

Resource Materials for establishing GIS- based Database

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Context

This document contains the overall process of establishing GIS-based database required for establishing IMIS in a city including the process of preparing city's GIS data, household survey for establishing containment database, etc. This database will become a main source of data for IMIS for efficient planning, management, and M&E of sanitation system and service delivery with the principle of CWIS.

IMIS promotes sanitation as a public service and integrates sanitation data with inter-related urban sub-sectors domain (e.g., water supply, solid waste management and transportation networks, sewer networks). Multiple types of spatial and non-spatial data sources have been carefully identified by the IMIS development team comprising of System Analyst, Data Analyst, GIS expert and sanitation domain experts focusing on CWIS core outcomes and functions. IMIS data requirement checklist is presented in Appendix A which describes necessary data layers and its necessary attributes for efficient planning, management and M&E of sanitation system and service delivery as well as for overall urban management of the Local Governments.

Establishing a geo-database for IMIS involves creating a structured and organized repository for storing spatial data and non-spatial data. All these data layers are seldom readily available in LGs. In addition, even available data is often outdated or missing key attribute information. Therefore, a series of steps need to be followed to establish required database of IMIS that may include data acquisition through field survey and conversion of relevant spatial data from various sources, such as satellite imagery, master plan data and existing paper maps as well.

Establishment of GIS database for IMIS shall be led by a competent, qualified, and experienced consultant who has a demonstrated track record in working in the geospatial domain with previous experience in conducting city wide geospatial survey for establishing the GIS database. The consultant must have a full-time GIS Expert with at-least bachelor's degree in GIS with 5 years of working experience in their team.

Workflow

The general workflow for establishment of GIS database for IMIS is outlined as follows:

2.1 Exploration data available with local government & other stakeholders

A key informant interview (KIIs) with local government officials and other stakeholders (e.g. Central Bureau of Statistics, Ministry of Local Government, etc.) is a first step in for ascertaining availability of various spatial and non-spatial data needed for IMIS. During the KIIs, availability/unavailability, creation year and form of data(digital/paper) must be ascertained for each data. In case of unavailability of data, it must be inquired if the data can be generated with the help of KIIs with any officials of LGs or other stakeholders. In that case, the person who can provide information must be identified as well.

2.2 Acquisition of available data and standardization

All available data layers must be acquired from LGs and other stakeholders. If the certain data layers are in the paper form, then scanning the map at high resolution, performing georeferencing to assigning spatial coordinates to the scanned map image and digitizing features on the scanned map using the GIS software's digitizing tools along with its attribute data is necessary. It's essential to perform quality control to ensure reliability of GIS data obtained from the paper maps. All available data layers must be subsequently scrutinized for its sufficiency with a detail comparison with the corresponding necessary attributes as mentioned in Appendix A. It is mandatory to perform data cleaning and pre- processing procedure to identify errors, duplicates, missing values, and inconsistencies for all available data layers that have been identified as meeting the IMIS data requirements and therefore not needed to collect through the field survey.

2.3 Acquisition of high-resolution satellite imagery

A very high-resolution satellite imagery is a pre-requisite to establish a robust and reliable base dataset required for IMIS specifically for digitizing building outlines, road data and water bodies. High-resolution satellite imagery can be created through downloading freely available high-resolution Google Imagery given that acquisition of images under Area of Interest (AOI) have been done recently (less than a year ago).

A freely available SAS Planet software (<https://www.sasgis.org/>) provides a simplified procedure to acquire Google Imagery of highest resolution. The SAS Planet software outputs georeferenced single imagery under AOI in various raster formats (TIFF, JPEG or ECW). Some well-known commercial vendors that provide high-resolution satellite imagery include Maxar (formerly Digital Globe), Airbus Defense and, Space Planet etc. All commercial vendors have a catalogue service

that can be inspected to ensure that they have data coverage for desired AOI and have acquired images recently with minimal cloud cover (< 5 % cloud cover is desirable). However, purchasing high-resolution satellite imagery through reputable commercial vendors that offer high-resolution satellite imagery is preferable. Requirements about the data (e.g., data formats, spatial and spectral resolutions, requirements related to the data must be clearly outlined (e.g., AOI, data formats, spatial and spectral resolution) when placing any order to commercial vendors. Preparing high-resolution image using Drone Survey is highly recommend if the fund is available with LGs. This technology helps produce high resolution images compared to satellite images and also reduces field verification time.

2.4 Digitization of data-layers using high-resolution satellite imagery

The high-resolution imagery will be the sole basis for identification and digitization of intended features (e.g., building footprint, road network) through visual inspection and a manual digitization process by a person having proficiency in GIS within a GIS based software. A proprietary GIS software ArcGIS or an open-source software QGIS (www.qgis.org) can be utilized for the process of digitization of the data layers. During the digitization process, it is necessary to ensure that the digitized data is free from any topological errors and maintains geometrical requirements (e.g., right angle maintained for building outlines) that are needed to accurately represent the physical structure in the digital realm. During the process, a strict quality mechanism must be adopted such that digitized features are free from any errors. Topological errors (silver lines, over-shoot, under-shoot, cross breaks, and dangling objects) in case of road features and overlapping polygons, silver & dangles of polygon features must be carefully checked. In addition, it must be ensured that no features visible in the imagery are missed during the digitizing process. It is recommended that error checking is done by a person not involved in the digitation process to guarantee high accuracy and reliability of digitized data.

2.5 Field verification of buildings, roads, sewerage, drainage and water supply

Since building footprints, roads and containment data are the most crucial datasets for IMIS, a field verification process is needed to ascertain presence of all digitized features (e.g., building footprints and road networks) on the field and digitize features that are not visible on the high-resolution satellite imagery. In the process, some digitized buildings may require splitting if there are multiple buildings on the field within the boundary of the digitized buildings.

2.6 Field survey for collection of attribute data

Building data must be mapped with sanitation system available in the buildings, as well associated access road, drain, sewerage network and water supply networks for IMIS. This information must be collected through an extensive census field survey within the LG's boundary. A questionnaire that has been devised for collection of attributes related to buildings and containment data based on IMIS data requirement is presented in Appendix B. The questionnaire shall preferably be translated into the local language.

Between two modes of data collection for household surveys: paper and pencil interviewing (PAPI) and computer-assisted personal interviewing (CAPI), the CAPI is recommended due to numerous inherent advantages such as skip logics, recording geolocation ability, the ability to capture photographs and real-time monitoring of survey responses. Field survey conducted adopting CAPI tends to be more efficient and of high quality because errors are greatly reduced as well. There are many digital tools (mWater, Open Data Kit (ODK) and KoBo Toolbox) available for field data collection, however MerginMaps has been adopted as a recommended tool based on previous experience of collecting geo-spatial data for establishing IMIS for Mahalaxmi Municipality in Nepal and Pourashavas (e.g. Kushtia, Benopole, Gazipur) in Bangladesh. MerginMaps is an ecosystem developed by Lutra Consulting that allows capture of geospatial easily through a mobile device and efficiently store and track changes of collected geodata on a cloud. Multiple surveyors can work simultaneously, and their data can be combined and shared securely through the MerginMaps web platform.

2.7 Composition of survey team

Three different groups of people are required to smoothly conduct the survey.

- i. Enumerators: Responsible for collecting information on the field
 - ii. Supervisors: Overall monitoring of enumerators
 - iii. Coordinator: Setting the mobile and web application for survey and periodic data monitoring.
- A person with GIS knowledge is essential.

It is essential to carefully select enumerators as well as field supervisors to ensure that information to be collected meets the optimal quality standards in terms of accuracy and reliability. Some of the criteria in choosing enumerators include previous survey experiences, good interview skills, familiarity with the local language and familiarity with usage of mobile phones. It is advisable to select enumerators having at least Intermediate academic qualification and priority should be given enumerators having higher academic qualification. All pre-selected potential enumerators candidates are invited to participate in a training session where the final selection is made after their field performance is assessed. A training program is designed to acquaint enumerators with the content, flow, structure of the questionnaire as well as familiarity with intricate details of MerginMaps mobile application for conducting the field survey.

In addition to enumerators, field supervisors are needed to manage field work implementation and monitoring of enumerators to ensure that field survey get completed within the intended allocated time as well as to provide any assistance required by enumerators related to the field mobile application or the questionnaire. Enumerators must maintain regular communication with the supervisors on a daily basis. The recommended ratio of supervisor and enumerator is 1:20.

2.8 Conducting field survey using MerginMaps

A field survey using MerginMaps requires extensive training to enumerators on how to use MerginMaps and conduct data collection accurately and efficiently. Besides training to enumerators, a curtailed training to a person with GIS knowledge to act as a survey coordinator who will setup/modify forms in MerginMaps and performs/monitors the synchronization of collected data with the use of QGIS software is required. The IMIS Field Data Collection User Manual for Coordinator and IMIS Field Data Collection User Manual for Enumerators are attached with this report. An elaborate training shall be provided for both Coordinator and Enumerators before the commencement of the survey. A general workflow for conducting a field survey using MerginMaps is as follows:

- i. Designing the Survey Form in QGIS that includes the required data fields to capture information during the field survey. The form needs to be tailored to specific data collection needs.
- ii. Configuring the GIS data and survey form in QGIS before conducting the survey in the field such that there is direct linkage between survey form with the relevant data layers with needed styling, field validation rules and skip logics. It is essential to incorporate data validation rules with the survey form to minimize errors during the field data collection.
- iii. Acquiring necessary space privilege on MerginMaps for data storage by purchasing a suitable plan that is most appropriate as the requirement of the project and transferring the QGIS project in MerginMaps.
- iv. Providing elaborate training to both coordinator and enumerators about the use of MerginMaps applications (web and mobile apps). Enumerators are given training related to mobile applications only whereas coordinators are given training related to both mobile and web applications. Mobile application is primarily used during the field survey whereas web application is meant both for configuring the survey as well as monitoring and synchronization of collected field data.
- v. Collection of data in the field by enumerators with a mobile device loaded with MerginMaps application. Enumerators can collect data and input the information directly into digital form.
- vi. Synchronizing data collected in the field with the central database using MerginMaps cloud. The step ensures that all data is consolidated and updated in the main GIS database of the project. Enumerator performs the synchronization of data once the surveyors have a strong internet connection. Synchronizing data using mobile data connection is not recommended.
- vii. Regular monitoring of collected data by coordinators to ensure that any inconsistencies or inaccuracies are identified and addressed properly by conveying the information to field enumerators through supervisors.

Appendix A. DATA DICTIONARY FOR GIS- DATABASE

SN	Feature Description	Feature Geometry	Attributes	Priority	Remarks
1	City Boundary	Polygon	<ul style="list-style-type: none">Total Area in Sq. KmCity Name	High	
2	Ward Boundary	Polygon	<ul style="list-style-type: none">Ward numberWard area in Sq. Km	High	
3	Tax Zone	Polygon	<ul style="list-style-type: none">Tax zone number	High	

Building
Footprint

Polygon

- BIN (Unique Building Identification Number)
- House Address
- Holding ID/Tax Code
- Ward number
- Owner name
- Owner gender (Male, Female, Others)
- Owner contact number
 - Structural type (RCC, Load Bearing with cement mortar, load bearing with mud/lime mortar, wooden/mud/CGI/Temporary, steel structures)
- Floor counts
- Building plan area in Sq. m
- Building Construction

High

		<ul style="list-style-type: none">• Others population• Differently abled Male population• Differently abled Female population• Differently abled others population• Offices/business names• Low Income Household Status• Low Income Community Name if Low Income Household• Toilet use information (Private, shared, public toilet, community toilet, Open defecation)• Toilet counts in the building• Toilet connection (Sewer Network, Drain Network, Septic Tank, Pit/ Holding Tank, Onsite Treatment (e.g., Anaerobic Digester/	
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5	Containment	Point	<ul style="list-style-type: none">• Containment Code (Unique Containment Identification Number)	High	
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			<ul style="list-style-type: none">• Associate d House Number/H olding ID/Tax Code• Containment type (Septic Tank connected to Sewer Network, Septic Tank connected to Drain Network, Septic Tank connected to Soak Pit, Septic Tank connected to Water body, Septic Tank connected to Open Ground, Septic Tank without Outlet Connection, Septic Tank with Unknown Outlet Connection, Double Pit, Permeable/ Unlined Pit/Holding Tank, Lined Pit connected to a Soak Pit, Lined Pit connected to		
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6	Public/Community toilet	Point	<ul style="list-style-type: none"> • Unique Code • Associated BIN • Ward Number • Category (Public/Community) • Nearest road distance in meter • Separate facility for male and female (Yes, No) • No. of male seats • No. of female seats • Facility for handicapped people (Yes, No) • Facility for children (Yes, No) • Facility of sanitary supplies and disposal (Yes, No) 	High	
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			<ul style="list-style-type: none"> • Presence of proper sign (Yes, No) • Owner (Municipality, Private) • Operator entity name • Caretaker name • Caretake contact number 		
7	Emptying Service providers	Point	<ul style="list-style-type: none"> • Service provider Code (Unique Code) • Company name of the service provider • Ward number • Place • Email of the service provider • Contact person name • Contact person gender (Male, female, others) • Contact person contact number 	High	

8	Emptying service providers employees' inventory	Non- spatial	Service provider Code <ul style="list-style-type: none"> Employee Name Employee gender (Male, Female, Other) Employee contact number Employee type (Driver, helper, supervisor, management , others) Year of experience in years Monthly wage Employment start date Training obtained (Yes, No) 	High	
9	Emptying service providers vehicles inventory	Non- spatial	Service provider Code <ul style="list-style-type: none"> Vehicle plate number Size of desludging vehicle in liters Width of desludging vehicle in meter 	High	

10	Treatment plants	Point	<ul style="list-style-type: none"> • Treatment Plant Code (Unique) • Treatment plant location 	High	
			<ul style="list-style-type: none"> • Ward number • Treatment capacity/day in m3 • Caretaker name • Caretaker gender (Male, female, others) • Caretaker number 		

11	Road Network	Line	<ul style="list-style-type: none"> • Road Code (Unique code) • Road Name • Road Hierarchy (Highway, district road, Feeder Road, urban roads, trial) • Road Surface Type (Metaled, Earthen, gravel, stone/brick) • Road length in Meter • Road carriage width in Meter • Right of Way 	High	
12	Water supply Network	Line	<ul style="list-style-type: none"> • Water supply Code (Unique) • Water supply pipe diameter in mm • Water supply pipe length in Meter • Corresponding Road Code 	Medium	Through secondary sources on

13	Sewer network	Line	<ul style="list-style-type: none"> • Sewer Code (Unique) • Sewer pipe diameter in mm • Sewer length in Meter • Corresponding Road Code 	Medium	Through secondary sources on
14	Drain network	Line	<ul style="list-style-type: none"> • Drain Code (Unique) • Drain diameter in mm • Drain Cover Type (Open, closed) • Drain Surface Type (Lined, Unlined, Unknown) • Drain length in Meter • Corresponding Road Code 	Medium	Through secondary sources on
15	Water body	Polygon	<ul style="list-style-type: none"> • Water body Code (Unique) • Water body Type (River, Pond, canal, lake) • Area in sq. m 	High	

16	Environmental sensitive areas (ESAs)	Polygon	<ul style="list-style-type: none"> • ESA Code (Unique) • ESA type (Landslide/Erosion, flooding, agriculture etc.) 	Low	Through secondary sources on
17	Contour	Line	<ul style="list-style-type: none"> • Elevation in Meter 	High	
18	Land cover/Land use map	Polygon	<ul style="list-style-type: none"> • Land use class (Built up, commercial, open space, forest, water body,) 	Medium	
19	Low Income Areas	Polygon	<ul style="list-style-type: none"> • LIC Code (Unique) • Economic situation (Extremely, poor, very poor, moderately poor, poor) 	High	
20	Water table	Polygon		Low	Through secondary sources on
21	Soil	Polygon		Low	Through secondary sources on

22	Point of Interest (POIs)	Point	<ul style="list-style-type: none"> POIs Code (Unique) POIs Type (Educational, health, business, place, ward offices, post offices, petrol stations) 	High	
23	Water borne diseases hotspot	Polygon		Medium	Through secondary sources on
24	Water logging areas	Polygon		Medium	Through secondary sources on
25	Landfill site	Point	<ul style="list-style-type: none"> Coverage area in Sq. Meter 		

Appendix B. CHECKLIST FOR CENSUS SURVEY OF BUILDING & CONTAINMENT ASSESSMENT FOR IMIS

Date: __/__/____

Surveyor Name:

Respondent Name:

Respondent Gender (Male/Female/Others): Respondent Contact Number:

Owner Information

1. Owner Name:

2. Owner Gender:

- i. Male
- ii. Female
- iii. Others

3. Owner Contact Number:

Building Information

4. Main Building:

- i. Yes
- ii. No

5. (If Q. 4 is “No”) BIN of Main Building:
6. Ward Number:
7. Road Code (RXXXX):
8. Road Name:
9. Tax Code/ Holding ID (XX-XXX-XXXX-XX):
10. House Address:
11. Structure Type:
 - i. RCC
 - ii. Load bearing with cement mortar
 - iii. Load bearing with mud/lime mortar
 - iv. Wooden/Mud/CGI /Temporary
 - v. Steel structure
 - vi. Other (Specify):
12. Year of Construction (YYYY AD):
13. Number of Floor (including ground floor):
14. Functional Use of Building:
 - i. Residential
 - ii. Commercial
 - iii. Mixed (Residential and Commercial)
 - iv. Offices
 - v. Educational
 - vi. Hospital/clinic
 - vii. Industrial
 - viii. Assembly
 - ix. Other (Specify):
15. Subcategory according to Functional Use:

16. Office or Business Name (List out names):

17. Number of Households:

18. Population of Building:

- i. Male:
- ii. Female:
- iii. Others:

If differently abled:

- iv. Male:
- v. Female:
- vi. Others:

Low Income Community Information

19. Is Low-Income Household:

- i. Yes
- ii. No

20. Located in Low Income Community:

- iii. Yes
- iv. No

21. (If Q. 20 is "Yes") Low Income Community Name:

Water Source Information

22. Main Drinking Water Source:

- i. Jar Water
- ii. Rainwater
- iii. Spring/River/Canal
- iv. Private Tanker water
- v. Tube well
- vi. Dug well
- vii. Deep boring
- viii. Pond
- ix. Municipal/Public water supply
- x. Others

23. (If Q. 22 "Municipal/Public water supply") Water Supply Customer ID:
24. (If Q. 22 "Municipal/Public water supply") Water Supply Pipeline Code:

25. Well in Premises:

- i. Yes
- ii. No

26. (If Q. Error! Reference source not found., "Yes") Distance of Well from Closest Containment (m):

Solid Waste Management Information

27. Do you have a solid waste collection service:

- iii. Yes
- iv. No

28. (If Q. 27 "Yes") Solid Waste Service Provider:

29. (If Q. 27 "Yes") Solid Waste Management Customer ID (if any):

Toilet & Containment Information

30. Presence of Toilet:

- i. Yes
- ii. No

31. (If Q. 30 "No") Defecation Place:

- i. Community Toilet
- ii. Open Defecation
- iii. Shared Toilet
- iv. Others (Specify):

32. (If Q. 31 "Community Toilet") Community Toilet Name:

33. (If Q. 30 "Yes") Number of Toilets:

34. (If Q. 30 "Yes") Households with Shared Toilet:

35. (If Q. 30 “Yes”) Population that uses Shared Toilet:

36. (If Q. 30 “Yes”) Toilet Connection:

- i. Sewer Network
- ii. Drain Network
- iii. Septic Tank
- iv. Pit/ Holding Tank
- v. Onsite Treatment (e.g., Anaerobic Digester/ Biogas, DEWATS)
- vi. Composting Toilet (e.g., Ecosan, UDDT, etc.)
- vii. Water Body
- viii. Open Ground
- ix. Community Toilet
- x. Open Defecation
- xi. Shared Containment

37. (If Q. 36 “Septic Tank”) Containment Type:

- i. Septic Tank connected to Sewer Network
- ii. Septic Tank connected to Drain Network
- iii. Septic Tank connected to Soak Pit
- iv. Septic Tank connected to Water body
- v. Septic Tank connected to Open Ground
- vi. Septic Tank without Outlet Connection
- vii. Septic Tank with Unknown Outlet Connection

38. (If Q. 36 “Pit / Holding Tank”) Containment Type:

- i. Double Pit
- ii. Permeable/ Unlined Pit/Holding Tank
- iii. Lined Pit connected to a Soak Pit
- iv. Lined Pit connected to Water Body
- v. Lined Pit connected to Open Ground
- vi. Lined Pit connected to Sewer Network
- vii. Lined Pit connected to Drain Network
- viii. Lined Pit without Outlet
- ix. Lined Pit with Unknown Outlet Connection

39. (If Q. 36 “Septic Tank” or “Pit/Holding Tank”) Containment Volume (m3):

40. (If Q. 36 “Septic Tank”) Does septic tank have at least 2 chambers, outlet at top, sealed/lined base, and walls:

- i. Yes

- ii. No
- iii. Don't know

41. (If Q. 36 "Septic Tank" or "Pit/Holding Tank") Containment Construction Date (YYYY AD):

42. (If Q. 36 "Septic Tank" or "Pit/Holding Tank") Containment Location?

- i. Inside the building footprint
- ii. Outside the building footprint

43. (If Q. 36 "Septic Tank" or "Pit/Holding Tank") Containment Accessible to Desludging Vehicle?

- i. Yes
- ii. No

44. (If Q. 36 = "Septic Tank" or "Pit/Holding Tank") Have you ever emptied your "Septic Tank" or "Pit/Holding Tank":

- i. Yes
- ii. No

45. (If Q43 is "Yes") Last emptied date (year):

46. (If Q. 36 "Sewer Network" or Q. 37 "Septic Tank connected to Sewer Network" or Q. 38 "Lined Pit connected to Sewer Network") Sewer Code:

47. (If Q. 36 "Drain Network" or Q. 37 "Septic Tank connected to Drain Network" or Q. 38 "Lined Pit connected to Drain Network") Drain Code:

48. (If Q36 "Shared Containment") BIN of Pre-Connected Building: