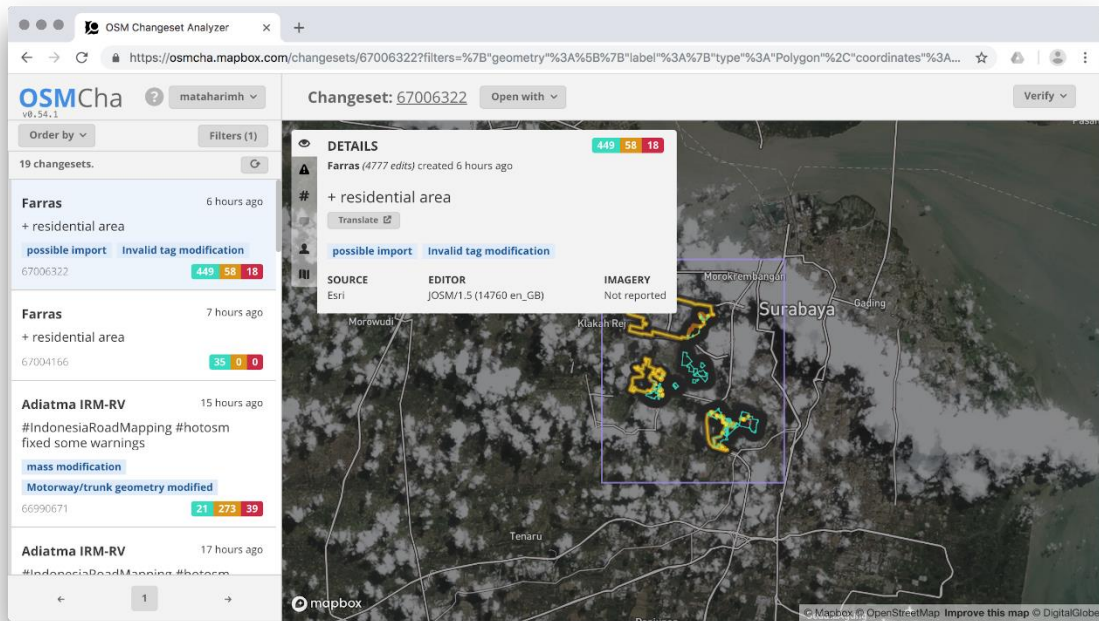
Figure 14: OSMCha, an online tool designed to review uploads and changes to OSM data. Images © Mapbox © OpenStreetMap © DigitalGlobe

Reference	Link
LearnOSM Data Validation	https://learnosm.org/en/coordination/review/#data-validation
OSM Wiki JOSM Validator	https://wiki.openstreetmap.org/wiki/JOSM/Validator
Missing Maps Validate	https://www.missingmaps.org/validate/
OSMCha Guide	https://osmcha.mapbox.com/about
OSM Wiki Osmose	https://wiki.openstreetmap.org/wiki/Osmose

Table 15: Quality Assurance Resources

5.9. DATA QUALITY

Quality assurance is a large part of any dataset and is true with OSM data. It is also known as the maintenance of a desired level of quality in a product. The higher quality your data is the more useful it is, so it is essential to manage the process along the way. Again, there are many ways to assess the data quality and ensure that it is reaches a high standard.

One of the methods used in previous projects to quantify the quality was to do a simple comparison of the data in the area of interest, before and after the completion of the survey. This comparison is assessed with the use of JOSM and the validation tool, which provides a number of 'Errors and Warnings' of the analysed data.

Running this tool on the data before the survey, and comparing to the data in the same area after the data is collected, should demonstrate that the quality is improving through the increase in the number of features (objects) and a decrease in the number of errors and warnings. This process of quantifying OSM data is one way to assess data quality, another way is to look at the overall data completeness, which one of the newer tools HOT has been developing, aims to do.
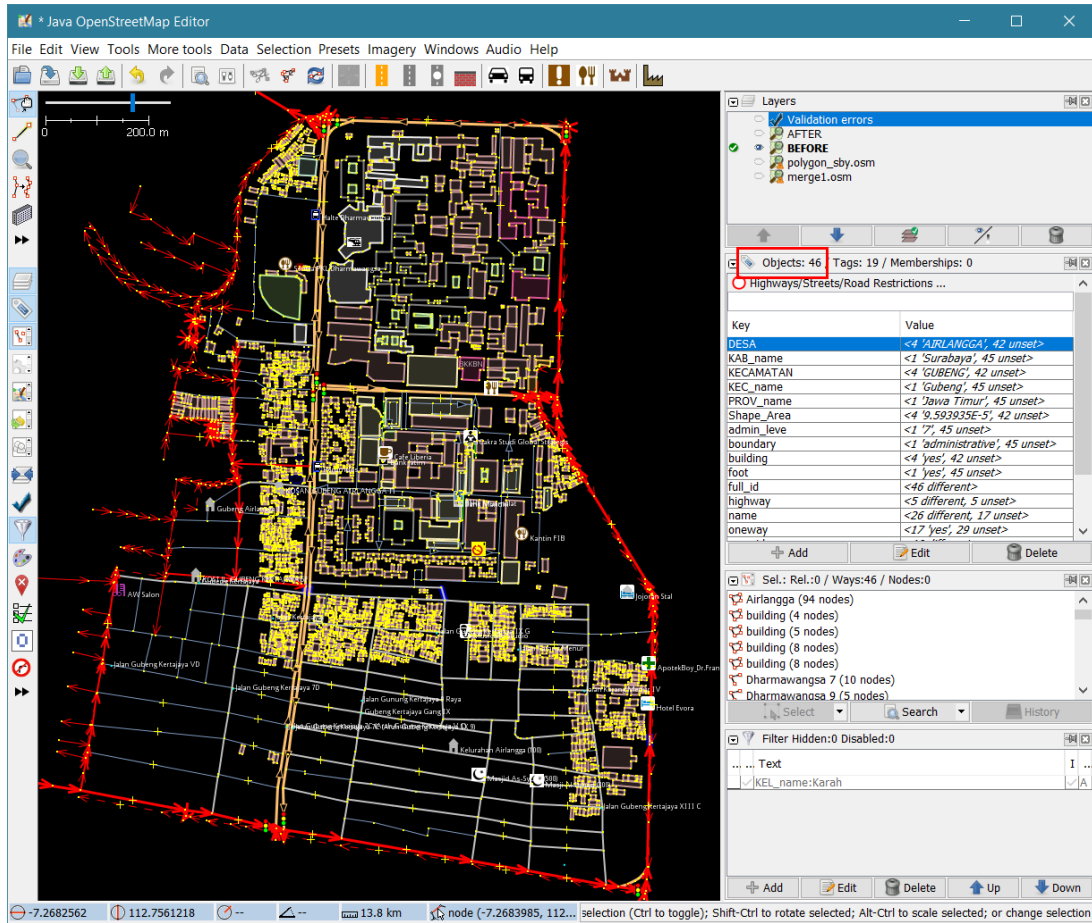
Figure 15: Before and After Comparison of Object Errors in JOSM

No.	Villages	BEFORE					AFTER				
		Object	Error	Error (%)	Warning	Warning (%)	Object	Error	Error (%)	Warning	Warning (%)
1	Airlangga	1775	0	0.0%	266	15.0%	5243	0	0.0%	194	3.7%
2	Gubeng	772	0	0.0%	300	38.9%	3184	0	0.0%	59	1.9%
3	Kertajaya	759	1	0.1%	148	19.5%	6351	0	0.0%	146	2.3%
4	Pucang Sewu	193	0	0.0%	140	72.5%	4072	0	0.0%	164	4.0%
5	Wonorejo	1426	1	0.1%	32	2.2%	4671	0	0.0%	13	0.3%

Table 16: Before and After Data Quality Assessment

MapCampaigner[25] aims to assist with the collection and assessment of detailed attribute information on the ground through crowdsourcing methods. Project managers may use this tool to setup a campaign, add the area of interest, as well as what OSM features to focus on and the corresponding tags to collect, which is specified through a data model. This allows the managers to evaluate the progress of surveying efforts on the ground and the overall quality of the data collected. The tool provides statistics on a number of key components when mapping on the ground, such as the number of features collected, how much of the area has been covered, attribute completeness, features by type, errors found and information on user engagement.

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[25] https://campaigns.hotosm.org/

Figure 16: Example of MapCampaigner interface, a tool for the collection and assessment of detailed attribute information on the ground through crowdsourcing methods.

Table 17: Quality Assurance Resources

Reference	Link
MapCampaigner Resources	https://campaigns.hotosm.org/resources

6. Extracting Data

During the data collection phase, extraction of data from OSM is generally carried out through JOSM for data validation and quality assessment. However, for those who are not familiar with using JOSM and are not interested in carrying out further edits, the use of the Export Tool[26] would be preferable. The Export Tool was created by HOT as way to provide individuals with low technical skills, the ability to easily extract data from OSM through a user friendly interface and straight forward process (Figure 17).

The Export Tool allows users to create custom OSM data extracts for anywhere in the world, simply by selecting an area of interest, map features and file formats to convert the data into. Within minutes, up-to-date OSM data is exported, filtered and converted. Areas of interest can be selected either through searching, bounding box coordinates, drawing a box, free drawing, using the current view or importing a GeoJSON file. File formats that are currently available for export through the tool includes Shapefile (.shp), GeoPackage (.gpkg), Garmin (.img), Google Earth (.kml), OSM (.pbf), MAPS.ME (.mwm), OsmAnd (.obf) and MBTiles (.mbtiles). Map features and specific tags can either be selected through the Tag Tree or by configuring some YAML code.
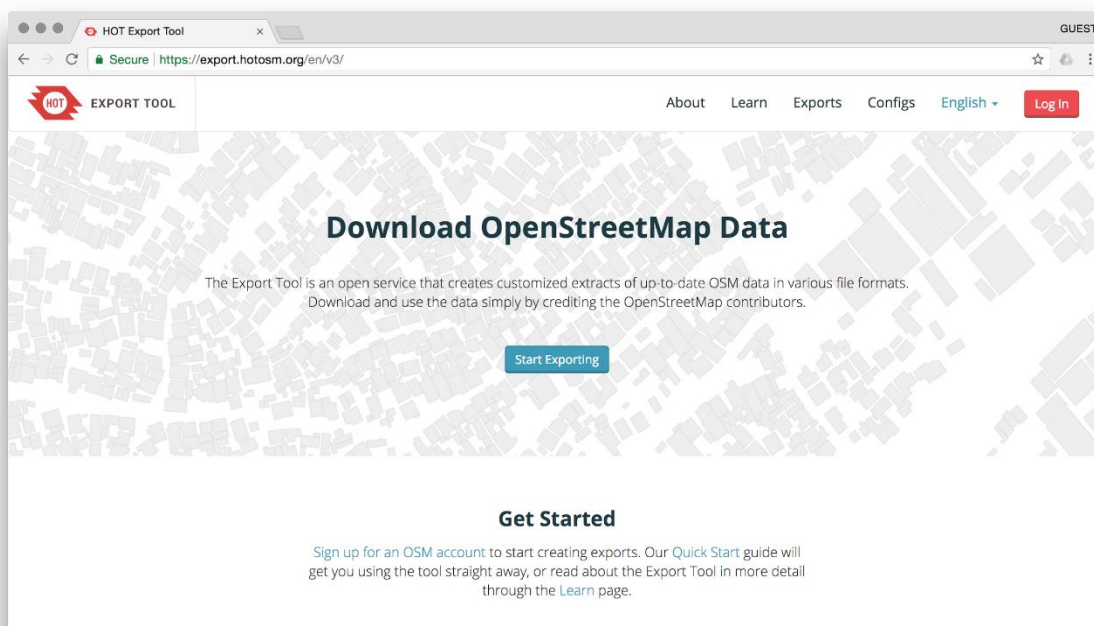
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[26] https://export.hotosm.org/

Figure 17: Export Tool, used to customise OSM data extracts for anywhere in the world

1. Start by logging in using your OSM username and password, by clicking the red **Log In** button in the top right-hand corner. Then you will need to confirm your email address.
* *The email is required for the tool to send a link of your completed export job - in case for some reason you are disconnected, the job will not be lost*

2. After logging in, click **Create** or **Start Exporting** to begin setting up your first export.

3. Define your area of interest on the map to the right. This can be done by searching, drawing a box or polygon around your area of interest, or simply exporting everything in the current view. There is also the option to upload a GeoJSON file by pressing **Import**.
* *The size of an export is limited by the amount of data in your area of interest. The job will not run if there are too many features within the selected area.*

4. On the left-hand side will be a number of tabs, use these to create the parameters of your export:
Describe Fill out a name and description of the project
Format Choose your GIS file format. Shapefile is the default option though Geopackage is becoming more commonly used and has certain advantages
Data Select which features you want to query and include in your download package
Summary Download your files by clicking **Create Expor**t - the export may take some time to run depending on the size of your area and how many features were selected in your query

5. Download the exported file by clicking on the highlighted link. This should be the name of your project and the format you selected. This appears as a .zip in your computer's downloads folder.
* *It will also automatically send a link to the file in your email.*

6. Browse to the downloads folder on your computer, right click and **Copy** the .zip file. Browse to the location where you want to keep your files and paste. Right click .zip file and **Extract** the file.

7. The extracted data will work with most GIS software. However, the free and open source QGIS desktop software is generally used in HOT led projects. The data can be added via the **Add Vector** button, which you should now be able to view within the map and in the layers window.
* *See QGIS tool for more details on how to use the GIS desktop software.*

Reference	Link
Export Tool Learn	https://export.hotosm.org/en/v3/learn
LearnOSM	http://learnosm.org/en/osm-data/geofabrik-and-hot-export
QGIS Documentation	https://www.qgis.org/en/docs/index.html

Table 18: Export Tool – QGIS Resources

7. Sustainability

A common concern about crowd-sourcing mapping initiatives is their ability to have a sustainable impact after the end of the project cycle. In this case, sustainability can take on multiple meanings, including continuing use and maintenance of the data, continued activity of the local mapping community, or ongoing investment in the project by new participants. Defining at the start of the process, what goals are most relevant will help ensure organisers can design and implement the project in the ways most likely to achieve them. It is also important to take stock at the end of a project of what was learned during the implementation, in order to guide continued work or new efforts in other locations.

Not only is it important to outline the methodology, goals and lessons learned from a project, but it is key as to how this is communicated with the OSM community and stakeholders. One of recommended ways is to ensure that this is documented online so that is easily accessible by everyone, such as the OSM wiki[27].

The wiki is a common place for documenting projects related to creating data in OSM. It is also the first place that should be checked for similar projects conducted in the local area. This way the processes and lessons learned can be reviewed and built upon. It is also common to provide the details of the project manager who can be contacted for further discussions regarding the work and provide feedback.

The OpenStreetMap Foundation[28] (Figure 18) provides an overview on the expectations for organised editing efforts in OSM through their 'Organised Editing Guidelines' page[29]. This was developed through the consensus of discussions with the community, the OSMF advisory board and humanitarian mapping efforts. Their goal is to provide a framework to both organised mapping initiatives and the communities to encourage good organised mapping, which will assist with the sustainability and usability of the data created.

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[27] https://wiki.openstreetmap.org/

[28] https://wiki.osmfoundation.org/

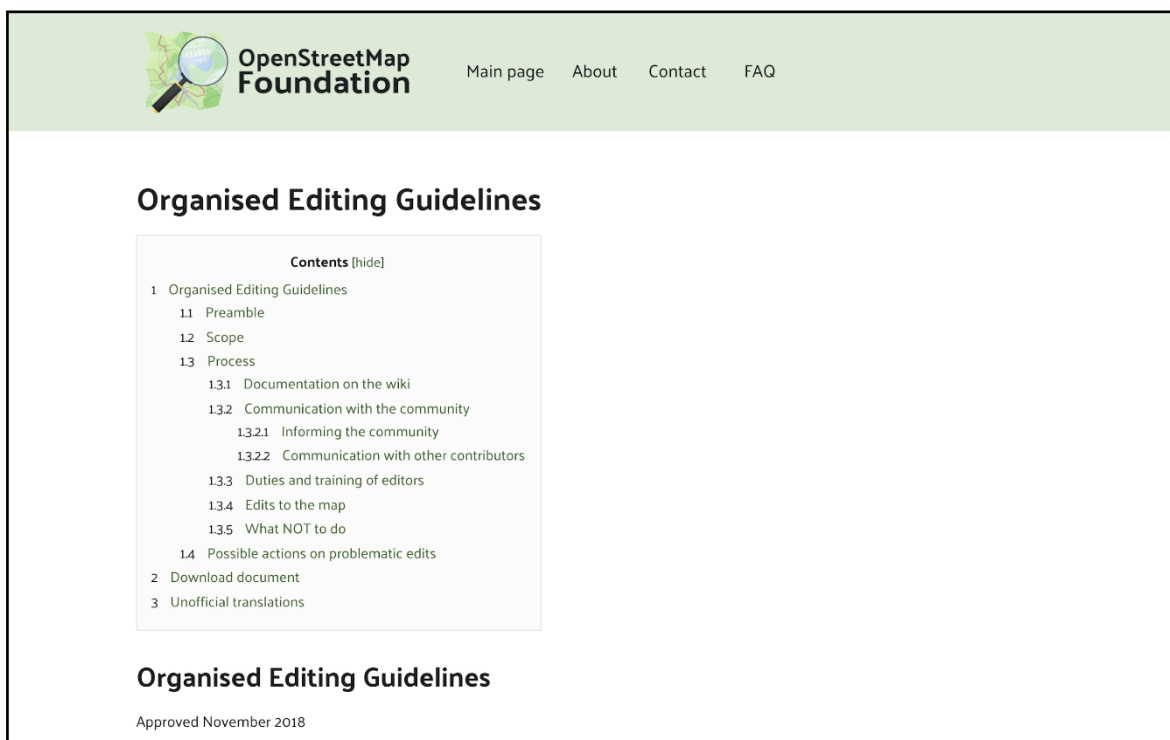[29] https://wiki.osmfoundation.org/wiki/Organised_Editing_Guidelines

*Figure 18: OSM Foundation Organised Editing Guidelines
(https://wiki.osmfoundation.org/wiki/Organised_Editing_Guidelines). OpenStreetMap
Foundation is a not-for-profit organisation that supports the OpenStreetMap Project*

The organised editing guidelines apply to any edits that involve more than one person and can be grouped under one or more sizeable, substantial, coordinated editing initiatives. One of the key sections of the guidelines focus on the creation of a wiki page, to assist with the recording and sharing of activities with the rest of the OSM community for constructive feedback:

- ❖ the coordinating person or organisation
- ❖ a way to contact the organiser
- ❖ a unique hashtag to be used in the changeset comments
- ❖ the goal of the activity, explaining also why the goal is being pursued
- ❖ the timeframe for the activity
- ❖ any non-standard tools and data sources used, and their usage conditions
- ❖ links where the community can access any non-standard tools or data sources used
- ❖ the accounts of participating persons that wish to be identified, with any details they wish to include
- ❖ if the success or performance of participants will be measured in any way, a description of the metrics used for this
- ❖ if participants will receive training material or written instructions, a copy of, or link to, these materials
- ❖ plans for a "post-event clean up" to validate edits, especially if the activity introduces new contributors to OpenStreetMap
- ❖ after the activity has completed, or at least once a month for ongoing efforts, a description of the results

A page for the METEOR project has been set up on the HOT website[30], with contact details for the project manager, as well as links to news update blogs and other key pages related to the

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[30] https://www.hotosm.org/projects/modelling-exposure-through-earth-observation-meteor/

work. Both local partners in Kathmandu and Dar es Salaam have set up pages on the OSM wiki for the data being created in their respective countries, as part of the METEOR project following the OSM Foundation 'Organised Editing Guidelines'.

The main sections of the wiki pages created by Kathmandu Living Labs and Ramani Huria include an overview of the project (manager, contact details, timeframe, etc), the purpose and goal, as well as details of the data creation process. This includes links to the Tasking Manager projects, imagery used, building statistics before and after the digitisation stage (quantity and quality), as well as before and after maps of the homogeneous zones for the remote digitisation phase.

Key parts to communicate for the data collection on the ground include the localised OSM data model derived from the GED4ALL schema, tools used for the data collection, statistics of attribute completeness before and after data collection, and statistics of data quantity and quality before and after surveying.

Local Partner Organisation	Link
Kathmandu Living Labs	https://wiki.openstreetmap.org/wiki/Directed_Edits/METEOR_Digitizing_Kathmandu
Ramani Huria	https://wiki.openstreetmap.org/wiki/Meteor_project_in_Tanzania

Table 19: OSM Wiki Project Page

These wiki pages will assist with the sustainability of the data created as part of the METEOR project. Geospatial data is constantly changing, as the details on the ground change, these changes need to be reflected and updated in OSM. The areas of focus in Kathmandu and Dar es Salaam will be areas of focus in the future, both for data creation and for data use. Providing easily accessible information will provide users with the background knowledge on how it was created, so that they can continue contributing to the efforts and also have the have the confidence to apply the data it to their own needs.
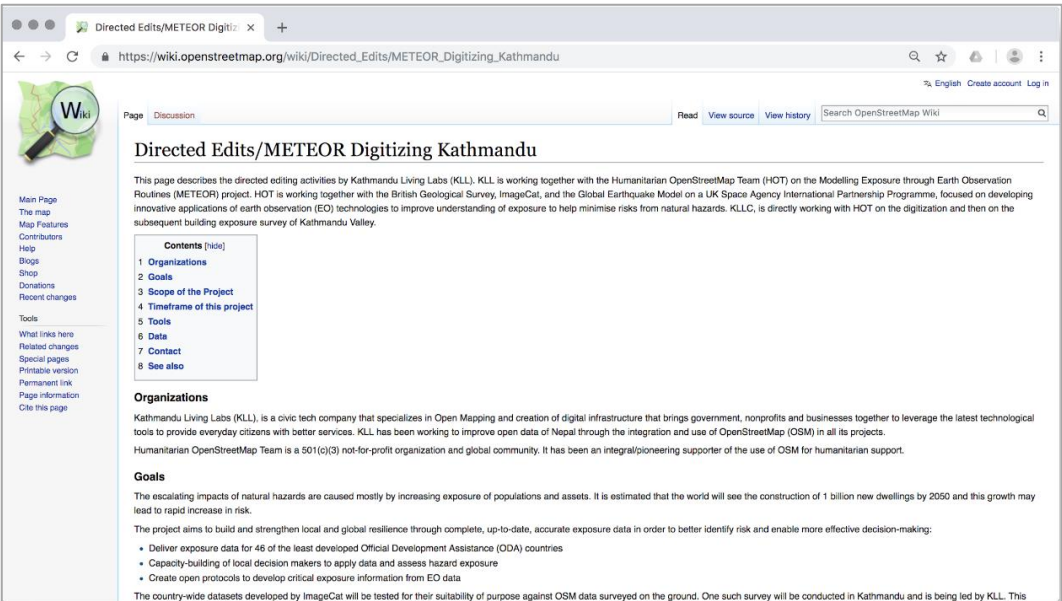

Figure 19: The OSM Project Wiki Page for the editing activities undertaken by Kathmandu Living Labs (KLL) for Kathmandu mapping in the METEOR project

8. Conclusion

This concludes the protocols for crowd-sourcing regional exposure data, but by no means is an exhaustive and comprehensive reference for all the processes and tools that can be used for collecting data in OSM. No one solution fits all, and an approach should be formulated based on the data collection focus, the local community and the area of interest. Approaches that work in one country might not work in another, and newer more appropriate tools for data collection may become available. HOT has been conducting data collection in OSM for the last five years, with the methodology continuously evolving as lessons are learned, and processes become more streamlined. Many of our software development projects are focused on assisting the creation, extraction and analysis of OSM data, as one of the biggest contributions we can make towards the OSM community is helping to provide the tools to empower local capacity to place themselves on the map, as we work towards the Sustainable Development Goals (SDGs) together.

Appendix

Item	Help	Example
overlapping building ⬛ item=0 map list	**Details** In France, probably a building imported from *cadastre without the controls needed. Error is frequent on areas where lots of building are drawn manually, such as the HOT activations. • Class 1 "Building intersection" : the intersection surface is probably due to inaccuracies in the cadastre/import tools • Class 2 "Large building intersection" : a large overlap. Requires a visual check (Bing, cadastre, on site) • Class 3 "Building too small" : there is no intersection, but the surface is too small to be a building. • Class 4 "Gap between buildings" : space separation is probably due to inaccuracies in the cadastre/import tools • Class 5 "Large building intersection cluster" : group of important overlaps. Major problem like a double import. **Fix** Class 1 "Building intersection" : Class 2 "Large building intersection" : Class 3 "Building too small" : Class 4 "Gap between buildings" : Class 5 "Large building intersection cluster" :	
split building ▬ item=1 map list	**Details** • Class 1 "Merge building (triangle)" : • Class 6 "Building in parts" : **Fix** Class 1 "Merge building (triangle)" : Class 6 "Building in parts" :	

duplicated node ■ item=1010 map list	**Details** A path passes several times by the same node. **Fix** There are several types of issues: • A way that makes one or more loops; the way must be split into several sections. • A path that goes back on itself (often at one end); the path must be cut to isolate the wrong section and recreated properly afterwards. There are certainly many other cases. In general, it is better to make several roads / areas than a single complex one so that tools working with OSM data can function properly. **Traps** These errors require a good command of your editing tool. Some corrections are not necessarily intuitive.	 Double polygon connected by a string to remove
invalid polygon ■ item=1040 map list	**Details** The polygon intersects itself. The marker points directly to the error area of the crossing. • Class 1 "Invalid polygon" : • Class 2 "Invalid multipolygon" : **Fix** Find where the polygon intersects itself (ie it forms an '8 ') and correct geometry for a single loop (a '0') or by removing nodes or changing the order of these nodes, by adding new nodes or by creating multiple polygons. • Class 1 "Invalid polygon" : • Class 2 "Invalid multipolygon" : **Traps** Make sure the nodes to move do not belong to other way.	
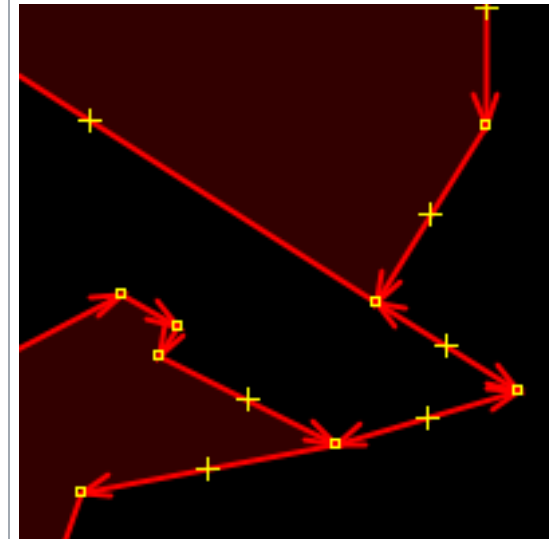
37
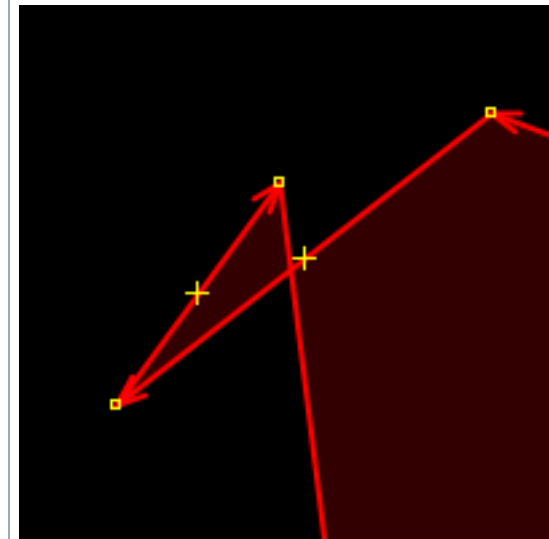
reverse roundabout
 	
🟨 item=1050
map list
	Details
	The circulation of the roundabout is draw clockwise, but in countries where they drive on the right the sense of roundabouts is counterclockwise, and vice versa for the other countries.
	
	    ● Class 1 "Reverse roundabout" :
	    ● Class 1050 "Reverse roundabout" :
	Fix
	Class 1 "Reverse roundabout" : For roundabout `junction=roundabout` : change the direction by reversing the order of nodes in the path. In JOSM, select the roundabout and use the tool *reverse path* (shortcut: *'R'*).
	Class 1050 "Reverse roundabout" : For the mini roundabouts `highway=mini_roundabout` : the tag `direction=*` indicates the direction, in countries driven on the right, the default is `direction=anticlockwise`, in this case it is uselass as tag.
	Traps
	Make sure that it is a roundabout (for example, no a side way in oposite direction around a square or a central roundabout, or driveways separated by traffic islands at an intersection without cross).
		
		Clockwise rotation.

boundary intersect 🟨 item=1060 map list	**Details** Borders crossing. **Fix** Check the type of border and keep the best or merged. **Traps** The borders are part of relationships, they normally form loops.	

		Tow definitions of the same border

objects overlap
 item=1070
map list
	Details
	Objects that can not be overlapped in the same location.
	    ● Class 1 "Highway intersecting building" :
	    ● Class 2 "Tree intersecting building" :
	    ● Class 3 "Tree and highway too close" :
	    ● Class 4 "Highway intersecting small water piece" :
	    ● Class 5 "Highway intersecting large water piece" :
	Fix
	Move an object or check the tags.
	    ● Class 1 "Highway intersecting building" :
	    ● Class 2 "Tree intersecting building" :
	    ● Class 3 "Tree and highway too close" :
	    ● Class 4 "Highway intersecting small water piece" :
	    ● Class 5 "Highway intersecting large water piece" :
	Traps
	The object may be missing a tag e.g. `tunnel=*`, `bridge=*`, `covered=*` or consider `layer=*` on the buidling where a road or railway enters a structure. Warning, information sources can be contradictory in time or with spatial offset.
		
		Intersection lane / building.

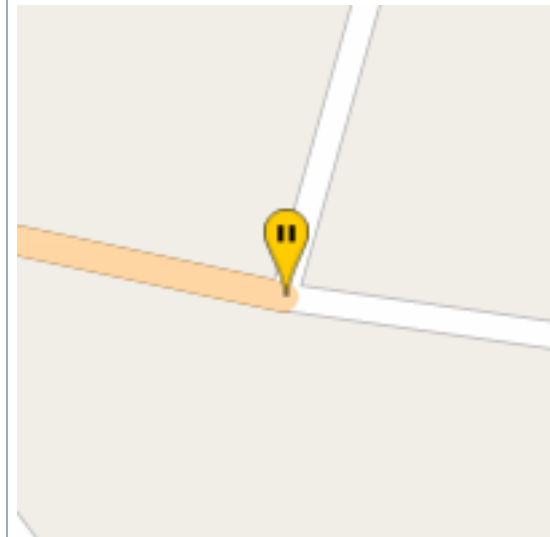|		
orphan nodes item=1080 map list	**Details** Concentration of nodes without tag and not part of a way. **Fix** Find the origin of these nodes. Probably in trouble in import. Contact the contributor submiting the nodes.	 Group of orphan nodes.
sudden highway type change item=1090 map list	**Details** A way connects directly to the street classification much smaller. • Class 1 "Bad topology way level 1" : motorway, primary, trunk • Class 2 "Bad topology way level 2" : motorway_link, primary_link, trunk_link, secondary, secondary_link • Class 3 "Bad topology way level 3" : tertiary, tertiary_link **Fix** Review the classification of streets. • Class 1 "Bad topology way level 1" : • Class 2 "Bad topology way level 2" : • Class 3 "Bad topology way level 3" :	 Secondary connecting directly to the residentials.
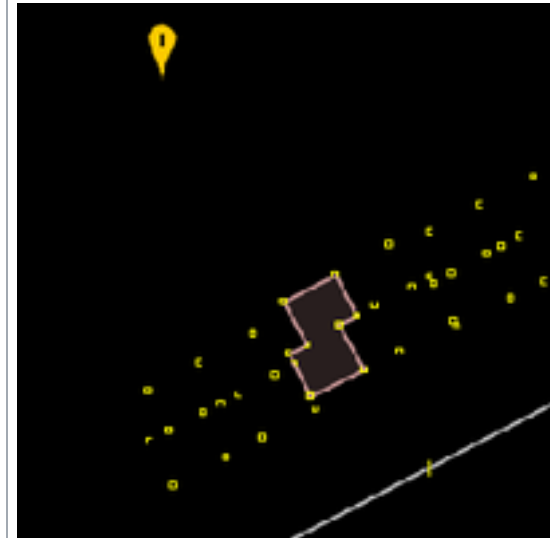
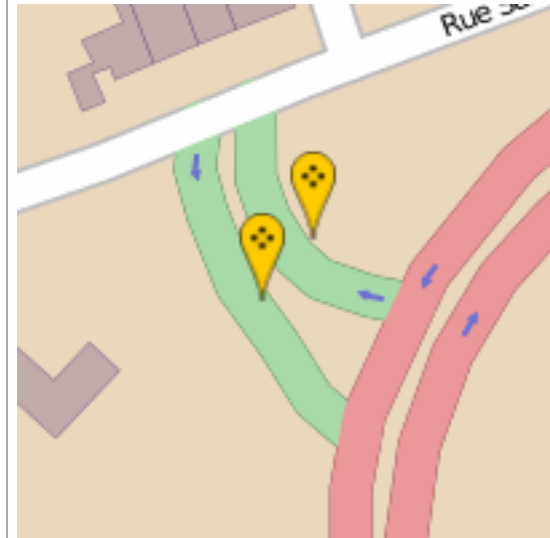|		
unclosed area item=1100 map list	**Details** a way has the tag area=yes, but is not closed. **Fix** If the object is not a surface to remove the tag `area=yes`, otherwise ensure that the way is a loop.	
bad *_link highway item=1110 map list	**Details** - Class 1 "Bad *_link highway" : check way type consistency for `highway=trunk_link` `highway=primary_link` `highway=secondary_link`. - Class 2 "Highway too long for a *_link" : - Class 3 "Bad *_link highway" : **Fix** Class 1 "Bad *_link highway" : change classification *_link to match the way which is connected. Class 2 "Highway too long for a *_link" : check if way is a *_link, else remove _link. Be sure to check both ends of the way. Class 3 "Bad *_link highway" :	 `highway=trunk_link` linking `highway=primary`.
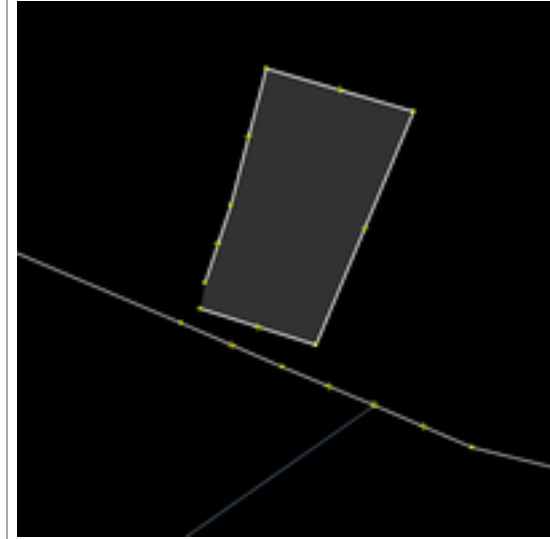
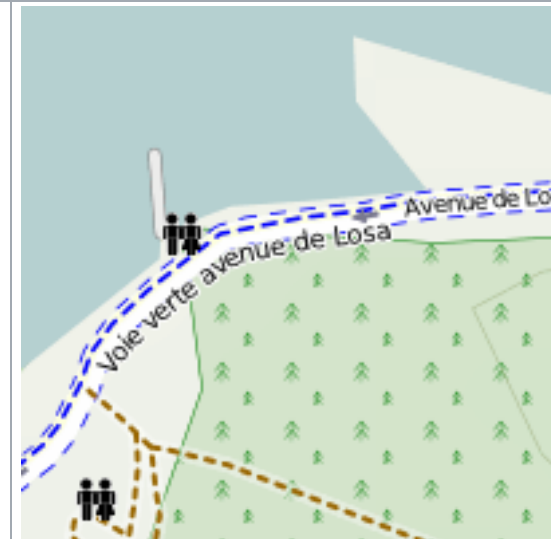|		

broken highway continuity
 	
![icon] item=1120
map list
	Details
	Check the continuity of way types `highway=*`. The classification of a highway should normally be consistent along the entire path. For example a highway=tertiary should remain highway=tertiary until it intersects with a road of higher classification
	
	    ● Class 1 "Broken highway level continuity" : motorway, motorway_link, trunk, trunk_link, primary, primary_link
	    ● Class 2 "Broken highway level continuity" : secondary, secondary_link
	    ● Class 3 "Broken highway level continuity" : tertiary, tertiary_link
	
	Fix
	Making continuous classification.
	
	    ● Class 1 "Broken highway level continuity" :
	    ● Class 2 "Broken highway level continuity" :
	    ● Class 3 "Broken highway level continuity" :
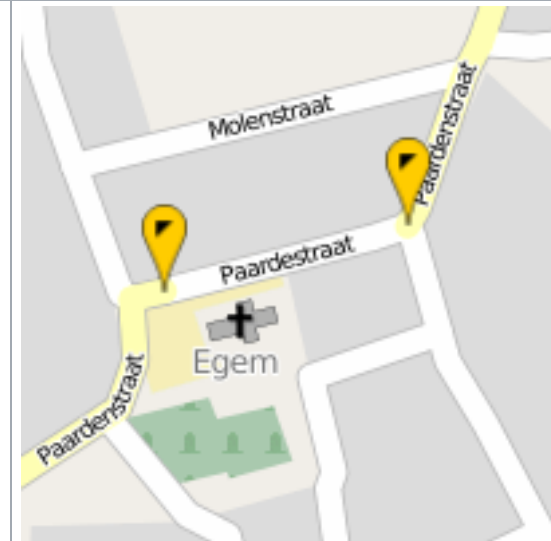		
		`highway=secondary` becoming a local residential.

double cycleway ![icon] item=1180 map list	**Details** double bikeway, `highway=*`+`cycleway=track` parallel to `highway=cycleway` **Fix** When the cycle lane is explicited, must removed `cycleway=track` from the main way.	 Double mapping of the bike lane.

approximate way	**Details**	
item=1190 map list	Way draw seems to be done crudely, there is a discrepancy between the drawing and the real way especially in the curve. Use Bing or Mapbox imagerie - Class 10 "Approximate railway" : - Class 20 "Approximate waterway" : - Class 30 "Approximate highway" : **Fix** After checking (orthophotos), add a node or move existing nodes. - Class 10 "Approximate railway" : - Class 20 "Approximate waterway" : - Class 30 "Approximate highway" : **Traps** On service ways, train stations, train workshops that may be either a false positive	`railway=rail` way crudely drawn.

Item	Help	Example
junction=roundabout □ item=2010 map list	**Details** This looks like a roundabout, but the tag `junction=roundabout` is not present. See Roundabout for more info. **Fix** If it is really a roundabout, add the tag `junction=roundabout`, verify that the path is in the counter-clockwise when driving side is on right, and remove the tag `oneway=yes` if present. **Traps** Ensure that it is a roundabout, using satellite imagery or a local survey.	
elevation □ item=2020 map list	**Details** Some elements, including the peak (`natural=peak`) and mountain_pass (`mountain_pass=yes`), has an evelation. This is shown in OSM with tag `ele=*` in meters. **Fix** Complete the tag `ele=*` missing.	

| **oneway**

➕ item=2030

map list | **Details**

● Class 2 "Missing oneway" : short ways are connected to roundabout and join together, it's often a sign of roundabout insertion way. These segments are often one-way.
● Class 20301 "Opposite cycleway without oneway" : the way have a tag `cycleway=opposite` or `cycleway=opposite_lane` but it's not a on-way street.

Fix

Class 2 "Missing oneway" : after verifying that it is access roads to the roundabout and they were well oriented, position the tag `oneway=yes` on the two segments.

Class 20301 "Opposite cycleway without oneway" : check if the way is really a one-way for car, else simplify with `cycleway=lane`.

Traps

If a way is prolonged after joining the second segment, cut the way before putting the tag oneway.

Two roundabout close can be connected by a small lane in both directions. |

Lack oneway to access roundabout. |

Item	Help	Example
highway roundabout ■ item=3010 map list	**Details** ● Class 1 "Wrong highway on roundabout" : it must match the highest level of connected routes, except highway and trunk. ● Class 3 "Roundabout shortcut" : several roads connect to one node of a roundabout. In the case input and output follo of vehicles bypassing the priority rules and traffic. ● Class 4 "Roundabout crossing" : way through the roundabout without stopping. **Fix** Class 1 "Wrong highway on roundabout" : adjust the tag `highway=*` of roundabout. Class 3 "Roundabout shortcut" : séparez les nœuds de jonction en plusieurs distincte.. Class 4 "Roundabout crossing" : check it's really a roundabout and cut the way.	 level highway should be secondary.
bad source tag ■ item=3020 (FR) map list	**Details** The source tag is incorrect. For example, for an object based on the cadastre, the year is YYYY instead of being properly initialized. Or the source is still "Cartographes Associés", which is an imprecise and dubious source or an illegal source as "Google" or IGN. **Fix** Correct the source and use the register for the position of the object if necessary. If the source is illegal promptly notify the contributor to remove contributions.	