Current Progress on Underground Utility Mapping in Malaysia

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SUMMARY

Underground utility mapping refers to the detection, positioning and identification of buried pipes and cables beneath the ground. Accurate information on underground utilities is vital for planning and installation of new utilities. This requirement is furthermore critical when it involves excavation of existing utilities for repositioning and others. Lack of knowledge on the whereabout of these facilities during excavation can result in fatality and catastrophic damages to existing underground utilities. This inevitably may results in disruption to utility services. Industries that depend on these services may suffer greatly in terms of financial loss and in the long run would undermine the country ability in providing a favourable atmosphere and condition for economic growth.

Utility providers are responsible for mapping and keeping their own utility network information accurate and up-to-date. This information is usually kept in their own format, independent of any standards and are used for their internal purposes. Sharing of information at the moment is through agreement between interested parties and through mechanism provided under the Underground Utility Mapping Technical Committee.

The Department of Survey and Mapping Malaysia (JUPEM) has been mandated to compile and manage underground utility data provided by various utility providers or agencies in Malaysia. The data are retained in a database under a single repository that would serve as a centre for utility data. Currently, there is no legislation to compel utility providers to deposit their data to JUPEM as the custodian for underground utility data. Without the proper legislation, JUPEM would have to move within its mandate to implement underground utility mapping in Malaysia through engagement with all interested parties and stakeholders. JUPEM has taken the necessary short term and long term measures to ensure that the decision to have a single repository for the country is fulfilled.

This paper discussed the progress made by JUPEM in particular and the land surveying profession as a whole in anticipating and meeting the future demand of underground utility mapping in Malaysia.

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1. INTRODUCTION

Underground utility mapping is a process of identifying, locating and labelling public utilities situated underground. These utilities include telecommunication cables, electricity distribution cables, natural gas pipes, water mains and wastewater pipes or any others which compete for space underground.

The Department of Survey and Mapping Malaysia (JUPEM) is the official agency mandated to compile and manage data and information on all undeground utilities in Malaysia for the government. This is mainly attributed to the department's responsibility in managing geospatial information and for being the authority on national mapping for Malaysia.

In Malaysia, land surveyors have always been associated with all kinds of survey and positioning activities. The profession has now ventured into a new realms of mapping which requires certain specific knowledge in the field of geophysics. It is currently spearheading the effort in mapping all underground utilities to assist in mitigating the problem of disruption of utility services due to ground excavation work in projects involving utilites. Underground utility mapping presents a completely new challenge for land surveyors in which mistakes made in identifying underground utilities may caused fatalities and unnecessary cost to those involved.

Currently in Malaysia, utility agencies or providers are mainly private entities or government linked companies (GLCs). They are subjected to various legislation that govern their activities. However there is no specific legislation that requires them to deposit their utility information to any particular body that can act as a repository for the country. With this constraint, JUPEM has to work within its mandate to engage all the industry players and come up with a solution to the issues that would satisfy all aspects and parties.

2. JUPEM's ROLE IN UNDERGROUND UTILITY MAPPING

JUPEM's role in underground utility mapping began with the establishment of the Utility Mapping Division in 2006 (previously known as Utility Mapping Section of the Mapping Division) to compile and manage utility information for the entire country. It first started with the directive from the Malaysian Cabinet to compile and manage information on all underground utilities for the country because of frequent disruption of water and electricity supplies caused by the damage to water pipes and electricity cables during excavation works. These problems come about during installation of new utility facilities or during upgrading or

widening of roads **(Figure 1)**. This situation is attributed mainly to the lack or inaccurate information on the position of the existing underground utilities.

Figure 1: Damage utilities due to excavation works

JUPEM started with the current workforce of 55 personnel comprising of both office and field teams. It acquired a Utility Mapping package consisting of both office and field equipment and subsequently developed a national underground utility database called PADU. The main aim of having PADU is to provide a medium in which data from all utility providers including JUPEM may reside and act as a repository for reliable and accurate underground utility data. The data comprising of geospatial information for power and telecommunication cables, gas, water and sewerage pipes is kept in a systematic geographic information system (GIS) format. The data submitted by the providers are subjected to various checks and verification processes to meet the necessary standards before they are deposited into PADU.

There are four major components of information in PADU namely large scale 1:500 base maps, cadastral overlays delineating all land parcels, topographic details and the series of utility layers, each containing utility features and attributes **(Figure 2).** These data are tied to the geodetic coordinates system of Malaysia. These data are kept in a seamless geo-database format for efficient access, analysis and sharing purposes. The final products of the whole mapping process are utility maps available on print-on-demand **(Figure 3)** basis.

To ensure an orderly management of underground utility data, JUPEM working in tandem with the utilities provider and other government agencies has established procedures and specifications, in the form of standard guidelines for underground utility mapping. In 2006, JUPEM produced a Standard Guideline for Underground Utility Mapping (Director General of Survey and Mapping Circular 1/2006) with the aim to provide standard procedures for collection, compilation and presentation of underground utility data. This guideline is the culmination of concerted efforts of the Underground Utility Mapping Technical Committee with members comprising of underground utility stakeholders functioning under the auspices of the National Committee for Mapping and Spatial Data; a national body responsible for the coordination of mapping activities in Malaysia. This guideline addresses issues such as the roles of stakeholders and data quality.

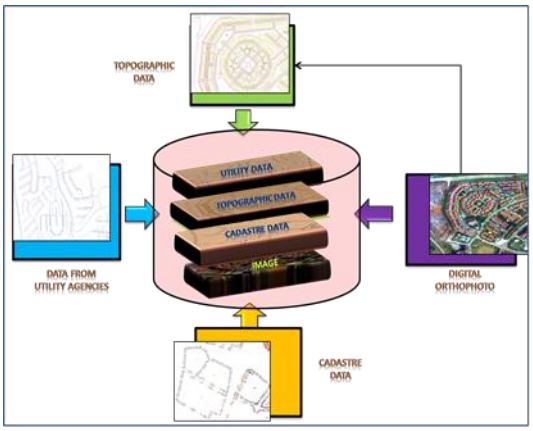

Figure 2: PADU Database Components

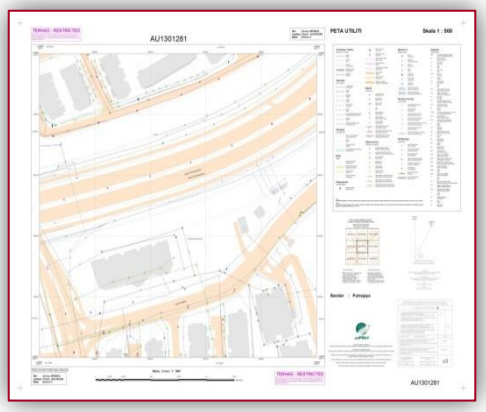

Figure 3: Utility map produced by JUPEM

It also provides specifications on underground utility maps and creation and maintenance of underground utility database. With this, the related utility data can be easily shared and made available to utility agencies and all other relevant parties.

3. PROGRESS IN UNDERGROUND UTILITY MAPPING

3.1 Quality of Utility Data

Data quality remains a crucial part in the integrity of a data set. The level of quality of a data set would indicate the worthiness of the data. JUPEM as the main custodian of utility data, collect and compile data from all utility providers and deposit them into PADU. The data collected are checked for their quality. Most of the data received are data of low accuracy and does not meet the standards as laid down by JUPEM. Comparison made indicates large positioning difference which could be deterimental to users as shown in **Figure 4**. This is further proven with verification checks done in the field.

Some utility agencies provides schematic maps/plans of their utilities rather than their actual locations. Thus, a more detail survey would have to be carried out before any excavation work could be done. Obviously, this defeats the real intention of the Government's directive for JUPEM to compile and keep data from all utility agencies. This also lead to increase in costs, time and resources.

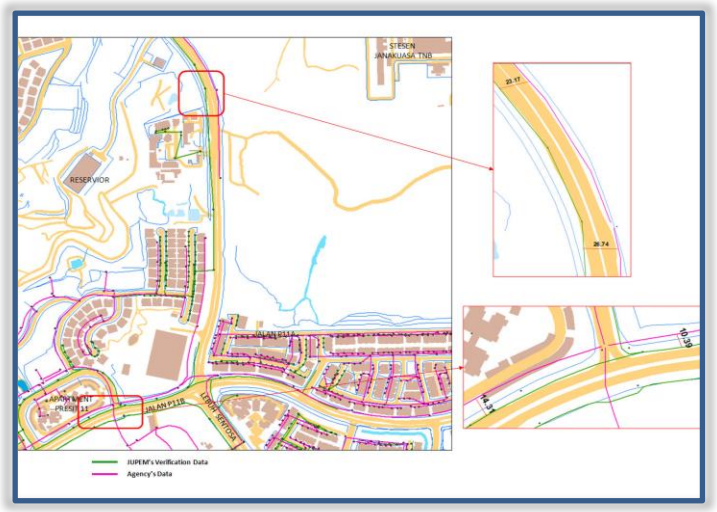

Figure 4: Comparison between agency's utility data and JUPEM's verification data

Utility maps kept by the various utility providers had their own formats and specifications. It is difficult to gauge how good the as-built information on underground utilities are manage, kept and updated. Usually they are used by the providers themselves for planning, installation of new utilities and also for asset management purposes. The mapping specifications and accuracy requirements between the utility providers vary depending on their purpose and budget. Most of the utility providers are under the jurisdiction of different ministries and regulatory bodies such as Malaysian Communication Multimedia Commission (MCMC), National Water Service Commission (SPAN) and the Energy Commission. The abovementioned Commissions provide the necessary guidelines and advice in accordance to the legislation to the relevant utility providers.

Currently, there is no requirement for any individuals or organisation to provide an accurately surveyed and endorsed as-built plan. Without endorsement by a qualified land surveying professionals, there is no guarantee that the utilities are surveyed to the required accuracies and standards. In practice, certain local authorities engage contractors and land surveyors to execute underground utility detection before any re-development is carried out. However, the final deliverables would depend on the clients requirements. The as-built plan could be in any reference system and problems may arise when overlaying with information coming from different sources.

Understanding the coordinate system and the accuracy of equipment and methodology for interpretation of data is critical in overcoming this problem. In most cases, surveys are done in Cassini Soldner projection. These spatial data could easily be transformed to any system if the data is GIS-ready and the transformation parameters are readily available. At present, the coordinate system used in JUPEM is the new geocentric reference system based on the International Terrestrial Reference Frame (ITRF) known as Geocentric Datum of Malaysia (GDM) 2000.

It is also important that utilities database kept by the providers are updated continuously. Sometimes, utility pipes or cables are relocated during repairs or relocations, but not updated in their database. The result of digging or drilling in the presence of unknowns, unmarked, unmapped, or incorrectly located utilities may caused major damage, downtime, and the worst cases personal injury or death.

3.2 Equipment and Technology

With the existing technology, basic equipment such as ground penetrating radar (GPR) and electromagnetic locator (EML) are able to detect underground facilities using the principle of RADAR and electromagnetic wave. Detection using GPR is done by pushing or towing the RADAR transmitter cum receiver across or along the facilities. The buried utilities can be detected and interpreted through GPR profiles or tomographic images **(Figure 5)**. EML on the other hand, allows the detection of metal pipes by detecting electromagnetic field created or inherently present in the facility **(Figure 6)**. Depending on the type of utility, electromagnetic (EM), magnetic, sonic/ acoustic, ground penetrating radar, live line detector, and robotic crawler techniques are used to detect and trace buried utility lines. In materialising the full potential of the available techniques, JUPEM's personnel have undergone specific training and courses which allows the field parties to efficiently and safely carry out their jobs.

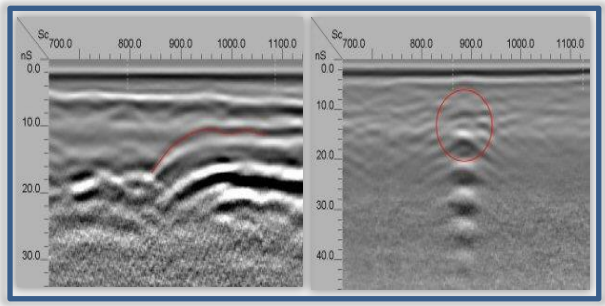

Figure 5: Left profile displays edge of excavation and right profile indicates presence of non-metallic utility pipes

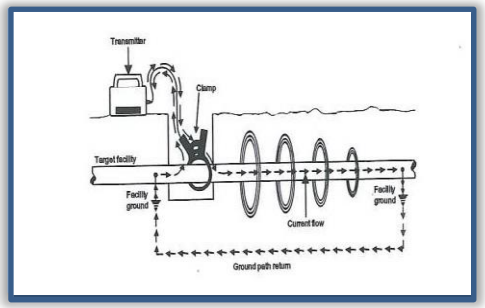

Figure 6: Detection of metallic pipes with EML Source: Utility Training Academy (UTA)

In underground utility mapping, providing highly accurate utility positions (detected utility) is essential. Survey control is usually by global navigation and satellite system (GNSS) and the above ground survey by total stations. The survey data is subsequently used to produce utility maps or overlays for GIS.

Usually in underground utility mapping both the electromagnetic detection and RADAR techniques are used in unison. Both equipment has diffrent capabilities and inherent weaknesses. EML are unable to detect non-metallic buried services including plastic, water and gas-pipes and clay drainage pipes. The ground penetrating radar has the advantage of detecting virtually anything below the surface. They also gives an indication of the location

and depth of buried utilities but does not identify them. The depth of detection depends on the soil condition of the site. In general, electromagnetic detection and ground penetrating radar techniques detect utilities up to 3 metres below the ground surface. The depth of penetration of the radar can be increased but often at the expense of resolution. To overcome this potentially hazardous situation, land surveyors often combine the use of electromagnetic detection with GPR.

To avoid messy excavation and unnecessary utility incidents, a technique using horizontal directional drilling or HDD are used for the installation of underground pipes, conduits and cables along a prescribed bore path by using a surface-launched drilling rig. Once the pipes go beyond the detection range of conventional detecting technique the pipes are blind to anyone trying to locate their positions. Thus it is important that prior to any installation, effort should be made to survey or detect the routes either real time during drilling or post processed using gyro based equipment. At the same time the location of both ends of the underground utilities need to be surveyed accurately.

3.3 GPR Calibration Facility

All survey and surface geophysical detection equipment used to acquire the underground utility data need to be appropriately calibrated to ensure accuracy as specified in JUPEM standard guidelines. Early this year, JUPEM has decided to embark on constructing a GPR calibration test facility. This will provide a built-for-purpose facility that allows GPRs used for detection to be tested for their accuracy in a controlled environment. The facility will be the only state of the art calibration facility for GPR in Malaysia.

3.4 Legislation and Guidelines in Populating PADU

The challenges faced by PADU is primarily in its data content. Most of the data compiled or provided by the utility agencies have low accuracy and not reliable. To date, JUPEM has managed to obtain utility data from 5 major providers; namely Telekom Malaysia (TM) for telecomunication cables, Tenaga Nasional Berhad (TNB) for electricity cables, Indah Water for sewerage pipelines, Gas Malaysia for gas pipelines and Syabas for water pipelines. They are mainly fit to be used as guide to the existance of utility but not for excavations works unless accompanied by detection data surveyed by qualified land surveyors. This is to be expected as the utility agencies has no legal requirement to provide high quality data or as-built data to PADU. The reason is mainly due to the utility agencies not having high quality data themselves. In verifying those data, JUPEM has to perform the detection and survey of the underground utilities. This will wittingly upgrade the accuracy of the data. In order to meet its objective of populating PADU with high quality data, one of the steps taken is to establish guidelines whereby the utility agencies have to engage qualified land surveyors to execute detection and survey works of existing underground utilities as well as during the installation of new utilities. A copy of the utility plan including digital data produced has to be certified by licensed land surveyors and one copy submitted to JUPEM.

With the decision made during the National Council for Local Authorities Meeting in 2014, it was agreed that all new utilities including those with HDD must be surveyed during the installation stage and must be carried out by qualified land surveyors and copies of as-built plan sent to JUPEM for inclusion into PADU. This requirement will be one of the required conditions at the development order stage. JUPEM has just recently completed a guideline to be used by the local authorities on the same matter. The guideline has already being distributed to all the local authorities in the country for implementation. In addressing the matter further, a series of roadshows will be conducted by JUPEM to help the local authorities in understanding the guidelines and importance of underground utility mapping to the country. However, in the long run, it would be beneficial to have a proper underground utility legislation that would encompase all the requirements and needs of underground utility mapping for the country.

3.5 Accreditation and Role of Qualified Land Surveyors

To ensure competencies as well as enhancing and updating the practicing land surveyors with the latest technological know-how in utility mapping, an accreditation course has been introduced with the cooperation of JUPEM, the Authorised Land Surveyors Association (PEJUTA) and Land Surveyors Board (LJT). This course is conducted for a duration of six months and consists of three (3) main modules: (1) Fundamental and Basic Principal of Measurement – principle of measurement and tools, fundamental of geophysics, data management, data processing and interpretation, limitation of data analysis; (2) System Operations and Applications – coordinate system, adjustment and transformation, datum conversion and projection, data loading, translation, coding and formatting; (3) Professional and Society - utility mapping standards and safety requirements, underground utilities system design.

The course consists of lectures and practical assignments which includes reports and documentation of each module/dissertation/project documentation, competency test and skills and oral interview. A certificate will be awarded to participants who fulfil the accreditation prerequisite. At present, 70 licensed land surveyors have been accreditated and certified to carry-out the job of underground utility mapping detection and survey.

3.6 Professional Consultant Services and Standard Rate on Utility Survey

In the latest development, the Ministry of Finance (MOF) has accepted a proposal by the Land Surveyors Board (LJT) to place all works comprising utility detection and survey under the Professional Consultant Services. This allows the works to be carried out by qualified land surveyors with the necessary certification as mentioned in paragraph 3.5. At the same time, MOF has also deliberated and considered the standard rates for utility detection as proposed by LJT. With this policy implemented, it is hoped that all underground utility detection and surveying job will be implemented in accordance with the specification and standards laid down by JUPEM.

3.7 Standard Codes and Marking

Cooperation and sharing of utility data is essential between utility agencies and relevant authorities. Currently, there is no policy to allow the sharing of utility information which is considered a sensitive issue to some due to its business and legal implication. Furthermore, the use of independent features coding by different agencies add to the existing problem in data sharing. In addressing this issue, the Underground Utility Mapping Technical Committee with cooperation with Technical Committee 2 SIRIM has developed standards for feature and attribute codes and has become part of the Malaysian Standard MS 1759: Geographic Information/ Geomatics - Feature and Attributes Codes. Hopefully, such action would positively encourage all concerned parties to follow and satisfy the standard requirements set therein. In order to facilitate their use, all underground utility maps produced must be accompanied with appropriate metadata which complies with the Malaysian Standard Metadata specifications.

In addition to the Malaysian Standard MS 1759, JUPEM has also developed a standardised marking system for underground utility mapping. The marking system allows surveyors to properly use and identify marking on the ground easily base on specific marking and colour coding.

3.8 3D Utility Mapping

Visualising the utilities in 3D is an important aspect in the decision making for utility development project. This is an area that requires new expertise. 3D utility mapping allows the depiction of underground utility from different perspective. Such skills and knowledge would provide that extra edge to land surveyors. As such surveyors need to invest in education, in terms of attending courses and investing in hardware and software. The end product would be a 3D underground utility maps. The current practice in utility detection does not allow the production of orthometric 3D utility map because of lack of accurate and precise heighting and DTM. When this is fully realised in the future, JUPEM will have the capability of 3D maps for both above and below ground for more informed and intelligent decision making and planning.

3.9 Continuous Capacity Building in Utility Mapping

The tools and technology for underground utility detection were only available during the last decade. Detection tools with better capability are continuously being developed. However, in any industry that involves the use of high technology equipment, knowledge and expertise is a major requirement. Knowledge in underground utility mapping is still lacking and need to be further developed at the tertiary education level. Some universities in Malaysia have introduced the subject into their undergraduate programmes and Universiti Teknologi Malaysia in particular has taken steps to introduce a Master of Science in Utility Mapping programme. This is a good development for future and potential land surveyors and those who are already in the industry.

In addition, as mentioned in paragraph 3.5, the Land Surveyors Board in collaboration with local and overseas partners has embarked on a special accreditation and certification programme to produce practitioners with the knowledge and skills in underground utility detection and mapping. Under the new requirement by MOF this certification will become one of the requirement when engaging in any underground utility mapping project.

While knowledge can be obtained through tertiary education level, expertise can only be obtained through experience and training. Training in JUPEM is an on-going process for both office and field personnel. However there is no true substitute to actual field experience. JUPEM personnel would still need on-the-job training on relatively uncomplicated sites and subsequently followed by verification work on more developed and difficult sites. This will allow them to gain enough experience at an acceptable pace.

At the same time, personnel must attend short courses conducted in-house or by training centres such as the National Land and Survey Training Institute (INSTUN) and National Institute of Occupational Safety and Hazard (NIOSH). INSTUN focusses in disseminating technical knowledge on underground utility mapping, while NIOSH on the safety and occupational hazard aspects in the field.

3.10 Going Beyond The Klang Valley

The setting up of the Utility Mapping Division by JUPEM in 2006 is meant to cater for underground utility mapping activities in the Klang Valley. With the new development on the requirement by the local authorities, the Division available capacity would not be sufficient to handle data for the whole country. Thus there is a need for JUPEM to expand to allow its underground utility mapping activities to go beyond its current capacity.

JUPEM is also planning to embark on an ambitious effort to map underground utilities for the whole country. Within the project, JUPEM is looking at the posibility of upgrading its capabilities and setting-up a ’call centre’ where clients can obtain utility information by dialing directly to the centre. However this will only work well when JUPEM have sufficienly accurate data for the whole country.

4. CONCLUDING REMARKS

With the mandate given by the Government, JUPEM has developed and maintained a national GIS ready underground utility database called PADU. This database is the basis for a national repository of reliable and accurate underground utility data. However, the data submitted by the various utility providers are subjected to various checks and verification processes which reveals data of low quality and accuracy unacceptable to PADU and insufficient to be used as a base data for excavation work. Issues pertaining to acquiring accurate data is the main issue and challenge faced with regards to providing accurate utility data for the nation.

One of the initiatives undertaken is the implementation of the decision of the National Council for Local Authorities where all new utilities must be surveyed during installation. This directive provides an excellent mechanism for aquisition of accurate and quality data. Surveying of underground utility during installation will be carried out by qualified land surveyors and the final as-built plan deposited to JUPEM.

Having the detection and surveying work classified under Professional Consultant Services and a standardised rate will also enhance the role of land surveyors in the field of underground utility mapping. This will provide accountability on the part of the land surveyors in ensuring the deliverance of accurate and quality products fulfilling the specification and accuracy standards. In addition JUPEM is also preparing to go beyond its current capacity within its mandate to include underground utility mapping for the whole country. In conclusion, JUPEM as the authority in survey and mapping is being pro-active in providing the survey and mapping services for the nation. It is currently spearheading and venturing into a new non-traditional field of expertise for land surveyors.

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BIOGRAPHICAL NOTES

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