

# A Framework for Effective Management of Underground Utilities

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**Abstract**—Space under urban public roads is usually full of disordered pipelines and cables. This disarrangement has engendered frequent excavation and prolonged occupation to public roads and further caused huge expenditure in public finance, i.e., degradation of public roads, traffic delay, damage to trees and other utilities. Information share and informed decision-making have been proved to be effective methods towards managing underground utilities. This paper proposes a framework of enhanced methodology for managing underground utilities with employment of an information system and administrative measures with an example of Hong Kong. Vertical allocation of underground space is proposed with reference to common practices and technical standards. Utility information database, application and approval procedure, inquiry functions, clash analysis and other components are discussed in detail.

**Index Terms**—urban underground space, utilization, space management, urban utilities, information system, framework

## I. INTRODUCTION

Land, a nonrenewable resource due to its scarcity, is especially valuable in metropolises with intensive population. The fast-paced urbanization and incessant development has made cities' space shrunken for both aboveground and underground. Ever since the privatization of public utilities, we witnessed a huge increase of underground utility categories and lengths; disorderly excavation, damage to properties, reckless competence for space occupation also emerge consequently.

Managing underground utilities is often regarded as a daunting challenge for public authorities. As illustrated in Fig. 1, different organizations have different concerns and interests around the use of public roads complicated interests and conflicts need to be balanced among communities around public road. All these increase the difficulty to find an equilibrium and universal solution to these problems, not to mention the underground space is like a labyrinth to many government officers – numerous utilities are installed under cities' public roads. Thus, this spaghetti-like mess remains a headache to many engineers and public officers.

Another reason that deteriorates the underground chaos is a lack of direct jurisdiction on the use of public underground space in some cities. Take Hong Kong as an

example: Lands Department (LandsD) is responsible for releasing licenses to those companies who wish to occupy public unleashed lands for construction and business. Nevertheless, LandsD does not have jurisdiction over the number and position of utilities [1]. New installation of telecommunication utilities are under the supervision of Office of the Communications Authority (OFCA), who administers telecommunication industry and provides fair opportunities of using underground space, but is not authorized to examine and oversee alignments of proposed utilities [2]. Likewise, most cities in China Mainland have even more sophisticated administrative procedures: Commission of Economy and Information is in charge of supervising utility companies behavior in the market; Urban Planning and Land Resources Bureau are in charge of management of underground lands and space; and Urban Road Bureau under Construction and Communication Commission exercise legislative rights in managing excavation activities in public roads. These separation of jurisdiction undermine governments' control to underground space.

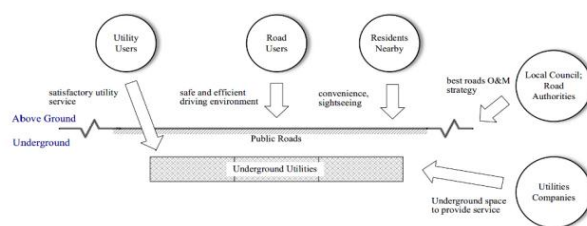


Figure 1. Different communities' interests around public roads

To overcome these problems, many cities have employed control methods to regulate the street-opening activities. For instance, public utility companies in Sydney have to obtain approval for applying opening licenses from Local Council or Roads & Maritime Services, of whichever the road authority is [3]; Highway Department (HyD) in Hong Kong employs Excavation Permit Management System (XPMS) to apply, manage, examine, approve and release permit for street-opening as stipulated by *Land (Miscellaneous Provisions) Ordinance* [1].

However, we should be aware that most of the problems are due to unclearness of underground, thus, in this regard, road authorities found vehicles like excavation permit and offline coordination have limited effort on managing underground utilities and space use,

whilst they have to bear the degradation of pavements due to repeat and reckless excavation. Many experts and government officers believe that prompt and effective communication and information share is of significant importance to prohibiting possible conflicts and beneficial to route selection. Nevertheless, the accuracy and quality of existing utility records is incapable of providing operational levels of information.

Based on these aforementioned needs and principles, we proposed a methodology that enhances the process of route selection and information share, in order to clearly demonstrate the underground space to utility companies, project owners, contractors and policy makers.

## II. EXISTING PROCEDURES AND SYSTEMS FOR INFORMATION SHARE

Currently, for route selections, the common procedure is to circulate as-built information among established industry association or other third party organizations. For example, in USA, Common Ground Alliance (CGA) have published continuous version of *Best Practices* detailing working procedures to share information among registered members [4]. As-built, disposed and spare utility records are collected and distributed to those members when project planning, feasibility evaluating, and route designing starts. One-call centre “811” is used as an efficient vehicle in this period. Members make telephone calls to “811” to contact owners or locators who have properties in the proposed construction site, then companies will deliver these records to callers.

Australia has a similar mechanism: “Dial-Before-You-Dig” (DBYB) works as almost the same with US’s one-call center 811. The different part is that DBYD has a website and user can submit their request online and one-call center will redirect the online request to utility companies [5].

In Hong Kong, Electronic Mark Plant Circulation system (EMPC) works as a platform for different utility companies to circulate as-built information [6]. If a company proposes a new pipeline in a specific area, he will first need to check if any other companies have existing properties in this specific area and sends out request via EMPC to other companies, and after other companies saw this notification, they will send their as-built records to EMPC and then to this company with new applications. EMPC itself will not store any data of other companies and it only works as an information exchange platform.

Many cities have their GIS-base system to manage the city infrastructures, like NYCity map in New York that provides undergoing infrastructure projects of the city. Hong Kong currently uses XPMS to manage and display excavation activities in public roads. Cities in China Mainland like Shanghai and Tianjin have tried to establish centralized databases to store and archive all the as-built utility records.

However, most of these databases only act as archives of utility records and fails to provide online procedures like application, editing and vetting. Aside from this, another dilemma that these cities face is the lack of an

effective mechanism for updating as-built records, yet many cities require contractors submit digitalized drawings to city after construction. An existing dilemma is that after huge initial investment by government, these databases and systems often lack prompt update and maintenance to the data, hence gradually some of the records become untrustworthy.

## III. PRINCIPLE FOR METHODOLOGY DESIGN

In this paper, we proposed a framework of improved methodology for managing the underground utilities. Components of this framework include administrative procedures and a utility information database and system with functions such as projects tracking, 3D GIS data inquiry, existing utility information database and clash analysis that facilitates the implementation. In order to provide clear demonstration, this paper takes Hong Kong as an example to explain procedures of this methodology. The detailed procedures are introduced in Section IV.

### A. Overall Procedure and Functions

Utility companies will be able to use a utility information system to estimate available underground space for utilities, updating discrepancies between as-built records and planning and records for special cases, such as abandoned ducts, spare ducts and shared trenches.

This utility information system can provide inquiry functions for estimating available underground space for utilities, updating discrepancies between as-built records and planning and records for special cases, such as abandoned ducts, spare ducts and shared trenches. Moreover, a featured function—“Clash Analysis” embedded in the system will provide the spatial clash detection function to facilitate users checking feasibility of the proposed alignment and availability of underground space. Fig. 2 depicts the overall procedure of this methodology.

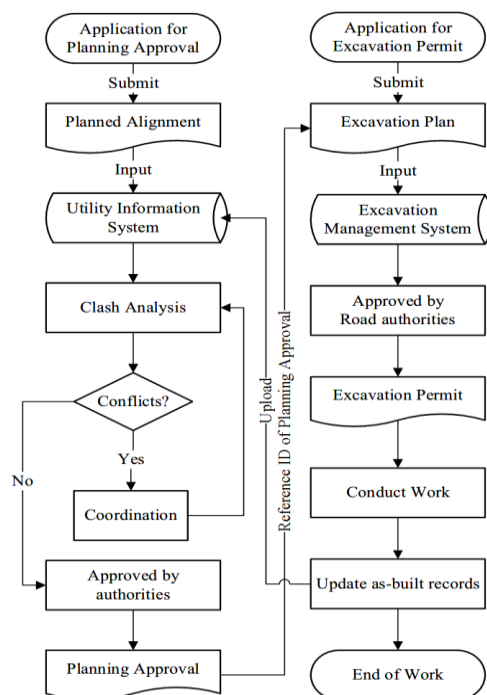


Figure 2. Procedures of the overall framework

For utility companies who wish to conduct new utility construction, two permits are required to obtain prior to any construction work: Planning Approval (PA) and Excavation Permit (XP), which is issued by land authority–LandsD and road authority - HyD respectively. At first, applicants must prepare and submit their installation plan via the utility information system to apply for PA. The plan should include street and target location, utility depth and alignments, types and volumes of pipes, etc. Then, system will conduct “clash analysis” based on the installation plan applicants provided. The result will be delivered to all the applicants, and coordination will start if any conflicts exist. If no conflict is found, the result will be submitted to LandsD and OFCA for further review. These two authorities will confirm if the planning approval granted would be acceptable under the respective licenses conditions issued by them. HyD would also exercise the approval as HyD’s satisfaction to the proposed alignment and disposition pursuant to the relevant condition.

If all the authorities approve the application, PA will be issued to applicants and application data will be stored in the system with a reference ID. Applicant can then access to Excavation Permit Management System to apply for XP. If the proposed excavation involves any new utility installation, applicants are required to provide the reference ID of a possessed PA. XP will not be issued without a valid planning approval.

Construction should be conducted in conformity with approved plan, and utility companies are also required to conduct reinstatement and update as-built information of utilities after construction work. If there is any divergence from proposed plan, utility companies are required to notify relevant departments and upload the as-built records to the information system, in order to avoid further deviation for future application. Acceptance from authorities on as-built records indicates the end of the work.

#### B. Vertical Allocation of Underground Space

The underground space is usually distributed based on the utility function. The minimum depth of cover for underground utilities within public roads varies depending on utility, type and location. In order to achieve better utilization of space as well as to increase safety level of underground environment, a common practice is to allocate the underground space based on their volumes, materials, functions and construction methods. In Sydney, New South Wales Street Opening Conference (trade association in New South Wales) also gives guidelines related to the allocation of underground space. Different types of utilities are allocated and installed in different areas underneath public roads, and approval for encroachment need to be acquired from influenced companies.

In this methodology, we tried to regulate the “recommended depth and alignments” to strengthen utilization of the scarce underground space underneath public roads by providing a possible solution for current underground congestion and a relatively reasonable allocation of underground space. This allocation, with

respect of different utilities type, function, volume, installation methods, etc., is designed to help applicants test and determine the optimum disposition of utilities within the scope of recommended depth and alignments, and to solve the spatial conflicts between different UUs.

All the application of new utility construction will be confined in recommended vertical layers, and the space assessment, i.e. the “Clash Analysis” inside the system, is mainly based on the pre-set recommended depth and alignment. Relevant authorities still maintain design requirements for underground utilities to safeguard the public, protect city staff and contractors, and preserve the integrity of all buried plant within its streets.

Currently, different utility companies in Hong Kong have their own guidelines for installing new utilities. For example, in Hong Kong, the nominal depth for electricity is 760mm for their LV cables and 900mm for 11/22kV cables; water requires a minimum depth of 600mm for footway and 1000mm for carriageways [7][8]. *Guide to Trench Excavations (Shoring Support and Drainage Measures)* [9] stipulates that for excavation depth less than 4.5m, specific design for the support will not be necessary: undertakers only need to install adequate support to depth greater than 1.2m. Also, given that the different mechanical characteristics in footway and carriageway, for this methodology, we assume the total available space in footway is between the depth of 0.3-4.5m; in carriageway is between the depths of 0.9-4.5m. The clash analysis will be conducted in this circumstance.

What’s more, after considering the absence of such experiences and principles in Hong Kong, we checked related items in *Code of Urban Engineering Pipeline Comprehensive Planning* [10] and recommended a top-down allocation of underground space for different types of utilities as follows: electricity, telecomm, gas, water and sewage. Table I lists the recommended depth for utilities in Hong Kong.

TABLE I. RECOMMENDED DEPTH FOR UNDERGROUND UTILITIES IN HONG KONG (UNIT: MM)

Utility Type	Footway	Carriageway
Water	600 (minimum depth)	1000 (minimum depth)
Sewerage	450-6000	900-6000
Gas	700 (minimum depth)	700 (minimum depth)
Telecomm	450 (minimum depth)	NA
Electricity (LV)	760 (minimum depth)	NA
Electricity (11/22kV)	900 (minimum depth)	NA

In fact, given the scarcity of underground space, in some cases, the construction could not always meet the safety clearance. If utilities have relative small influence to each other—for example, electricity and telecomm, the clearance between them could be compromised. But for some particular utilities such as electricity cable and gas pipe, water and sewage, which have potential safety hazard or strong influence if they are too close, the installation of these utilities should strictly follow the regulated clearance [11].

#### IV. DETAILED PROCEDURES

##### A. Phase 1: Application for "Planning Approval"

Before any application, applicants should check the availability of spare ducts in the target area. If spare ducts are found in target area, applicant should consider using spare duct, which would be easier to pass the clash analysis. The owner of spare ducts have responsibility to provide adequate information of these ducts to applicants and related authorities. An installation plan needs to be submit to the system in order to conduct clash analysis. These installation plans should include content as shown in Table II:

TABLE II. CONTENT OF INSTALLATION PLAN

Category	Content
Project Information	Contractor/Work Type/Construction Methods; Estimated schedule of timing;
Location Information	Target area; Availability of spare ducts/existing equipment or utilities the proposed work may affect
Utility Property	3D Coordinates/Depth/Length; Number/Type/Diameter/Material.

Applicants should also convert the data format according to system's requirements. The coordinates should follow HK80 Geodetic Datum standard and are feasible to calculate relative and absolute elevations of the planned alignments.

Once clash analysis is finished, the result including detailed GIS coordinates will be delivered to utility undertakers. If the planned work fails clash analysis, applicants are advised to coordinate with the reference of the clash analysis result report, and try to achieve an agreement on the planned installation in this planning application period. If agreement is achieved, applicants will need to submit the revised installation plan and conduct the clash analysis again. If agreement is hard to be achieved or if any offense is observed during this process, authorities like OFCA or LandsD will involve into coordination process, making sure the coordination runs smoothly. If the agreement still cannot be achieved, or if the analysis result indicates the underground is already too congested to install any new utilities, applicants are advised to abort this application, and to seek available space in other area. Utility information system will also provide a congestion index of each street for applicants' reference.

If the planned work passes the clash analysis test, the result will be delivered to related authorities for further approval. Rejection from any authorities will lead to application failure. If all the authorities approve the application, PA will be issued to applicants and application data will be stored in the utility information system with a reference ID, which will be used as a connector for calling plan data during future XP application and records uploading.

Once the applicant decides to accept this PA, planned alignment data is stored and frozen, and is prohibited

from unauthorized modification during XP application. The valid period for PA will be 365 calendar days that start from the issued date. Only when the applicant wish to cancel previous application will they be permitted to modify input data, and apply for installation again.

Moreover, to ensure every utility company has equal opportunity to use the underground space, the maximum PA each company can hold is two. If the amount of applicants' registered PA has reached two and they still wish to add new planned works, they must conduct the planned work with valid PA as soon as possible, and after successful submission of as-built records, this PA will be archived and an available PA slot will be released in the system. Then, they may begin to apply for another new PA. If under some particular condition that they need an extra PA, exceptional approval is needed from authorities.

For those planned work with valid PA, if utility companies wish to modify the planned work, they need first to waive previous PA and apply again. Also, if construction has not commenced by the end of that period, i.e. 365 calendar days since the issued date of PA, related authorities must be notified that the installation has been cancelled, or a request to re-apply the plan must be made. It is the sole responsibility of applicants to ensure all changes are incorporated and conditions met.

##### B. Phase 2: Application for "Excavation Permit"

If any excavation involves new utility installation, applicants are required to provide the reference ID of a preoccupied PA. XP will not be issued without a valid planning approval. All the approved installation plan and alignment data during the PA application will be transferred to XPMS with the reference ID provided. Applicants need first to register and submit excavation plans that meet requirements from HyD. During XP application process, these data will be used to check whether the XP application is in conformity with previously approved space occupation.

##### C. Phase 3: Conduct Work

Utility company installation and maintenance work on city streets will be subject to all applicable urban standards, policies and codes. Work is to be carried out by the utility company's employees or their contractor, to the satisfaction of related departments or their representatives. New underground utility construction on the street may only proceed once obtaining planning approval and excavation permit. The construction should also be commenced in the period that aforementioned permits are still valid. If construction has not commenced by the end of that period, relevant departments must be notified that the installation has been cancelled, or a request to re-approve the permits must be made.

Also, an Audit Inspection Team (AIT) consisting several government officers from different departments will supervise and examine installation process in the trial area, to control the quality of the work and guarantee its compliance with approved plans. If discrepancy between planned work and as-built one is unavoidable, utility companies are advised to notify AIT as soon as possible in order to obtain help from relevant authorities. What's

more, it is applicants' responsibility to report any abandoned ducts to AIT. Offence to these requirements will be recorded in the system, and might influence further application to PA or XP in the future.

Utility companies should conduct construction in accordance with planned alignments and excavation plan. However, some unregistered plants in the underground may bring about unexpected obstacles in satisfaction with conditions of the plan. Thus, for some other emergency situation, such as weather and other construction works on streets, etc., UU should notify relevant authorities for exceptions to divergence in an acceptable scope, and UU are required to submit the modified as-built records to the system. In addition, related authorities reserves the right to claim a rework if UU fails to notify possible divergence in advance.

#### D. Phase 4: Update As-Built Records

After construction, utility companies must upload as-built records to utility information system to store information for further use. As-built records including digitalized drawings and hard copies with all information indicating changes made in the field. Table III lists requirements on submission of as-built records.

TABLE III. REQUIREMENTS ON SUBMISSION OF AS-BUILT RECORDS

Categories	Content
Data of installed utilities	3D coordinates of each alignment's vertex, material, quantity, diameter, installed total length, etc.
Digitalized drawings	A layout of the constructed utilities which clearly depict elevation, alignments, street, etc.
Project information	Contractor, work duration, construction methods, etc.
Discrepancies	Discrepancies with planned alignments, unregistered ducts and utilities

Comprehensive and accurate as-built records provide a clear vision to the underground space and lay the foundation of this methodology. In this regard, if utility companies fail to update satisfactory as-built records in the utility information system within 30 days after construction finished, authorities will suspend further application for PA in the future until submission of as-built records.

If discrepancies between as-built record and planned alignment happen, utility companies shall be provided and uploaded to System within 30 days following the completion of construction. All Record Drawings submitted must be certified by the applicant as the final as-built record drawings.

#### V. CONCLUSION

This paper depicted a framework and detailed procedures for enhancing the utilization of underground

space, which is dedicated to help authorities dealing with the situation that available underground space is shrinking due to heavy demand of utility installations. Major improvements of this methodology are: (1) the introduction of "Planning Approval" as a prerequisite for utility companies who wish to apply new installation in the underground; (2) inquiry function embedded in the hardly system to check available underground space; (3) clash analysis function to test possible alignments and overcome conflicts; (4) vertical allocation of underground space based on utility functions; (5) on-line procedures for project application and managing.

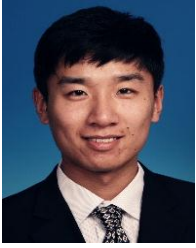
To summarize, the most important component in this methodology is the utility information system that facilitate the implementation of administrative procedures. Currently, the utility information database and web-based system is already under development. Meanwhile, several highly congested areas have been selected in Hong Kong to test and trial the proposed methodology. Data collection process has already begun in these trial areas. In the future, we hope to demonstrate this method's feasibility after an integrated and comprehensive trial process.

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