Development of Underground Utilities Information System (UUIS) in Hong Kong Special Administrative Region

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Key words: Underground Utilities Information System, Spatial planning, Engineering survey, Land management

SUMMARY

Hong Kong has a population of 7.5 million living in land area of 1114 square kilometres. Apart from carrying vehicular and pedestrian traffic, most of the 2238 kilometres of public roads in Hong Kong also provide underground space for accommodating utility services. Currently there are about 20 major utility undertakings who frequently carry out road opening works to install and repair their services such as fresh and flush water, electricity, gas, stormwater drains, sewers and telecommunication beneath public roads. Every year the vast majority of seemingly routine street excavations occurring around the territory are adversely impacted by the lack of usable information about buried utility infrastructure. A project can be delayed for days and weeks because extra time is needed to figure out where utilities are buried so the works can be planned and performed without undue risk. A large-scale construction project can be stalled for months, incurring delay claims and variation orders that significantly increase costs, because the locations of utility installations are not properly recorded or depicted and are later found obstructing planned foundation and construction works. What these kinds of risks and delay in works projects have in common is that they all can be prevented if accurate, comprehensive underground utilities (UU) information are available for rapid integration and analysis in the planning and design stage.

In 2021, relevant departments in HKSAR Government discussed the development of the digital UU information system for the whole territory. Lands Department (LandsD) later took up the task to establish a database of underground utilities with a mechanism for regular updating of the database and an IT system (i.e. Underground Utilities Information System (UUIS)) for the interoperability, integration and sharing of the standardised utility data.

Based on a prototype developed by Highways Department (HyD), LandsD liaised with major utility undertakings to develop a common data standard for UU Information and developed an initial set of digital UU information database for the whole territory in GIS format. In Phase one of the Project, massive utility data for the whole territory was collected from utility undertakings. UU data digitalisation; extraction of UU attributes and conversion of data forming a sharable database were carried out. The initial 3D Digital UU Information Database was established progressively in April 2023.

Phase two of the Project is to establish the IT system for the interoperability, integration, management and sharing of the standardised utility data. It supports UU data sharing in a 2D/3D geospatial platform to authorised parties and updating of UU data from utility undertakings.

The availability of digital UU data will facilitate the development of smart cities, realising the visions of the Smart City Blueprint for HKSAR[1] and bringing benefits to society as a whole.

[1] The Government published the Smart City Blueprint for Hong Kong in December 2017, setting out 76 initiatives under six smart areas, namely "Smart Mobility", "Smart Living", "Smart Environment", "Smart People", "Smart Government" and "Smart Economy".

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1. INTRODUCTION

The Underground Utilities Information System (UUIS) is a common online platform for Government and participating private utility stakeholders to contribute and share UU data. It not only provides comprehensive information for utility stakeholders, but also provide UU data in both 2D and 3D visualisation in one platform without the hassle to deal with various data format and software.

The key objective of UUIS is to consolidate and share UU data for better management and control of underground utility installation and better planning of the underground works. Moreover, the UUIS application offers handy functions that would help Engineers, Planners, Surveyors and Construction Workers in the planning and design stages. These functions included 3D Clash Analysis, Underground Space Occupancies Analysis, Vertical/ Horizontal Sectional Views, concurrent Top-view & 3D Visualisation, Map Print for Selected Layers etc.

This paper presents the initial database completed in the Project, including the preparation of the data specifications, technical specifications, assumptions and rules, maintenance guidelines and determination of the project implementation approaches. This paper also discusses design of the official platform to keep and disseminate data including the difficulties and challenges faced in the Project.

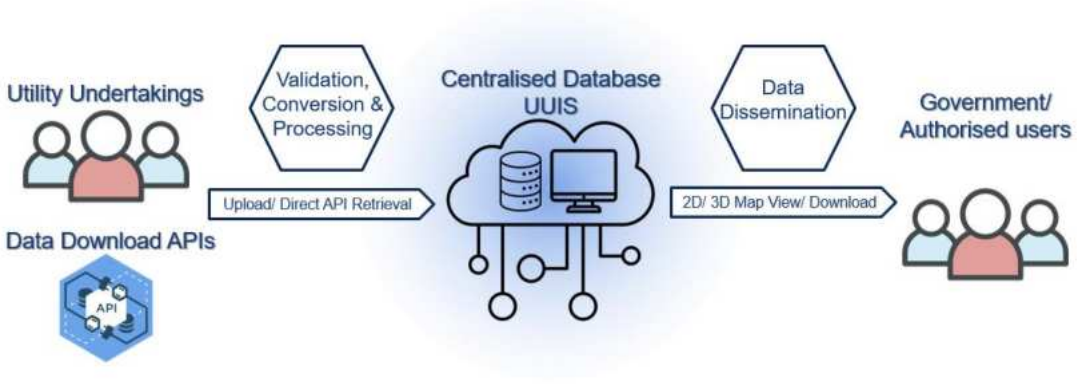


Figure 1 Overview of UUIS

2. PROJECT IMPLEMENTATION

For proper governance of the Project, a Task Force was set up in 2021 for the implementation of UUIS. The Task Force comprised members from various Works Departments of the HKSAR Government. LandsD subsequently commenced feasibility and technical studies on the development of UUIS.

The Project is implemented in two phases. Phase one is to develop geo-enabled utility data sharing models. It is necessary to standardise the sharing requirements and harmonise the utility data to facilitate sharing amongst various utility undertakings and prepare an initial database for sharing. The establishment of initial database will be completed in two stages with Stage 1 covering Government Departments and Stage 2 covering non-government utility undertakings excluding telecommunication companies.

2.1 Phase 1 - Develop geo-enabled utility data sharing models

To develop a common data standard for UU Information and develop an initial UU database for the whole territory in GIS format, LandsD liaised with major utility undertakings to solicit and identify right data to form the database; to design the common data sharing standard of utility data; to revamp the data from utility undertakings to comply with the common utility data sharing standard; to set up the on-going data maintenance framework and workflow; and to set up an initial utility database for sharing.

During the period from October to December 2021, there were two interviews with individual utility undertakings, a pre-workshop and a full-day engagement workshop arranged for them. Questionnaires were also sent to them to gather information of UU and related management practices across various sectors in Hong Kong.

The first interview focuses on the exploration of UU database and their data standards to be shared. The target interviewees are the data owners who are familiar with the existing UU data within the organisation and relevant UU standards/ guidelines;

The second interview focuses on the exploration of IT system(s) related to the management of UU data. The target interviewees are the IT system managers and database operators who are familiar with the current IT system for storing, manipulating, maintaining the UU data/ network and related infrastructure.

The pre-workshop focuses on the detailed design of UU data updating lifecycle and preparations for the later full-day workshop. The target interviewees are the works project engineers and IT system manager who are familiar with the current/ existing UU data workflow/ management practice and asset management/ facility management system including UU records and the workflow.

The full-day workshop focuses on the streamline of the data collection, standardisation and storage of UU data/ information, as well as finding the pain points and seek for potential solutions. The target participants are representatives having experience in the whole project lifecycle including design, construction, as-built, operation.

The engagements to UU stakeholders have provided highly relevant and invaluable local experience not only for the establishment of data sharing standard and on-going updating mechanism but also recommendations on the development and implementation of UUIS. Three major area of concerns and suggestions raised by the participants were: Data standardisation - quality and security; UU stakeholders' terms of reference - role and responsibility; Policy support - provision of relevant guidelines and specifications. These three area of concerns formed the basis of studies on the development of UUIS.

The 18 districts of Hong Kong were separated into six groups as shown in the below map, with three districts in a group for data collection, conversion into the common data sharing standard. (Details of the data specifications will be discussed in Section 3) The initial UUIS database was completed progressively in April 2023.

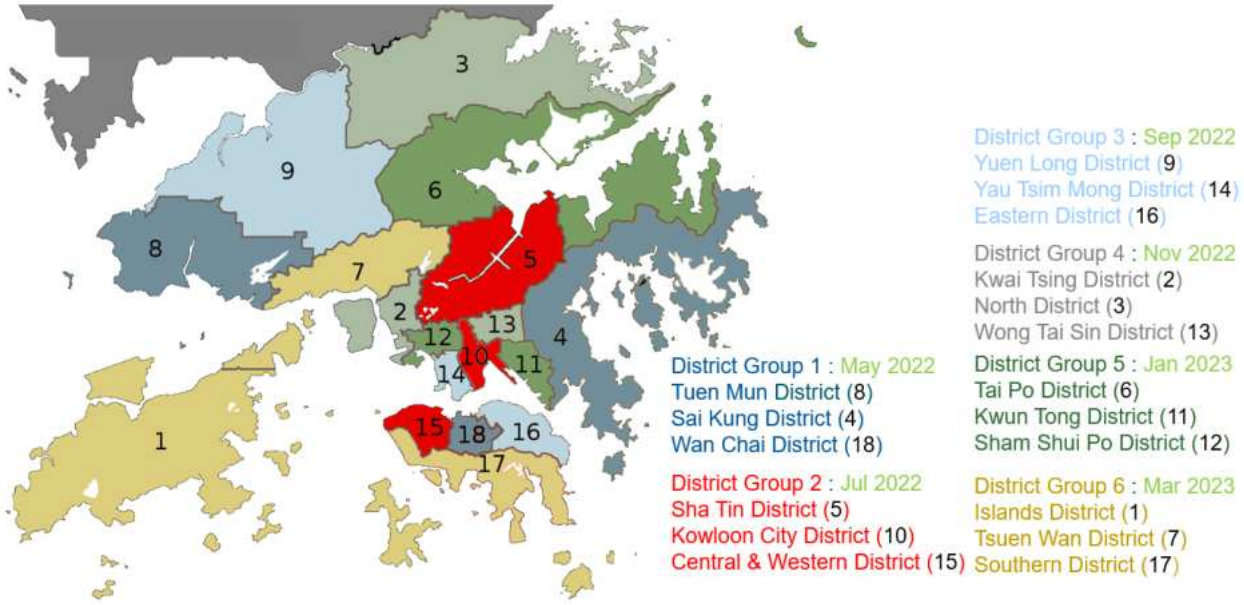


Figure 2 Schedule of Implementation of Initial UUIS Database (18 Districts)

2.2 Phase 2 – Develop the IT system

Phase two of the Project was to develop the UUIS for the interoperability, integration, management and sharing of the standardised utility data. The major functional requirements of the proposed IT system were examined by relevant participating stakeholders via the development of the Prototype in HyD's project and further enhancements were made by LandsD during the feasibility and technical studies. The Prototype has laid a foundation on the collection of high level user requirements on management of utility data.

LandsD has taken over the prototype developed by HyD since 2021 and further examine the technical details for detailed design and implementation of the UUIS. The further development of the Prototype proved the concept of capturing digital underground utility information to store 3D spatial data in GIS database. The underground utility database, coupling with establishment of a mechanism for regular updating of new utility information is progressively developed covering the whole territory. The data kept in the Prototype is collected from various

Government departments and utility companies. The data can be retrieved, viewed and updated on the Prototype.

At the current stage of the Project, the official UUIS is under development and proposed to be launched in 2024. Owing to the security concern raised by UU stakeholders during the engagements, the UUIS will be hosted in Government Cloud Infrastructure Services[2] (GCIS). To minimise the disruption of UUIS services, there are three environments: Production; Staging; and Development environment. These three environments are available for development and testing purpose and for continual development; on-going support and on-going maintenance of the UUIS operations.

3. PREPARATION OF DATA SPECIFICATIONS

The UUIS database includes features such as water mains, drainage pipes, box culverts, electric cables, cooling mains, gas pipes, and associated installations. Over 100+ datasets were collected from Government Departments and private utility undertakings to build the foundation of UUIS database. They include HyD, DSD, WSD, EMSD, LandsD, CLP, HK Electric, and Towngas. (Table 1 List of current Data Provider refers) To standardise and harmonise the data stored in the UUIS database, a Data Specification for UUIS was produced so that data can be shared, exchanged, combined, and understood by stakeholders and other data providers and users. The guidelines of CIC BIM Standards for Underground Utilities (Version 2.1 - 2021) and the report of 3D Spatial and BIM Data Use Case Requirements of the Hong Kong Construction Industry 2021 both published by the Construction Industry Council in Hong Kong were referenced when preparing the Data Specifications.

Data Providers
Highways Department (HyD) - Major works and Lighting
Drainage Services Department (DSD)
Water Supplies Department (WSD)

[2] The Office of the Government Chief Information Officer (OGCIO) has launched the Government Cloud Infrastructure Services (GCIS) for government department to adopt. It is the new generation government cloud services that provide secure, reliable and scalable IT infrastructure for government department to adopt digital solutions.

Electrical and Mechanical Services Department (EMSD)
Lands Department (LandsD)
CLP Power Hong Kong Limited (CLP)
The Hong Kong Electric Co., Ltd. (HK Electric)
The Hong Kong and China Gas Company Limited (Towngas)

Table 2 List of current Data Provider

Geographic Information System (GIS) was adopted in producing the foundation of Data Specifications for UUIS and relating different UU information in spatial content with location reference on the map. Moreover, the said Data Specifications has included the source data information and harmonised data information for easy sharing across utility stakeholders in Hong Kong. The database entities used in the UUIS database consist of System Defined Field, Data Owner Defined Field and Calculation Field.

- *System Defined Fields* are created in the UUIS database. The field names start with "UUMS_" to prevent any duplicated names among all data providers. Same field names are used to standardise the data and provide easy recognition for all parties. For example, data providers use different field name SHAPE, Shape, GEOMETRY to represent the same nature of data. To standardise the data, SHAPE is created for the purpose. When data source of a feature is not originally created in database format, the field names of "UUMS_" will also be created for storing the attributes of that feature.

- *Data Owner Defined Fields* are adopted from various data providers. Different field names with similar nature of data are expected to be found among all data providers in this category. However, the field name, data type and value should remain unchanged in order to communicate among stakeholders and achieve data synchronisation with them in the future.

- *Calculation Fields* are created in the UUIS database to estimate Z-value and dimension of features if applicable. If the source data do not have any reference of depth and dimensions of object or their de-facto value that does not meet the required standard, different estimation methods and rules are made depending on the source from data providers and are subject to change when more accurate information is available in the

future. The Calculation fields should be removed after the calculation process. More details about the estimation methods and rules are described in Section 4.

Field Name	Description
UUMS_UUFID	Underground Utilities Facility identifier
UUMS_DP	Data Provider
UUMS_STAT	Status
UUMS_Z	Z coordinate
UUMS_US_Z	Upstream Z coordinate
UUMS_DS_Z	Downstream Z coordinate
UUMS_RL	Reference Level
UUMS_QLS	Qualification Level Standard
UUMS_SHAPE	Shape or appearance

Table 3 Sample of System Defined Fields

Field Name	Description
CELL_NUM	No. of Cells in Box Culvert/Tunnel Path
WIDTH	Width (mm)
HEIGHT	Height (mm)
FEAT_NUM	Feature number
SHAPE_DESCRIPTION	Shape or appearance
TYPE	Type of feature
GEOMETRY_Length	Length Calculation of Geometry (metre, m)

Table 4 Sample of Data Owner Defined Fields

Field Name	Description
CA_Z	Z coordinate.
CA_WIDTH	Width (metre, m)
CA_LENGTH	Length (metre, m)
CA_HEIGHT	Height (metre, m)
CA_DEPTH	Depth (metre, m)

Field Name	Description
CA_US_IL	Upstream Invert Level of the feature (metre above Hong Kong Principal Datum, mPD)
CA_DS_IL	Downstream Invert Level of the feature (metre above Hong Kong Principal Datum, mPD)
CA_CL	Cover Level. Cover level of the feature (metre above Hong Kong Principal Datum, mPD)
CA_CROWN	Crown Level. Crown level of the feature (metre above Hong Kong Principal Datum, mPD)
CA_GL	Ground Level (metre above Hong Kong Principal Datum, mPD)
CA_DIA	Diameter (millimetre, mm)

Table 5 Sample of Calculation Fields

4. ASSUMPTIONS AND RULES FOR DATA CONVERSION

Since the current records as maintained by most of the utility undertakings are kept in 2D or 2.5D (i.e. featuring depth as an attribute to a horizontal position rather than as Z coordinate) format, with various levels of details and sometimes without field verifications for a considerable period of time, LandsD took the lead to establish the initial 3D digital UUIS dataset by converting the existing records / plans provided by the utility undertakings, including Government Departments, with appropriate assumptions such as depths and standard size of different types or classes of utilities. Therefore, conversion of data from 2D to 3D is one of the crucial steps in forming the 3D UUIS database.

Presenting underground utilities data in 3D offers several benefits over traditional 2D representations including but not limited to the followings:

- *Enhanced Visualisation and spatial context*: 3D representations provide a more realistic and intuitive visualisation of underground utilities. It allows UU stakeholders to better understand the spatial relationships, depths, and orientations of different underground features and structures. This can help in identifying potential conflicts, interferences, and effective planning of new routings.

- *Improved Planning and Design*: 3D representations enable better planning and design of infrastructure projects. Engineers and contractors can analyse the 3D models to identify clashes or overlaps between utility lines and proposed designs before construction begins. This helps in detecting potential conflicts earlier, reducing the risk of costly rework and delays during excavation and construction.

- *Avoidance of Damage*: Accidentally damaging underground utilities can have severe consequences, including service disruptions, injuries, or even fatalities. 3D representations assist in accurately visualising the location, depth, and alignment of utilities, enabling workers to exercise caution and take necessary precautions to prevent damage during excavation or construction.

- *Emergency Response*: In the event of emergencies, such as gas leaks or water main breaks, 3D representations of underground utilities can aid emergency responders in understanding the infrastructure layout. This knowledge helps them identify the exact location of utility lines and make more informed decisions, such as shutting off utilities, evacuating affected areas, or coordinating repairs.

The level values on most of the features were created by the assumptions with reference to the 2020 LiDAR Data - Digital Terrain Model (DTM) of Hong Kong[3]. The main objective of the assumptions was to estimate the dimension and z-level value of a feature. There are two main types of assumptions: General Rules and Specified Rules from data provider. The General Rules practically are referenced to the standard drawings provided by the data provider. The standard drawings often available on their official website under the technical reference. It also includes the standard dimensions and common depth value that would allow the data conversion to handle it in a more straight-forward way. Secondly, the Specified Rules are referenced to the information and details given by the associate data provider. It usually happens when standard drawing was not available and there are supporting information available in the attribute of the data. It would require a more detailed and thorough conversion subject to the complexity of the information. Furthermore, the conversion also included dimension and status information to

[3] Data Acquisition of the 2020 LiDAR data was commissioned by the Geotechnical Engineering Office of the Civil Engineering and Development Department covering all territories of Hong Kong. Digital Terrain Model from 2020 LiDAR Survey can be downloaded through Common Spatial Data Infrastructure (CSDI) Portal.

enhance the information accessibility.

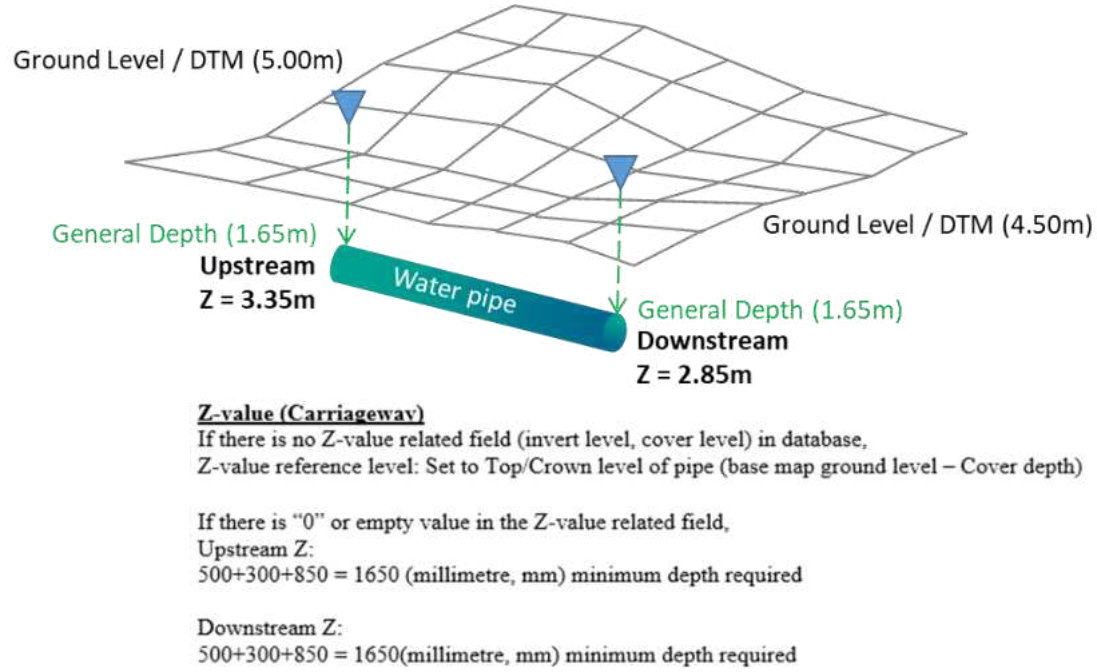


Figure 3 z-level value conversion by General Rule

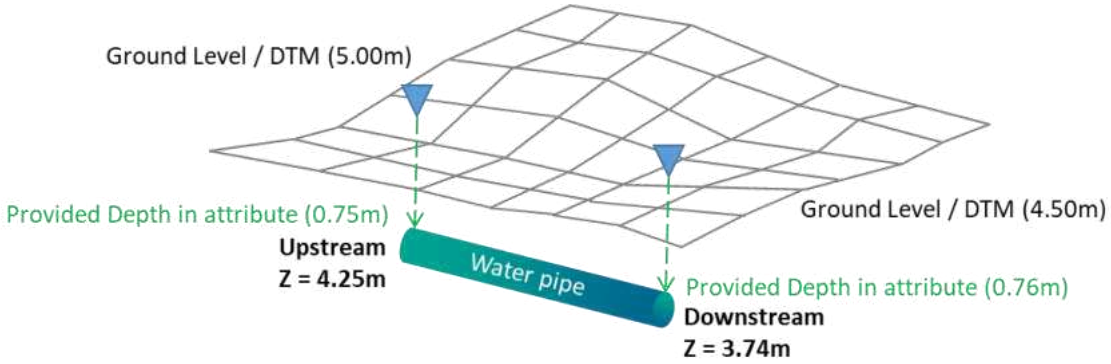


Figure 4 z-level value conversion by Specified Rule

To enable automatic data conversion processes in the subsequent stages of data updating in UUIS. Conversion Engine(s) was developed by LandsD to support 2D to 3D data conversion operations in accordance with the Assumptions and Rules established with the data providers. The proposed policy and requirements of UU data updating by as-built survey ensure the accuracy and integrity of the UUIS database. It is believed that the assumed values exist in the database will be replaced with accurate surveyed data progressively, providing more reliable

and comprehensive UU data in Hong Kong.

5. PREPARATION OF TECHNICAL SPECIFICATIONS

To set out the policy and requirements of the adoption of 3D UU database initiative, a Technical Circular[4] (Works) (TC) is drafted to require new government-funded works projects to provide accurate as-built survey data of UU constructed under the projects for incorporation into the UUIS database. The TC is targeted to be endorsed in 2024. LandsD has taken the leading role to create a Technical Specification for underground utilities surveying works for attachment with the TC. The Technical Specification presents the general workflow and procedure when performing underground utilities survey. The requirements of surveyed data quality and assurance, data processing, data presentation and data integration are discussed. These newly surveyed data plays an important part for the enhancement of data quality and these verified UU data are the key factors that would reduce road opening, to make safe excavations, and to provide better maintenance of utilities for UU stakeholders in the long run.

Considering the nature of the UU survey and the required accuracy of the surveyed utilities, four data acquisition methods corresponding to different quality levels as stipulated in PAS 128 (BSI, 2022), are identified in the current edition of the Technical Specification. It will be further updated and improved to align with the latest technology and best practice with reference to other international standards and local guidelines

[4] Technical Circulars (Works) set out procedures by which policy decisions are to be put into practice by Works Departments. As a general principle, where a Technical Circular (Works) sets out procedures for compliance, this is intended to be an instruction for Works Departments.

Figure 5 Four Data Acquisition Methods as stated in the Technical Specification

- *Laser/LiDAR Scanning Survey*, considered as Survey Type A in PAS 128 (BSI, 2022). The quality level achieved should be categorised as QL-A. The capturing of underground utilities when they are exposed on ground during excavation works provides the most accurate data to the database. However, the time frame allowing data capture by the contractor is usually limited due to optimisation of the excavation process and safety precaution considerations. The advancement and fast data capture technologies of laser scanning survey allow collection of comprehensive and accurate data in a short amount of time. The dense point clouds captured can also be used to trace back the raw scan data for verification and production of high realistic 3D models of the pipes and cables. Nonetheless, in view of obstructions of utilities occur, additional set-ups will be performed to ensure the quality and completeness of the surveyed data.

- *Photogrammetry by Unmanned Aerial Vehicle (UAV) and Close Range Photogrammetric Survey*, are also considered as Survey Type A in PAS 128 (BSI, 2022). The quality level achieved should be categorised as QL-A. Depending on the scale of the site, both methods capture survey grade data such as photographs and videos, through a photogrammetry software to create geo-referenced orthomosaics, point cloud models, elevation models or 3D mesh models of the site. These models can also be used to extract information such as locations and highly-accurate distances measurements. Low-cost portable devices with advanced development of the mobile phone camera,

sensors, and scanning application do provide affordable and wide-reaching solution for the industry to adopt to the 3D digital working environment.

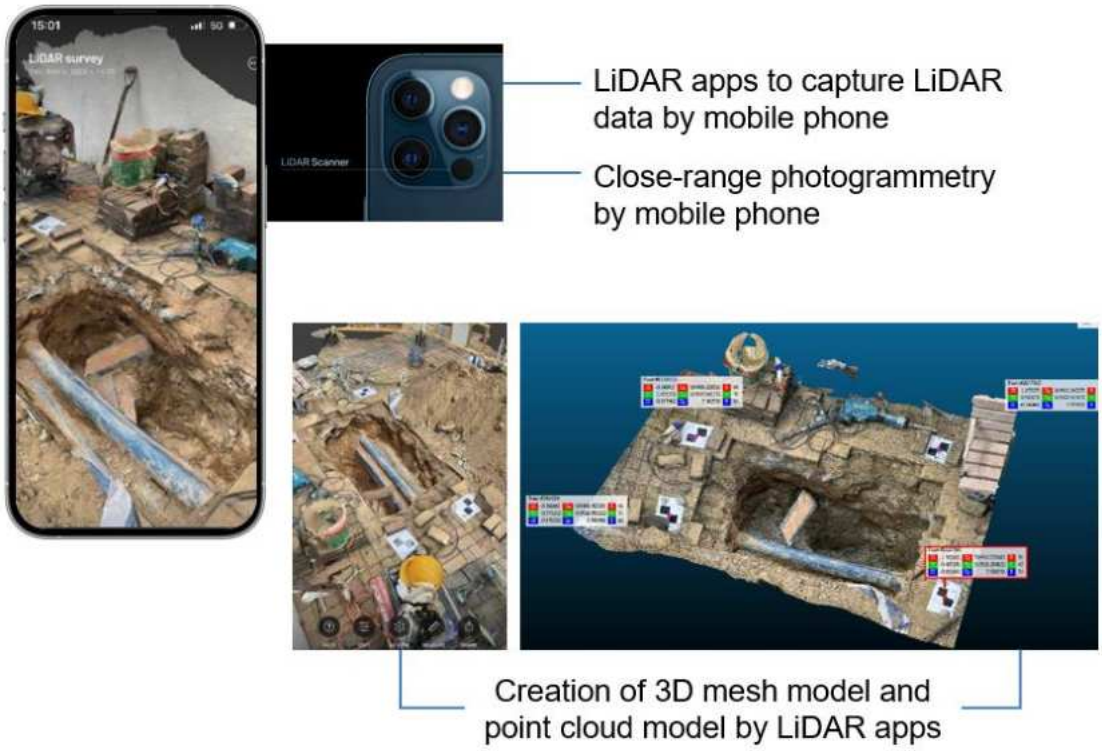


Figure 6 Illustration on Close Range Photogrammetric Survey and LiDAR Scanning Survey by iPhone

Non-destructive surveying method, Pipe Cable Locating (PCL)/ Electromagnetic Locating (EML) and Ground Penetrating Radar (GPR) Survey, considered as Survey Type B in PAS 128 (BSI, 2022). The quality level achieved should be categorised as QL-B.

- *PCL survey* is the most common way for locating buried utilities in Hong Kong when trial pit excavation is not possible. It has been used to locate metallic pipes and tracer wires laid for non-metallic utilities when there is a nearby access point, such as valve chamber or manhole. A comprehensive desktop search of available and 'best-known' utility maps will be carried out to provide the potential layout of utilities before the PCL survey.

- *GPR survey* usually provides additional and supplementary data to improve data quality

resulting from PCL survey without the need for trial holes. GPR is proving to be an increasingly useful geophysical technique, allowing detection of underground utilities including non-metallic utilities with a simple scan. With the advanced technology in survey techniques and instrumentation, car-towed Multi-Channel GPR survey enables complete site coverage for full-resolution imaging, and thus compared with traditional GPR survey (which are cart-based and use single/dual channel GPR). This road-lane-wide GPR survey greatly improves data collection, as it obviates the need for temporary traffic blockages and the corresponding arrangement works.

6. DATA UPDATING AND MAINTENANCE GUIDELINES

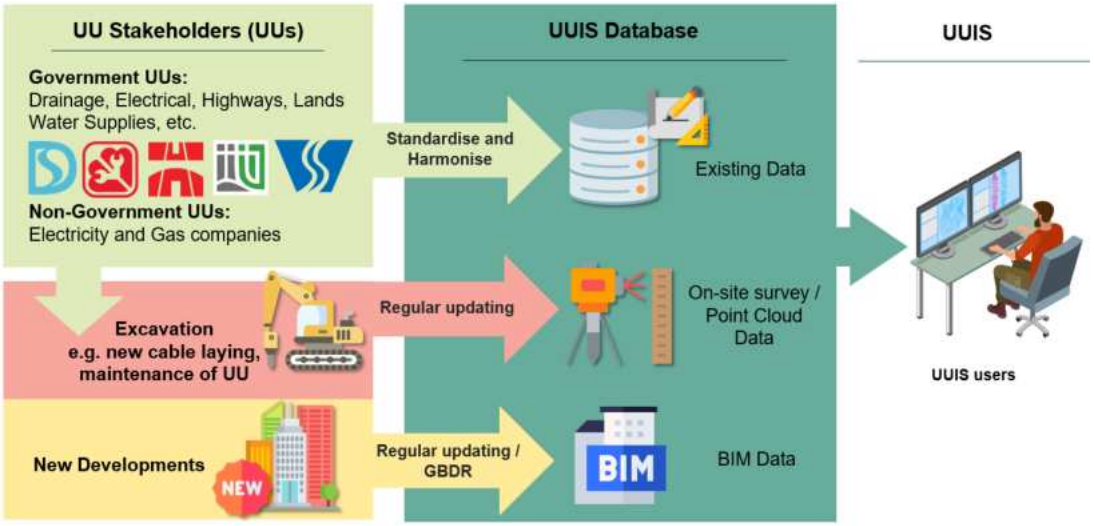


Figure 7 Mechanism of UUIS

The initial 3D UU dataset will be continuously updated regularly in accordance with the schedule agreed with data providers. It is planned that as-built UU data would be provided by site contractor of road excavation works, new pipe/cable laying works etc. in future with a view to gradually developing an updated and comprehensive 3D digital UU information database for Hong Kong. On the other hand, it will be further enriched by BIM data resulting from new development projects.

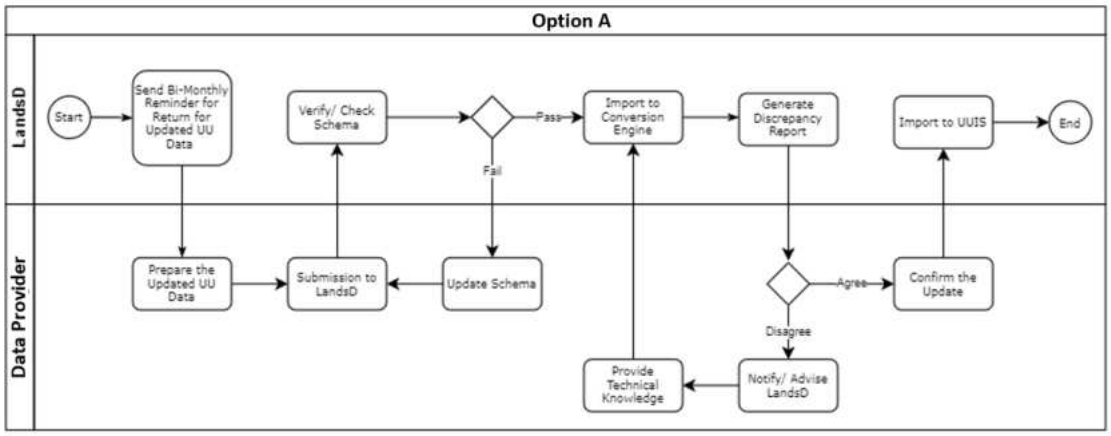
According to the Technical Circular (Works) No. 2/2021 issued by DEVB in December 2021, capital works projects with project estimates more than $30 million shall use BIM technology. It is expected the future UU data in these projects would be in BIM data format. With the support of DEVB, Lands Department established the Government BIM Data Repository

(GBDR), a data sharing platform for all BIM data collected from works departments. Interfacing between UUIS and GBDR will be established such that UU related BIM data for new development projects can be shared with UUIS users with appropriate accessing right.

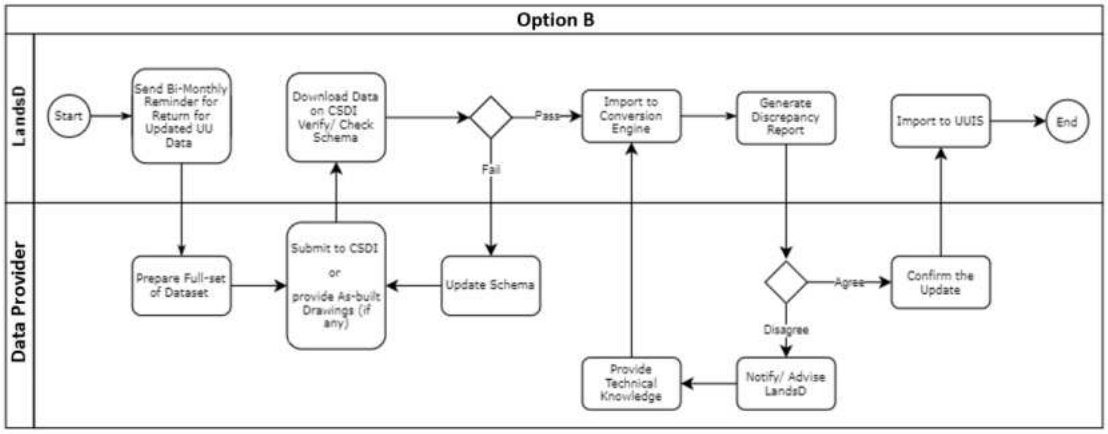
A guideline named the UU Data Updating Guideline to handle the future data updating in the UUIS database enables sharing, dissemination and maintenance of UU datasets and UU attributes across the UU stakeholders. These compromised data updating methods has experienced multiple trials since June 2023 to ensure the UUIS database can be sustained in the long run without disrupting daily operation from the UU Data Providers.

While GIS technology has already been prevalently used by most data providers as one of the information management tools in managing their assets, it is important to ensure the data between their internal management systems are synchronised with UUIS. In such situation, they will continuously provide datasets for updating in UUIS according to the Guideline until their internal management system could provide the 3D datasets in accordance with the data specification of UUIS.

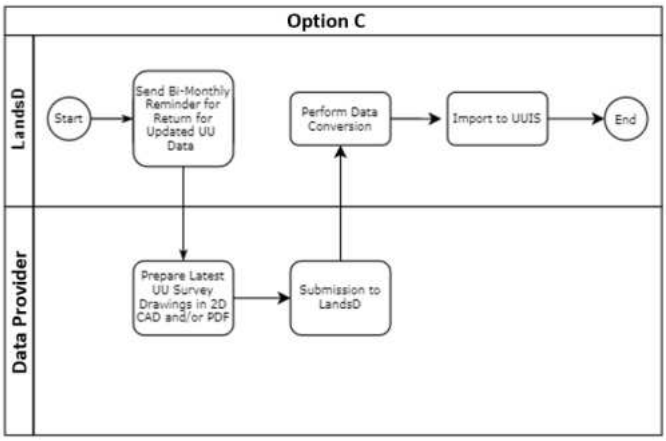
In general, there are three options of workflow adopted by different data providers to suit their corresponding data management system.



Option A – For data not available in CSDI



Option B – For data available in CSDI



Option C – For non GIS data

To enable automatic processing of the above processes in UUIS. Conversion Engine(s) was developed by LandsD to support detection of data change in the data from the data provider (Option A & B refers) and data conversion operations from UU data in FGDB/Shapefile/Oracle Spatial format to the required UUIS data formats.

The Guideline is to be reviewed regularly under the LandsD project team so as to upkeep with technological advancements and industry developments. It should however be understood that the Guideline is by no means a permanent arrangement. At an appropriate time when data providers can update and upload their 3D UU data directly into the UUIS database, the updating process can be conducted in a more direct and efficient way.

7. DATA QUALITY

Data from existing underground utility records cannot be very accurate unless they can be verified by on-site surveying when they are exposed by excavation. LandsD has taken the technical approach to review the most effective underground utility surveys techniques in Hong Kong resulting in the Technical Specification as described in Section 5.

The BSI PAS 128:2022 Underground Utility Detection, Verification and Location Specification has been referred as part of the quality standard for the database. The publication was sponsored by the Institute of Civil Engineers in the United Kingdom, and the standards provided a way to accurately map underground utility networks for Surveyors, Geophysicists and Engineers.

There are four appropriate survey types stated in the PAS 128:2022: Survey Type A – Verification; Survey Type B – Detection; Survey Type C – Site Reconnaissance and Survey Search and Type D – Desktop Utility Records.

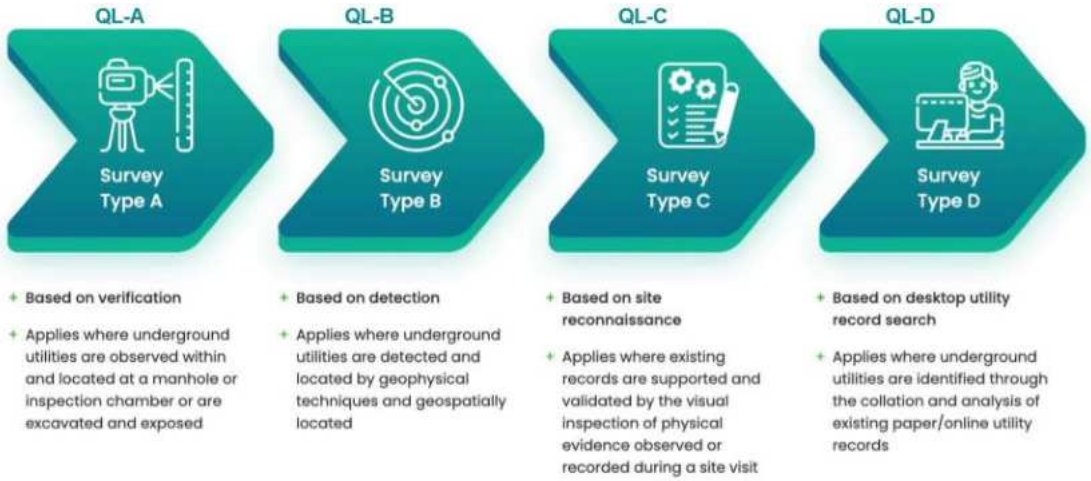


Figure 8 Illustration on survey types stated in the PAS 128:2022

Survey Type A is applied to where underground utilities are observed within and located at a manhole or inspection chamber or are excavated and exposed. The quality level achieved shall be recorded as QL-A as adopted in the Data Specification with location accuracy requirement is +/- 50mm for both vertical and horizontal location.

Survey Type B is applied to where underground utilities are detected and located by geophysical techniques and geospatially located. The quality level achieved shall be recorded as QL-B1, QL-B2, QL-B3 or QL-B4 depending on the achievable accuracy and the ability to detect the utility features. The accuracy requirements range from +/- 150-500mm for horizontal and +/- 15-40% of detected depth for vertical location.

Both *Survey Type C and D* do not require site survey to verify or detect the utilities. For the majority of UU data collected in the initial UUIS database are classified as QL-D where underground utilities are identified through the collation and analysis of existing utility records. It possesses the lowest level of data quality and can only be enhanced by Survey Types A to B in accordance with PAS 128.

The practice of conducting accurate as-built survey on new laying utilities and record survey on existing utilities are crucial to progressively developing a reliable and accurate UUIS database for Hong Kong. In the long run, it would be necessary for the existing 2D record systems adopted by most utility undertakings to be compatible with 3D digital data so as to meet the rising expectation and demand for more accurate underground utility records by the public.

UUIS serving as a common platform for sharing and viewing all the 3D UU records is capable of keeping the as-built record in a 3D standardised format contributing to different quality levels as reference to the PAS 128. Utility undertakings will be responsible for uploading, updating and maintaining their own utility records shared in such platform.

8. DESIGN OF OFFICIAL PLATFORM

This section aims to explain the design of the UUIS, including its basic functionalities, analytical features, access control, and security setting.

8.1 Basic Functionalities

8.1.1 Visualise and Search for UU data in 2D and 3D

UUIS provides the following basic visualisation and searching tools for UU data in both 2D Map and 3D Scene. These tools include but not limited to the following:

Function	Description
Show UU data in Web-based 2D Map and 3D Scene	In 2D Map view, the UU spatial features are displayed in form of 2D point, 2D polyline and 2D polygon. In 3D Scene view, the UU spatial features are displayed in 3D volumetric form with different sizes and dimensions. A switch button is provided for users to switch between the 2D Map and 3D Scene. The current location is maintained during switching between the 2D Map and 3D Scene.
Display 3D Scene side-by-side with additional Top view	In 3D Scene view, users can trigger additional top view to show side-by-side with the current scene.
Show Reference Dataset	The reference data display in UUIS including but not limited to: – Excavation Permit (XP) – Land Holdings Reference (such as Lot, Government Land Allocation and Buildings Ordinance – Schedule 5: Scheduled Areas, etc.)
Navigation Tool	Navigation toolbar is provided in both 2D Map and 3D Scene for users to navigate the current 2D Map or 3D Scene.
Measurement Tool	Measurement Tools are provided in both 2D Map and 3D Scene for users to measure point coordinates, line length and polygon area.
Legend and Layer Control	Legend of current displaying layers including UU spatial features and other

	reference datasets is provided in both 2D Map and 3D Scene.
Textual and Location Search Tool	Location search is provided for users to search the location by street name, address, building name and lamp-post/utility number. Textual search is provided for users to search UU data based on textual attributes.
Information Window	In the 2D Map and 3D Scene, users can identify the features by clicking them. A window showing the attribute information of the clicked feature is shown.
Bookmark	Bookmark widget is provided for users to save current layer on/off, transparency setting and viewpoint location as bookmark. Users can retrieve and load the saved bookmark when needed.

8.1.2 Enable UU data exchange and sharing capabilities

UUIS provides the following functions that enable UU data exchange and sharing capabilities in both 2D Map and 3D Scene. These functions include but not limited to the following:

Function	Description
Print 2D Map and Capture 3D Scene	Map printing tool is provided in 2D Map for users to print the current map. The users have to input the data provider, map scale, paper size and orientation. Scene capturing tool is provided in 3D Scene for users to capture specific area of the scene as snapshot and save as image.
Drawing Tools	Drawing tools are provided in both 2D Map and 3D Scene. Users can define the styles

	and draw point, polyline, polygon and text in the screen.
UU Data Export / Download	Export buttons are provided for users to export the 3D vector data of the searched or intersected UU features with the formats of GeoJSON, File Geodatabase or Shapefile. A separate download page is provided for users to download the 3D vector data of their approved accessible area with the formats of GeoJSON, File Geodatabase or Shapefile.
UU Data Upload	UUIS user interface and web API are provided for user with Data Provider role to upload raw UU data in agreed format and frequency for their organisation.

8.2 Analytical Feature

8.2.1 Clash Analysis Tool

Clash analysis is available in 3D Scene view for users to query UU features intersect with self-defined pipeline. Users can input the line depth and diameter of the drawn polyline (or by self-defined x, y coordinates) on map to define the proposed pipe. The intersecting features will be highlighted, and users can export the clash analysis result.

Figure 9 Illustration on Clash Analysis Tool

8.2.2 Underground Occupancy Analysis Tool

Underground occupancy analysis is available in 3D Scene view for users to check out the underground occupancy rate of specific scope box volume and depth. The users can input customised depth range, and draw a rectangle to form the scope box. The scope box will be shown and highlighted. The analysis will compute the occupancy rate (i.e. UU feature volume / Scope box volume) of each matched feature type.

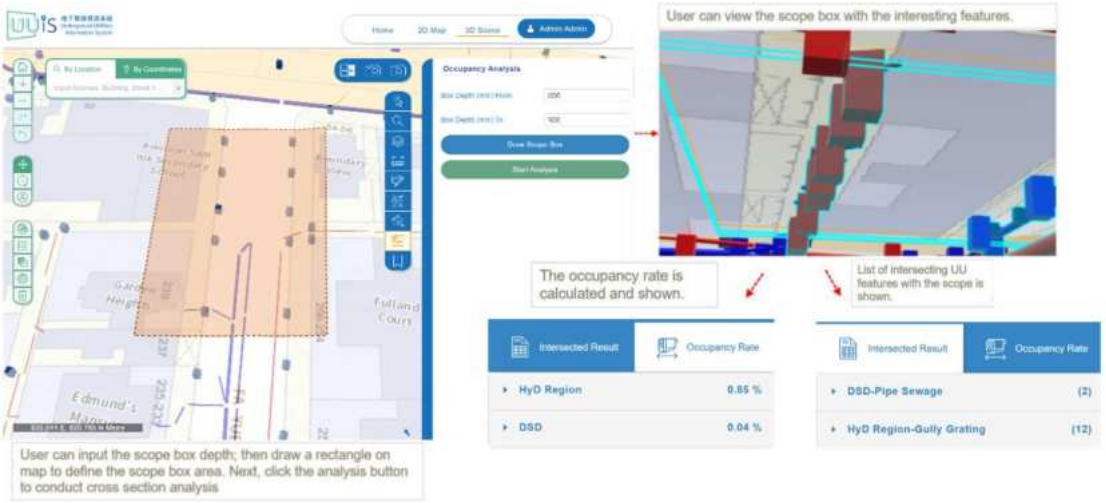


Figure 10 Illustration on Underground Occupancy Analysis Tool

8.2.3 Cross Section Tool

Cross section tool is provided in 3D Scene view for users to check out the vertical cross section of the UU features. The users can input the section depth and draw a line (or by self-defined x, y coordinates) to form a cross section plane. The cross section plane will be shown and highlighted. The tool can be used to cross check the UU feature identified in the B-scan by Ground Penetrating Radar (GPR) method.

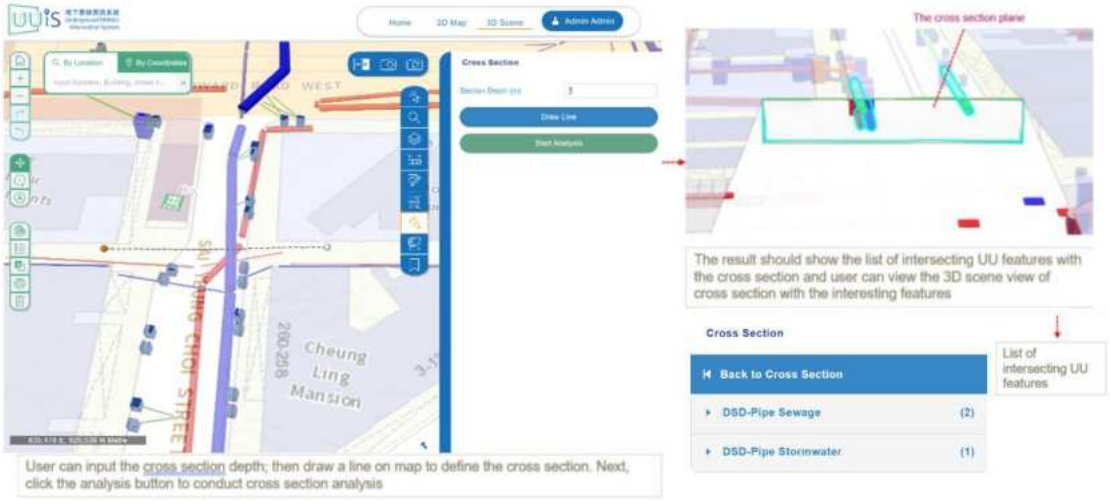


Figure 11 Illustration on Cross Section Tool

8.2.4 Slicing Tool

Slicing tool is available in 3D Scene view for users to reveal the occluded content of the 3D UU features. Users can draw a slice plane on the scene, adjust its tilt and heading angles and move the plane interactively among the 3D Scene to view the inside structure of the 3D UU features. The length, width and depth of the slice plane center point will be shown on the tool for users' reference.

Figure 12 Illustration on Slicing Tool

8.3 Access Control and Security Setting

8.3.1 Government Cloud

The system architecture was hosted in Government Cloud Infrastructure Services (GCIS) managed by the Office of the Government Chief Information Officer (OGCIO) of the HKSAR Government which support better security, scalability, and reliability.

8.3.2 Two-Factor Authentication (2FA)

The 2FA consists of user login and authentication application. User will receive the QR code together with the temporary password after UUIS account is created. Users can subsequently obtain the One-time password (OTP) from their authentication application. When login to UUIS, users have to input the username, password and OTP.

Using 2FA in UUIS login provides an additional layer of security beyond just a username and password combination. It helps to reduce the risk of unauthorised access, and enhance the overall security of user accounts and sensitive information.

8.3.3 Data and Function Access Control

UUIS restricts the amount of UU data which can be accessed and exported by users. The restriction will be based on spatial boundary (i.e. 1:1000 Map Sheet Grid) as defined by the system administrator when creating the user account.

Web function accessibilities were controlled according to the user roles. For Data Reviewers, they are able to access the visualisation platform functions. For Data Providers, they are able to access the UU data upload function. For System Administrators, they are able to access the system administration functions.

8.3.4 System Audit Logs

System audit logs of UUIS enable and review periodically to identify any signs of intrusion. System Administrator is allowed to retrieve audit trail on system and data access history.

The system activities to be logged	Information in each log record
− Login Success − Login Failure − Data Export − UU Data Upload via Web User Interface − UU Data Upload via Web API − Data Update	− Username − Name of the Organisation − Date and time of the activity − Activity Description

8.3.5 Data Governance Framework

Data Governance Framework (DG Framework) was established for UUIS. The DG Framework established the data governance strategy and policy for UUIS, and alleviated the data security and privacy concerns of the business stakeholders of UUIS.

DG Framework was established for UUIS to act as a guideline for all the users and stakeholders of the system. The DG Framework presented the findings of the current state of UUIS, identified the gaps between the current state and best practices and then proposed the framework that should be applied. It also provided guidelines, policies and references relating to the data governance framework. This policy covers UU data from all the government departments and utility companies of the UUIS platform covering the data security, data export and data upload functionalities of the UUIS platform. It provided policies to the government users, administration of UUIS, business users from utility companies, and contractors/consultants on different aspects of data governance.

8.3.6 IT Security Policy

IT security policy for UUIS was developed to support the security goals of confidentiality, integrity, and availability of UUIS and its data. It provides necessary security assurance to all stakeholders of UUIS.

The IT security policy applied for the development, operation and maintenance of the UUIS. Related stakeholders are required to understand the requirements stated in the IT Security Policy where applicable, including but not limit to:

- For the UUIS developer: Developer shall provide technical solution and implementation to comply with the requirements introduced in the set of policies.
- For the UUIS system operators or system maintenance team: Operators shall follow the defined procedures and processes to monitor, protect UUIS from vulnerabilities and external threats.
- For the UUIS users, including account administrators: Users shall be aware of users' responsibilities to protect UUIS from unauthorised access. Users shall follow the best practice introduced in the policies when utilise UUIS.

9. DIFFICULTIES AND CHALLENGES

9.1 Concern about data governance and system security

Utilities in Hong Kong are owned by government departments, public utility companies and private owners. Any person who wants to carry out utility works can obtain record of the vicinity from the utility owners about the existing underground utility system. Private utility companies operate in a competitive market. In their point of view, the idea of establishing a centralised database for sharing their data could provide insights to competitors about their operation and investment on infrastructure. The lack of incentives and regulations also create hurdles in the Project. Similarly, government departments and public utility companies also raise concerns on the potential public facilities' information misuse, jeopardising the security and safety of Hong Kong and sensitivity of data relating to the boundary-crossing areas.

It is agreed that the information to be handled in the UUIS is sensitive in nature, which required carefully handling. A consultant team with IT security expert was engaged by LandsD to conduct a thorough study on UU stakeholders' concerns resulting in the data governance framework and IT security policy of UUIS. The residing of UUIS on the Government Cloud

Infrastructure Services (GCIS) provides a secure, reliable and scalable environment for the delivery and development of the system. The access control and data sharing system set up in UUIS restricted the availability of UUIS and area of data access for registered UU professionals including appointed consultants / contractors and UU stakeholders only. Approaches were formulated with the intention of addressing the pain points and needs raised, allowing for safe and controlled data dissemination.

9.2 Data with different format and quality

Different format and level of details of data was kept by the UU stakeholders currently. To integrate the sharable data collected from them required significant resources and can pose technical challenges. The database of UUIS is defined in three database entities to ensure the data integrity from data providers. It facilitates data providers to share their different database format to UUIS depending on their own system requirement. Their entity name, data type and value should rely on the data source and should remain unchanged in order to communicate among all stakeholders or synchronise with other data providers consistently in the future. It also allows data providers to trace back data to their source and evaluate the corresponding data quality.

The current UU data kept by the stakeholders were mainly in 2D. To transform to a 3D Data system, it could be understood that the Z-value could only be assumed/interpreted in many cases. Also all data would still be subject to verification when opportunities for excavation could arise in the future. The refinement could continue for years but it is crucial to initiating it promptly. As there is no commitment or regulatory requirements currently for UU undertakings to submit as-built survey records and regular update of new utility information using a common data format and standard, the UUIS would highly improve the UU data management situation. The established Data Specification and Technical Specification for survey works standardise the approach and methodology for preparing and presenting 3D underground utility record accurately; it also provides a common platform for keeping the verified UU surveyed data while before that UU undertakings kept their UU surveyed data at own use. It highly enhances the efficiency of managing the data and the velocity of the data exchange.

9.3 Integration with other existing Systems

There exist several systems that are UU information or excavation related in Hong Kong. 1.

The *Electronic Mark Plant Circulation (EMPC)* System, was jointly developed by major utility undertakings and government departments to facilitate the speedy transfer of underground utility information among participating members for carrying out road excavation. Users of the system make requests and obtain plans of existing and/or proposed utility services from other members for planning of road excavation; 2. HyD's *Excavation Permit Management System (XPMS)*, a web based system for the government departments including HyD, Transport Department, Hong Kong Police Force and Leisure and Cultural Services Department etc. and UU stakeholders, to process various types of road excavation or works related permit application through e-platform; 3. *Common Spatial Data Infrastructure (CSDI)* Portal, an information infrastructure to share spatial data (including utility data) to public for supporting versatile smart city applications to help facilitate the dissemination, utilisation and innovative application of spatial data to expedite smart city development; and 4. *Government BIM Data Repository (GBDR)*, to collect, store and disseminate government owned BIM data (including UU BIM data) within the government departments.

To leverage technology and data to better serve the public, optimise resources and achieve the policy objectives effectively, the UUIS has established a certain level of integration with the mentioned systems at the current stage of the Project. One of the major difficulties present in the feasibility study of the Project is to manage different classification of data, access control settings of multiple systems, which is still a challenging task in order to achieve a harmonised integration between systems. Synchronisation of data across integrated systems requires appropriate adjustment in systems to ensure single source of truth. Application Programming Interfaces (API) could be a solution, however the quality of API support varies significantly among systems.

10. WAY FORWARD

The initiative of modelling the underground utilities in 3-dimensional digital format is aimed to assist UU stakeholders to better plan their new installations by avoiding the areas congested with underground utilities. The utilisation of underground space could then be optimised to support continuous growth of public services, and unnecessary excavation works and/or prolonged opening up of the footpath surface could be prevented due to insufficient underground space to accommodate the utilities. We are at the initial stage of achieving the goal while there are still significant amount of works, time and effort required to pursue it.

10.1 Completeness of database

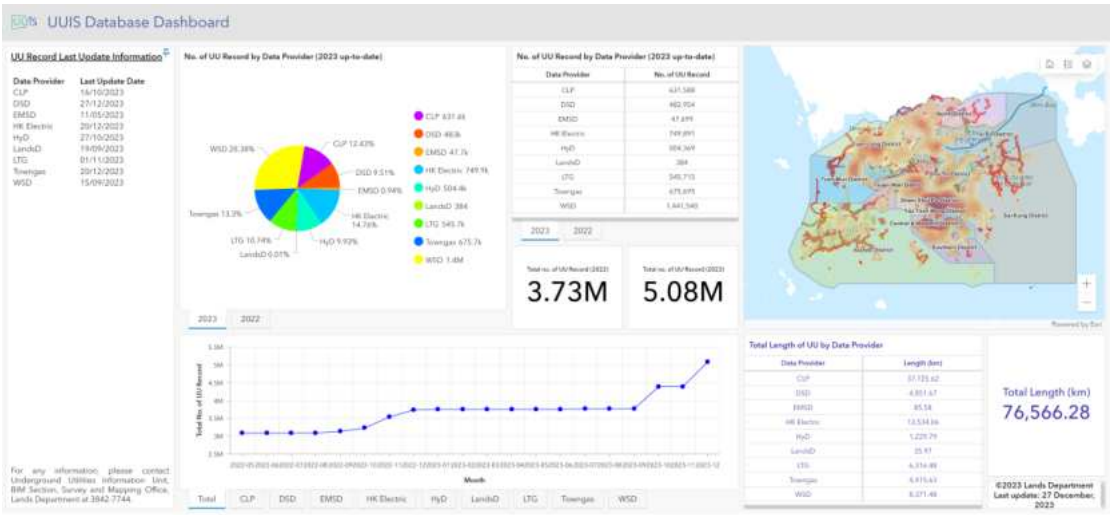


Figure 13 UUIS Database Dashboard

In Dec 2023, there are nine UU undertakings contributing their data in the UUIS database. More than 76,000 kilometers of UU data and 5.08 million of UU record are sharing in the Prototype. Nevertheless, the current UUIS database only involve the major UU undertakings, including Works Departments, the electricity and gas companies. There are several major UU undertakings that have underground assets in Hong Kong, such as telecommunication companies and railway companies. Having a complete and accurate database is important for the successful implementation of a new system, LandsD would continue identify and approach the remaining UU undertakings to participate in the UUIS initiative.

10.2 Improvement in data standardisation, quality and interoperability

LandsD will continue to explore, investigate and develop the UUIS until all UU professions in Hong Kong has established a mutually agreed data specification and survey standard for data sharing purpose. In order to speed up these processes, it would require contributions and support from bureaux, government departments, professional bodies and industry sectors in Hong Kong. In addition, frequent updating of the records with as-built survey data and verification of the accuracy of UU records by UU stakeholders are of utmost importance in order to improve data quality. Other than the current approaches such as regulatory requirements, establishment of common data sharing platform and provision of survey standard etc. LandsD will explore other

possible approaches by referring to overseas projects of similar kind. According to the latest DEVB Technical Circular (Works) No. 2/2021 taken effect on 1 January 2022, capital works projects with project estimates more than $30 million shall use BIM technology. It is expected that more works project would adopt BIM and their UU data would be in BIM format making both GIS and BIM to play major roles in UU data transition in future. Extra effort is required to enable interoperability of data from one system to another without causing data loss.

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BIOGRAPHICAL NOTES

Mr F.M. CHU is a professional land surveyor and obtained the membership of Hong Kong Institute of Surveyors and the Royal Institution of Chartered Surveyors for more than 30 years. He is the project lead in developing Underground Utilities Information System (UUIS) databases and the data dissemination platform through active liaison with consultants, contractors and stakeholders. He oversees the consultancy and associated contracts that involve developing data governance and security policy, technical specifications and standards for UU data, data quality assurance, data management in establishing a unified underground utility database of the Hong Kong territory. Before he led the UUIS project, he has practised in streams of surveying such as geodetic surveys, cadastral surveys, engineering surveys and IT/GIS management in both private and government sectors of the industry.

Ms Vicky CHAN is a professional land surveyor and has become a member of Hong Kong Institute of Surveyors and the Royal Institution of Chartered Surveyors for more than 10 years. She is actively participating in developing Underground Utilities Information System (UUIS) through collaboration with Underground Utility stakeholders. She managed the consultancy contracts that involve developing common technical specifications and standards for field data

collection, data quality assurance, data processing, data presentation and data integration in forming a unified underground utility database of the territory. She has practiced in both private and government sectors of the industry and has solid working experience in land surveying profession including territory-wide airborne LiDAR survey; independent land surveying services for construction projects; land resumption for Urban Renewal Authority projects; land surveying expert witness in court case; land boundary advisory and surveying for land sale sites and slope monitoring survey for Landslip Prevention and Mitigation Projects.

Ms Yannes YIP is an Assistant Land Surveyor working in the Survey and Mapping Office, Lands Department of the Government of Hong Kong Special Administrative Region. She is actively participating in developing Underground Utilities Information System (UUIS) through collaboration with Underground Utility stakeholders. She is currently a probationer of the Hong Kong Institute of Surveyors and is in the process of obtaining membership. She has practised in streams of surveying such as cadastral surveys and IT/GIS project in the government sector of the industry.

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