Building and Construction Authority

BIM Essential Guide

For Land Surveyors

Version 2

BCA acknowledges the leadership provided by the BIM Steering Committee in support of the production of the BIM Essential Guides.

The BIM Essential Guides have been drafted by SISV (Land Surveying Division), HDB, SLA and endorsed by the Centre for Construction IT on behalf of BCA and the BIM Steering Committee.

Building and Construction Authority
52 Jurong Gateway Road
#11-01 JEM Office Tower
Singapore 608550
www.bca.gov.sg

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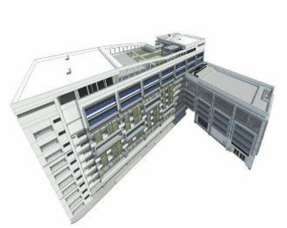

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Contents

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Version 1:

Singapore Institute of Surveying and Valuers - SISV BIM Committee

Ms Loh Suat Yen (Chair)

Mr Leong Kin Weng

Mr Leong Kai Weng

Mr Heng Fook Hai

Mr Jimmy Tan

Mr Foo Seng Heng

Mr Martin Ang Phar Teng

Mr Gerry Ong

Mr Terence Goh Chin Cheng

Dr Tor Yam Khoon

Mr Lee Li Chuan

Mr Loi Hwee Yong

Building Construction Authority (Centre of Construction IT)

Dr Tan Kee Wee

Ms Huang Yixiang

Housing & Development Board

Mr Larry Cheng

Mr Alvin Chong

Mr Chong Shyh Hao

Mr Tan Chee Meng

Singapore Land Authority

Dr Victor Khoo

Mr Soon Kean Huat

Ms Sandy Teo

Mr Ng Zhen Hao

BIMAGE Consulting Pte Ltd

DCA Architects Pte Ltd

Di-HUB Pte Ltd

P & T Consultants Pte Ltd

RSP Architects Planners & Engineers Pte Ltd

Tang Tuck Kim Registered Surveyor

Additional for Version 2:

Changi Airport Group

LEW Registered Surveyor

Objectives

The objective of this BIM Essential Guide is to assist Land Surveyors in understanding their role in BIM projects, including New Construction and A&A Projects. The guide serves as a code of practice for surveyors to understand their critical role and value proposition to BIM and the 3D community by looking into survey workflows and practice within the context of BIM requirements and coordination with other building professionals. The guide also shows the possible use cases of BIM and land survey deliverables for BIM at the various stages of the projects.

Following the Step-by-Step Land Surveying BIM guide for HDB Housing Projects, we have received feedback and requests from several registered surveyors and architects to develop a similar guide applicable for the surveying industry. Hence, this essential guide was developed to provide more information on survey deliverables across the construction lifecycle and situations where other building professionals may provide BIM models in lieu of hardcopy or CAD reference drawings to the surveyors. Appropriate references to existing survey standards are included in the guide. This guide aims to be as comprehensive as possible by incorporating traditional and newer surveying methods and workflows. With exciting developments in 3D surveying technology and software applications, this guide would need to be reviewed periodically to keep it current with technology advances, standards, and requirements.

The role of the surveyor is to certify the correctness and accuracy of survey measurements under the Land Surveyors Act (Cap.156). Hence, it is worthwhile to point out that geo-referenced survey measurements can only be certified correct by a registered land surveyor.

This general document draws some experiences from pilot projects and real-life projects. It is not an extensive document that covers all scenarios that might arise based on specific projects. Users shall adopt and adjust according to their needs.

This Essential Guide is not intended to be based on any particular BIM software and does not cover any explanation or steps on its usage. For help and guidance for your specific BIM software, please refer to your software user manual.

Based on the project requirements, do adopt the software recommended for use and implementation in the individual project.

Land Survey Site Models for BIM Design

Pre-Construction Planning and Design

For Field to BIM, it is useful to distinguish between the different types of topographic surveys – the general/preliminary site plans, the detailed topographic plans for construction and the as-built surveys. The general/preliminary site plans are pre-development topographic surveys carried out for designing and planning of development. As-built surveys are surveys carried out after the construction is completed. In more complex developments where conservation of building or integration to existing buildings are involved, measured building surveys and a "recreated" BIM model may be required.

Land surveyors survey existing site conditions, terrain and features to create the surface model. This model includes the model orientation and site configuration and is also geo-referenced to the national grid system. As only the surveyor can ensure that the geo-referencing process is authoritative, it is important for the surveyor to generate the geo-referenced BIM site model to facilitate the consultant's downstream works (add-on, design, etc.). An Integrated workflow for Site Development and BIM models is essential for the surveyor for such pre-construction topographical surveys.

The Step-by-Step Land Surveying BIM guide for HDB Housing Projects (Annex A) serves as a user guide to achieve this goal. In the development of this guide, the requirements for data capture and data format of topographical surveys to support BIM formats were studied. The CAD drawing standard to organise and name the map layers must be consistent. This is specified in the Standard and Specifications for 3D Topographic Mapping in Singapore (www.sla.gov.sg). This standard requires a new map layer (DTM layer) containing only surface spot levels, which was added to facilitate the importing of the points to create the site surface in the BIM model.

In the 2D topographic plan, the z value or level of the features is not important. This means that it does not matter whether the field surveyor picks the x, y, z position of the top or bottom of the lamp post or anywhere in between the top and bottom of the lamp post. For the 3D topographic plan, it is important to read only the bottom of the lamp post for the point to be copied to the DTM layer. Only points of 3D features on the surface are to be copied to the DTM layer for the creation of the surface.

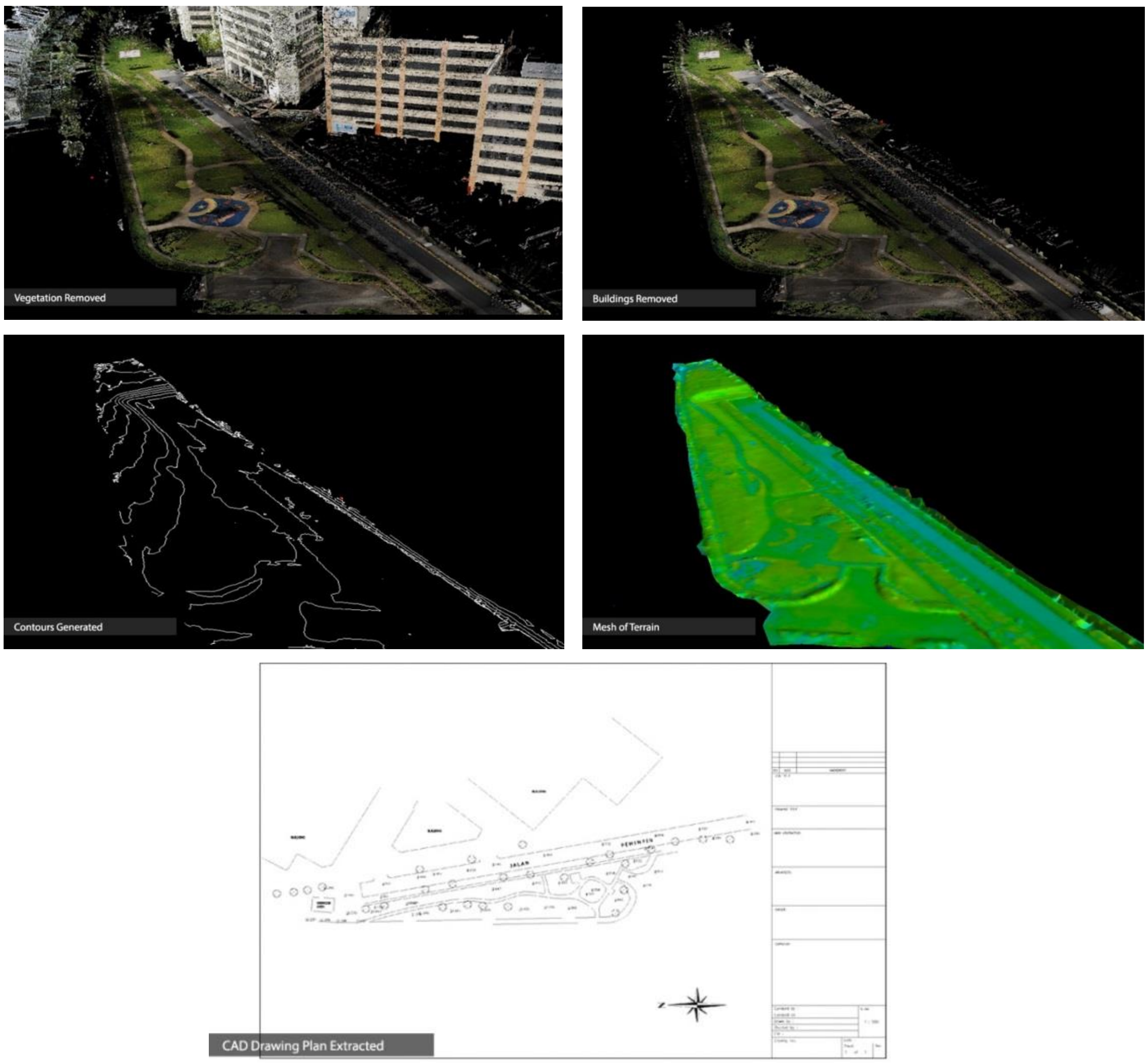
It is possible to have 3D topographic survey plans with 3D lines but 2D symbols for features like trees and lamp posts. If the 3D features are to be shown as accurate 3D models, then both the top and bottom of the lamp post shall need to be captured to scale the 3D symbols of the feature. This implies that additional map layers for the top of the 3D features will need to be specified in the Standard and Specifications for 3D Topographic Mapping.

The above guide adapts the traditional surveying methods using total station for BIM compatibility. BIM software can process the field survey data in both CAD and BIM format for use by other building and construction professionals. The surveyor needs to be familiar with importing survey data from survey equipment into BIM software or exporting data from BIM models for reference. Such use cases may involve the use of GPS, 3D Lidar or photogrammetric tools.

In the integration of BIM with other formats of information, an understanding of the differences between BIM, 2D CAD, 3D CAD and GIS is important. The surveyor must integrate BIM models, 3D models and 3D survey/GIS data such as TIN and DTM. It is not just the ability to perform basic BIM tools and functions or manage the user interface, setting preferences and reviewing projects. It is the ability to adapt and integrate data from different data sources with an appreciation and the intrinsic grasp of data accuracy and precision that only the surveyor can possess. It is also the ability to assess the appropriate level of information and data quality requirements (fitness of use) for the application or task at hand.

Producing the Surface Model from Topographical Survey

Acknowledgement: Mr Gerry Ong (GPS Lands Singapore)



Strata Surveys for Buildings

BIM Models and Cadastral Strata Surveys

A cadastral land survey delineates the land ownership boundary of a unique land lot. The proposed site boundary or cadastral boundary of the land lot will be incorporated into the BIM site model to allow designers to plan and design the building layout and orientation. Strata surveys depict the final boundaries of a strata lot in a Strata Certified Plan (CPST). As BIM models are rich data sources for buildings, BIM applications have huge potential to be applied to surveys involving buildings.

In the pre-construction stage, the architect would design the strata units in a BIM model, following which the surveyor is required to compute and certify the proposed strata area to facilitate the sale of the strata units. This strata area is subject to a final survey by the surveyor after construction is completed. The surveyor should be familiar with extracting relevant information from a reference BIM model for strata surveys. A BIM model allows for the collaboration and communication of architect and surveyor to be improved. The BIM model is used to coordinate and communicate the proposed strata areas for various unit layouts before the construction of the strata units.

The following use case is one of a public housing project where the architect designs the respective unit types in BIM format. Here, the strata boundary of each unit type is incorporated within the design to determine the strata area. The architect would then proceed with the design of the whole project based on this information. The unit type file is then sent to the surveyor for verification and endorsement.

The surveyor would verify and comment, if any, and the architect would revise the BIM model before returning it to the surveyor. After a final check, the surveyor would endorse the plans for the architect's use. This ensures a smoother coordination between the surveyor and architect.

By incorporating the strata boundary upfront during the design stage, the architect can factor in the strata area and how it would affect the overall design and yield of the blocks within the project. This minimises unnecessary drastic amendments to the design to meet the targeted yield arising from minor differences in the unit type area. A standard guide on defining the strata boundary for HDB projects also helps to enhance a common understanding of the strata area interpretation between the architect and surveyor.

Sample of a Unit Type Plan Extracted from a BIM Model

Acknowledgement: Housing & Development Board

Adopting a single BIM model over multiple reference CAD plans has advantages for the surveyor. A single highly structured data format from the architect providing complete, consistent, and clear information on the strata unit will benefit the surveyor. The 3D nature of the BIM model allows the surveyor to examine relevant information and visualise much better, especially when unit designs become more innovative and less regular in configurations. The capability of BIM to generate plans easily with standard templates for items such as surveyor's certification, north point and auto-generation of information such as strata unit areas can help avoid drafting or editing errors like wrong strata unit areas or wrong north points.

Calculations can be obtained and verified easily for GFA calculation of the whole building after the GFA has been defined in the BIM model. The native BIM file is submitted by the architects to the authority to support their GSA calculations. In parallel with the GFA, in time, it may be possible that more automatic verification of strata areas may become feasible for strata units with more uniform and standard designs.

Currently, there is a review of the existing cadastral system in Singapore to become a true 3D cadastre. BIM models, with its rich information, may serve as a source of information for building models with the 3D cadastral framework. This will be a potential use case of BIM models for further research and development.

As-built BIM Models and Laser Scanning

Use of Laser Scanning

Laser scanning technology is a powerful tool for capturing as-built information. Common applications like as-built documentation, BIM modelling, creating 2D plans, building inspection and verification can be done faster with 3D scanning data.

New buildings are being built with interesting and complex architectural designs for aesthetics, energy efficiency and space optimisation. There are also existing old buildings with historical value that need preservation. Surveyors are involved in the as-built survey of both new and old buildings. Conventionally, the as-built survey captures the geometry such as angles and distances to produce building facade drawings and the floor plan in 2-dimensional (2D).

Today, 3D Laser scanning technology – particularly the Terrestrial Laser Scanner (TLS) - is a faster and more effective tool to capture 3D points (x, y, z) in the form of point cloud. Capturing large amount of 3D coordinates using conventional survey equipment will be slow and costly. 3D as-built point cloud data combined with photo images can be used for many purposes, namely, verification of the construction, subdivision of buildings, preservation of heritage buildings and monuments, facilities management, etc.

The TLS scanning principle is not unlike conventional radial survey using total station. When taking measurements, the scanner emits a laser pulse to the object and the time taken for the laser to travel to the object and back to the scanner is measured to determine the distance. Together with the measured horizontal and vertical angles and having some known survey control points, the three-dimensional coordinates of every single laser point on the object can be determined. Generally, the TLS workflow can be categorised into planning, control and target establishment, equipment setup and scanning, and data processing.

Planning is to be carried out prior to the commencement of a project. Planning involves understanding of project requirements and site reconnaissance to identify any obstructions to the line of sight that may introduce voids or shadows in the data. Knowledge of project requirements and site conditions helps to determine which type of equipment to use and to identify the optimal set of setup locations. The number of station setups can be planned according to overlap requirements without compromising the allocated time frame. Areas that are difficult to scan should be identified and overcome by introducing additional setups or complementing the survey with other data collection methods.

A control network consists of a collection of identifiable points with integrity to their positional accuracy. The purpose of the control network is to control the data quality, registration, and verification of the position of an instrument. The control network may be tied to a coordinate frame used by the local jurisdiction. Target placement is also equally important as it is used to register scans taken from different positions. There is a. wide variety of target types: retro-reflective targets, spherical targets, paper targets, prism targets, etc.

Some registration software can recognise natural targets and use them for registration. Easily recognisable object corners, cracks, markings, and wall planes are promising natural targets. One basic and important principle to be mindful of when using targets, is that they need to be widely spread out, not only in the X and Y direction but also in the Z direction. Additionally, scan data of the building's interior and exterior can be combined using common targets, a control network or overlapping point clouds.

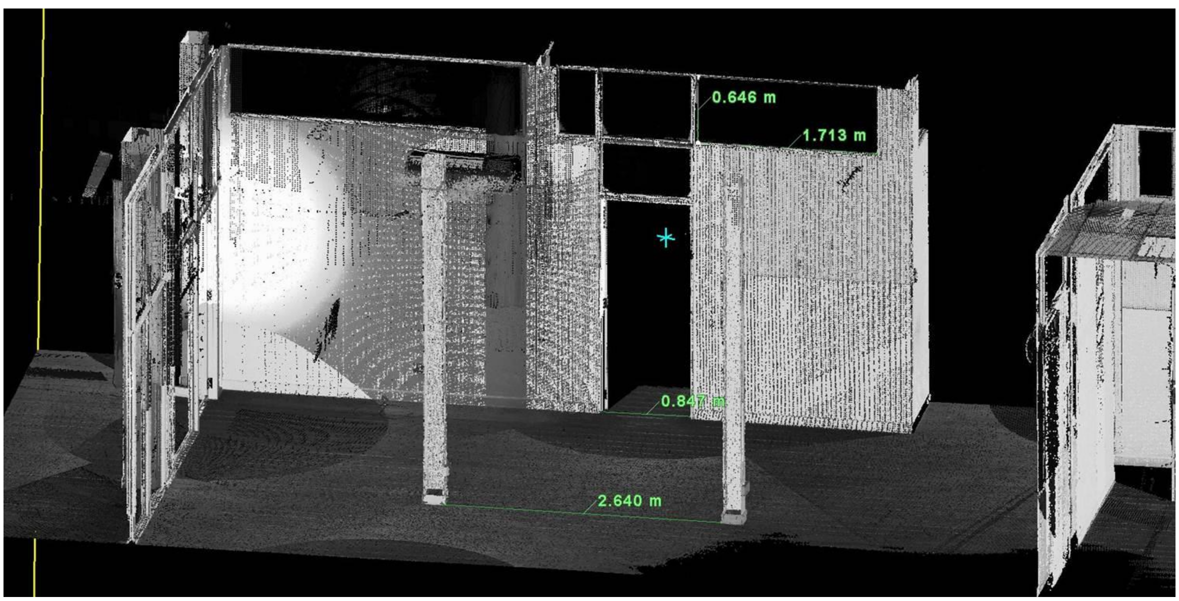
Terrestrial scanner is usually set up on top of a tripod on stable ground and levelled. Setting the scanner at a higher position provides a better inclination angle and will capture more of the data on the floor if there is a need to scan the floor. One of the key decisions in a scanning project is the selection of an appropriate resolution. Resolution is the distance between two subsequent measured points, determining the density of points in the point cloud. The resolution is selected according to the smallest detail of the surface structure that needs to be recognisable. Higher resolution means more points need to be scanned, and a resultant longer surveying time. Besides the time taken, the dataset storage size increases as well. It is good practice to re-check that the required targets and objects of interest are within the scanner's line of sight before starting any scan.

Data processing requires the scanned data to be transferred from the scanner to a computer. Some data cleaning processes are done when importing the point cloud into the software, such as filtering of noise and points beyond the scanner's effective distance. In most cases, a project has multiple scans to have complete coverage, instead of just scanning from one position. Each of these scans has its own scanner coordinate system.

Registration is the process to align and orientate these scanner coordinate systems into a global site coordinate system. There are several registration methods; the most common one is identifying and fitting common artificial or natural targets. Another way is by identifying and fitting the common point cloud features between the scanned data. One alternative is via the fitting of the common planes of the point cloud in three dimensions between the scan data. The next process is to translate the registered point cloud into the desired output format, which may be standard point cloud formats, GIS and CAD line formats, meshes, and 3D models.

Extraction of Measurements from a BIM Model

Acknowledgement: Singapore Land Authority



Clash Checks During Construction

The following use case of point clouds is clash detection for BIM integrity checks. It is an application where 3D point clouds are used for asset inspection.

BIM Integrity Checks for CleanTech

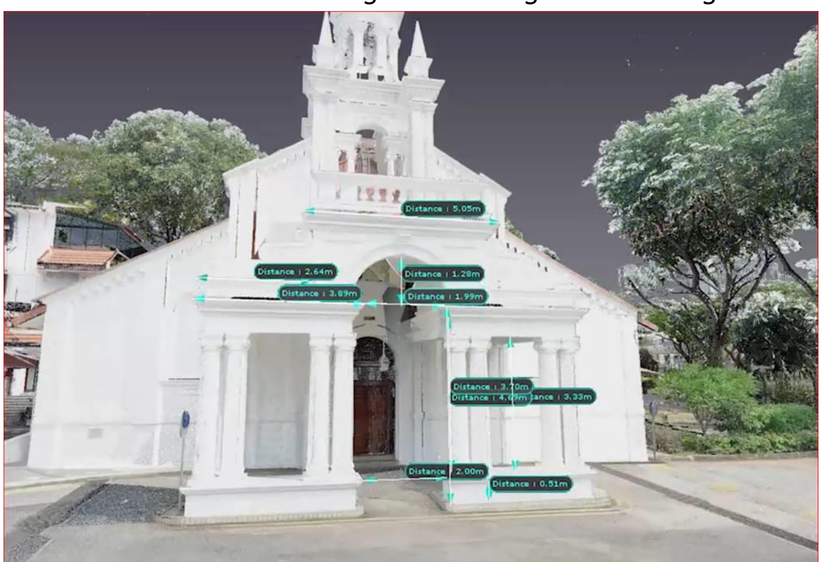
Acknowledgement: BIMAGE Consulting Pte Ltd

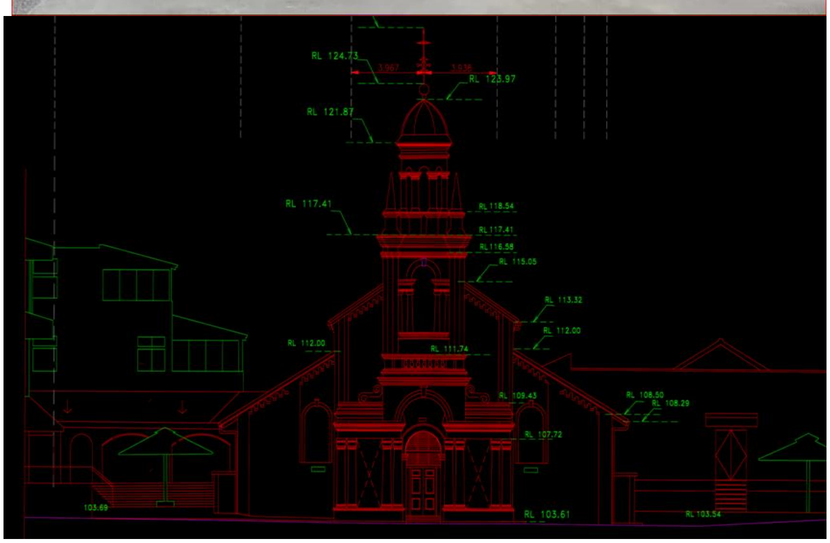
Surveys for Asset Documentation for Existing Buildings (A&A)

Some projects involve heritage buildings that need to be preserved and maintained. Such older buildings may not have documentation in the form of engineering or architectural drawings. By constructing models of the building assets, architects, engineers, and consultants alike are then able to build a catalogue of objects with full traceability.

Extraction of Line Geometry for Model Creation Directly from Source Data (High Integrity)

Acknowledgement: Tang Tuck Kim Registered Surveyor



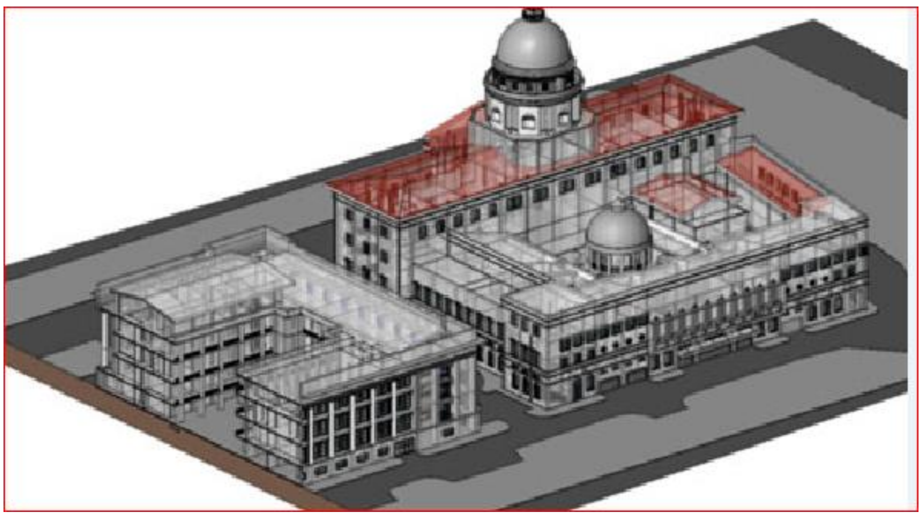


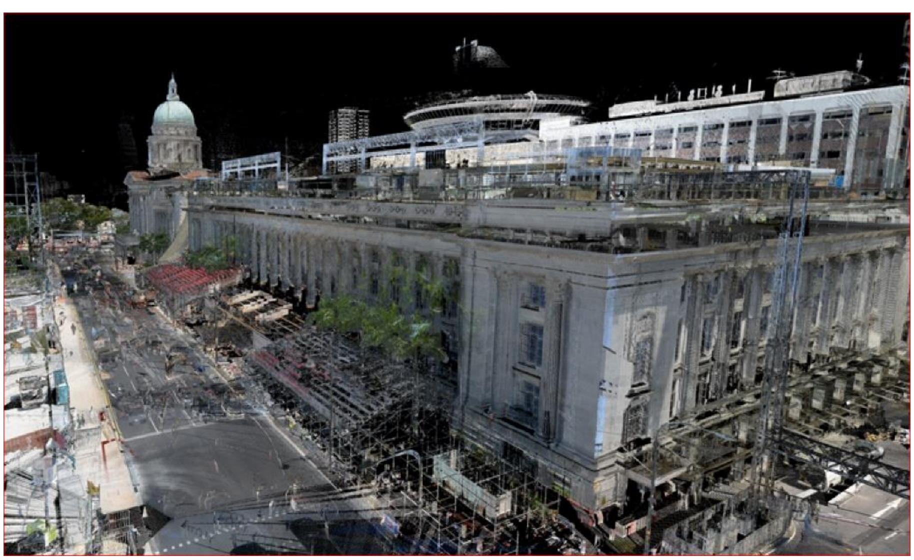
As-Built BIM Models

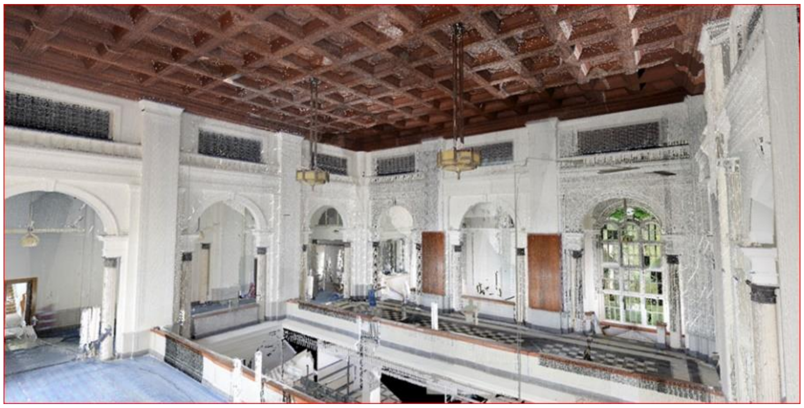
The as-built BIM model involves the technique of Scan to BIM. 3D Points are the building blocks of anything and everything in the natural and/or built environment that is represented on a plan. The below use case is the creation of as-built BIM model for the National Art Gallery.

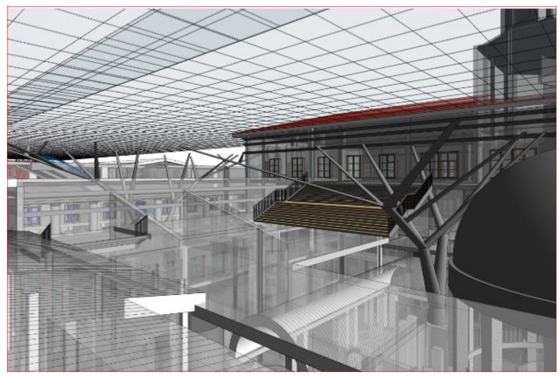
National Art Gallery Models

Acknowledgement: Di-HUB Pte Ltd









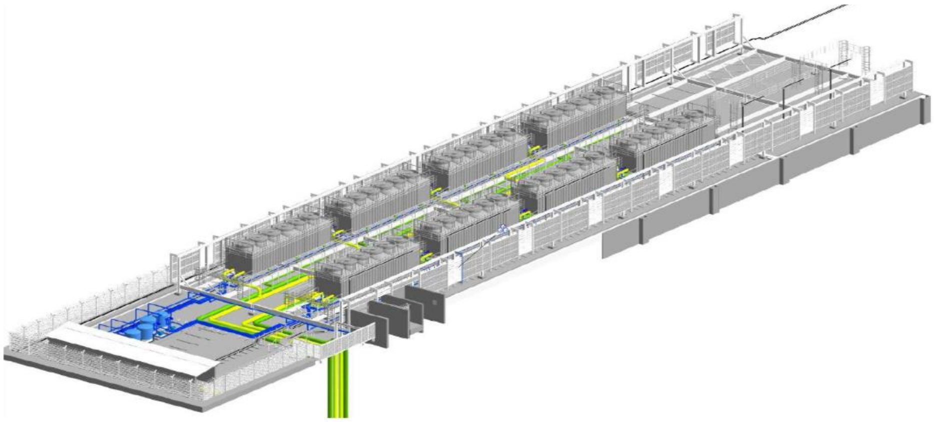
As-Built BIM Models for Facility Management

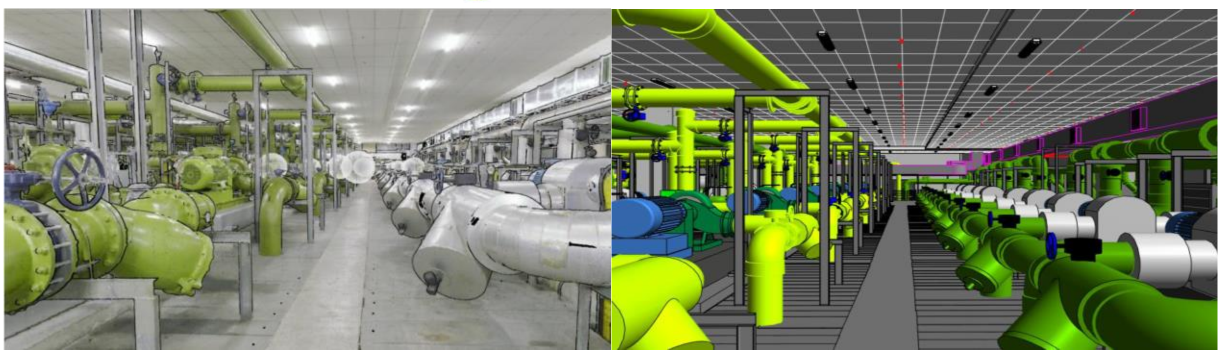
The richness of detail inherent in the 3D Point Cloud allows for the creation of BIM models at varying levels of detail (LOD) from a single data source – for example, LOD 300 for architectural and structural models, and LOD 200 for mechanical, electrical, and plumbing (MEP) models.

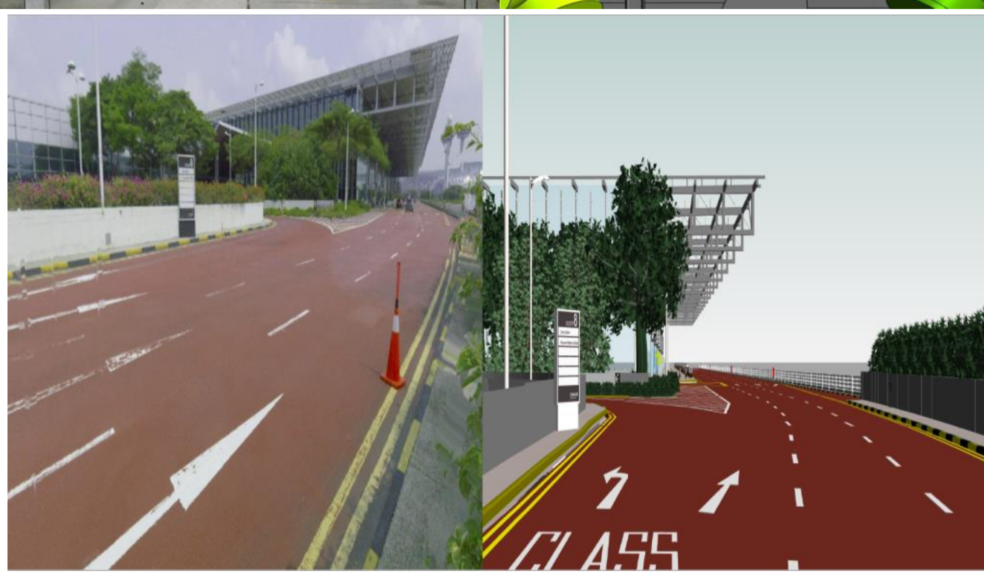
The use case below features the generation of technical drawings for architectural, structural, MEP and building services in 3D BIM format to facilitate facility and asset management, using a Terrestrial Laser Scanner. The site, Changi Airport Terminal 3, comprises scanning of every storey of the Terminal's main building and the two adjoining car parks, totaling 780,000 sqm. A TLS scanner was employed with over 27,000 scan stations throughout the 12-month field survey duration.

3D Point Cloud to MEP BIM models

Acknowledgement: Changi Airport Group and LEW Registered Surveyor







BIM to Field during Construction

BIM to field refers to the extraction of relevant BIM information and exporting it into survey instruments for setting out land boundaries and buildings during construction. Various survey instruments now have the capability to view, examine and extract relevant information from the BIM model. A BIM model is used for setting out in place of 2D plans and a set of pre-determined coordinates. This feature is increasingly common in survey equipment as BIM models may eventually replace more CAD drawings as reference information.

BIM-GIS Integration for Facilities Management and Smart City

Facilities management is probably the last frontier for BIM application in the construction industry. The facilities management sector relies very much on the monitoring of facilities for operations and maintenance of buildings. In order to track, monitor and plan pre-emptive maintenance regimes, a comprehensive system that manages massive information of the facilities, their status and location is an absolute necessity.

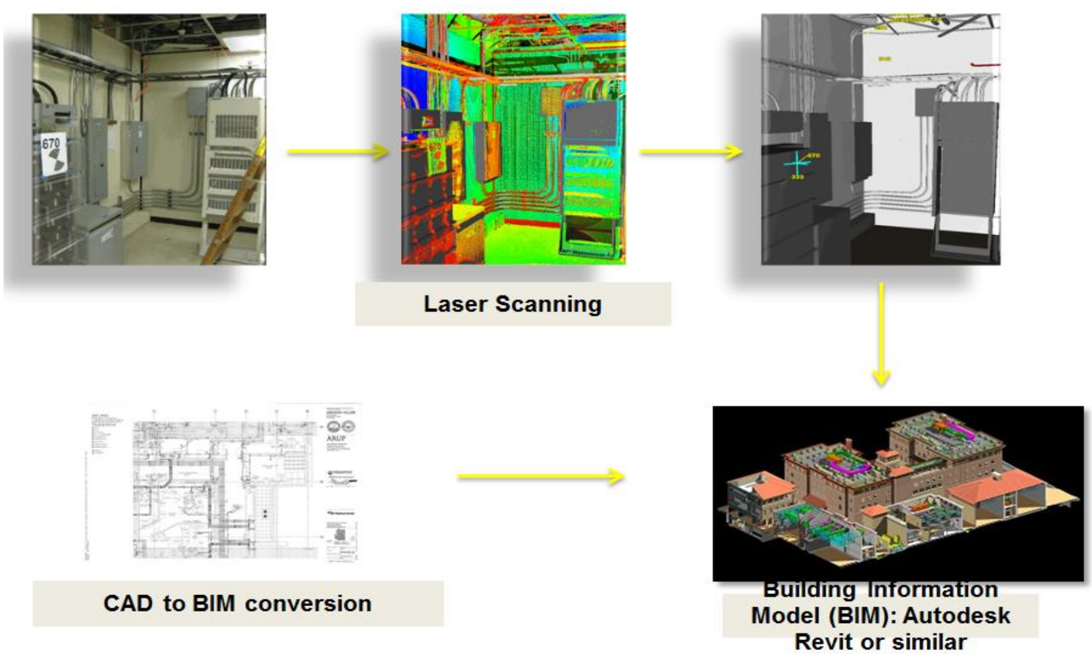
The primary challenge for FM as an industry is going beyond hardcopy plans – that is the need to go digital and manage it digitally. Initiatives, like Go Green, encourage digital data management as building information will enable the analysis and simulation. BIM offers the solution of being a good data source, and BIM for FM enables relevant information to be collected and populated in a standard format before construction. The as-built BIM model will enable FM managers to integrate data with FM systems and GIS. The surveyor can play a role in verifying the location of facilities in the verified as-built BIM during and after construction.

The buzzword “IOT”, or Internet of Things, connects sensors to central systems with internet connectivity for smart city initiatives. Developing smart city technologies and practices for infrastructure, municipal services, and green initiatives will enhance service delivery to people living and working in the urban environment. Managing complex and big data requires significant investment, deep skills and knowledge. As the original geospatial data collectors, the surveyor may consider adding value to their role as the data specialist to understand, integrate, manage, and apply data while retaining data integrity.

The following use case applies to Data audit and as-built BIM for AM/FM.

Data Audit for As-Built BIM for AM-FM

Acknowledgement: Mr Ajith Menon (BIMAGE Consulting Pte Ltd)

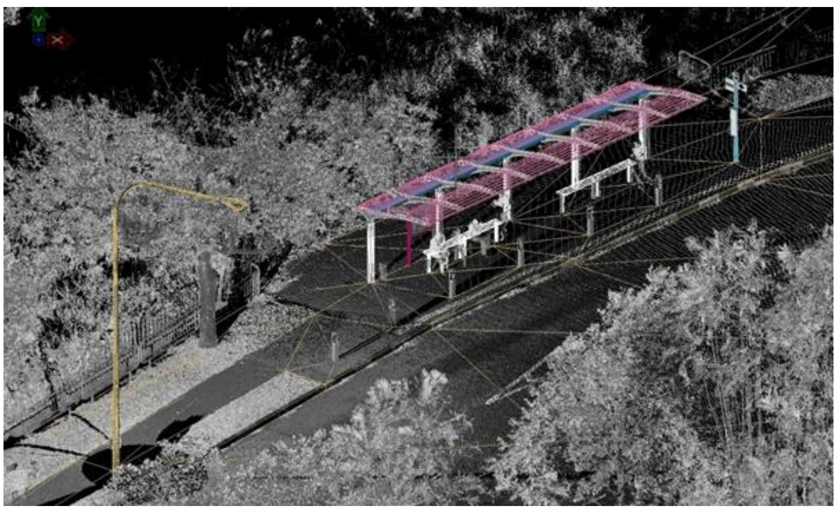


Surveys for Road and Rails (BIM for Infrastructure)

In the same way that Scan to BIM applies to buildings, it also applies to infrastructure. The following use case shows how line geometry may be extracted from point clouds.

Point Clouds and Line Geometry

Acknowledgement: Mr Leong Kin Weng (Surbana Jurong Consultants Pte Ltd)



Exporting 3D Model to CityGML LoD2

Acknowledgement: Mr Leong Kin Weng (Surbana Jurong Consultants Pte Ltd)

Surveys for Tunnel (BIM for Infrastructure)

Compared to 2D topo plans, a BIM model can aid visualisation and enhance design workflows within a 3D environment. This is especially relevant for subterranean infrastructure, such as an underground tunnel. A geo-referenced 3D BIM model of the tunnel can also serve as a reference dataset for adjacent projects by informing designers and planners of the required clearances from the tunnel for other works.

The use case featured below adopts a mobile scanning approach to overcome the difficulties of surveying along a busy expressway tunnel. A scanner mounted on top of a vehicle allows for fast and comprehensive coverage of the tunnel interior without disrupting ongoing traffic. Scan to BIM can thereafter create the required geo-referenced 3D BIM model.

Mobile Scanning of KPE Expressway Tunnel

Acknowledgement: LEW Registered Surveyor

This guide is part of the BIM Essential Guide Series

BIM Essential Guide	FOR EACH BIM PROJECT		FOR EACH ORGANISATION
	WITHIN EACH DISCIPLINE	ACROSS MULTIPLE DISCIPLINES	ALL DISCIPLINES
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For MEP Consultants	●		
For Contractor	●		
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For BIM Execution Plan		●	
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Building and Construction Authority
52 Jurong Gateway Road
#11-01 JEM Office Tower
Singapore 608550
www.bca.gov.sg

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