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3D TERRESTRIAL LASER SCANNER FOR MANAGING EXISTING BUILDING

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Graphical abstract

Abstract

Building Information Modelling (BIM) has gathered a lot of interest in Architectural, Engineering, Construction (AEC) areas. BIM introduces the 3D visualization element in designing and constructing new buildings, where the same design can be used to manage the building afterwards by assigned it as the 3D as-built. For existing building, professionals like architects and civil engineers need help from a specific hardware, like a 3D terrestrial laser scanner, to gather the data representing its interior and exterior. Although by applying 3D visualization or modelling for post-construction brings a lot of advantages, the implementation process are still slowly improving, compared for pre- and during construction, where it has reached its maturity. This paper will emphasizing on these advantages by discussing the benefits of implementing 3D as-built for current existing buildings and highlighting some case studies from projects done by Geodelta Systems Sdn. Bhd. towards several buildings in Malaysia. From here, having a 3D terrestrial laser scanner has brought a lot of improvement in managing existing buildings for various reasons, from fabrication, renovation to maintenance. Challenges of applying BIM for post-construction are also features here, to show on why the development are slow, compared to pre- and during construction process.

Keywords: Terrestrial laser scanner, building information modelling, 3D as-built

Abstrak

Building Information Modelling (BIM) semakin mendapat perhatian dalam bidang Senibina, Kejuruteraan, Pembinaan (AEC). BIM memperkenalkan elemen visualisasi 3D dalam merekabentuk dan membina bangunan baru, di mana reka bentuk yang sama boleh diguna pakai untuk menguruskan bangunan tersebut sebagai *3D as-built*. Bagi bangunan sedia ada, ahli profesional seperti arkitek dan jurutera awam memerlukan bantuan daripada perkakasan sedia ada, seperti pengimbas laser daratan 3D, untuk mengumpul data yang mewakili seni bina dalaman dan luaran bangunan. Walapun penggunaan visualisasi atau model 3D banyak memberi kelebihan dalam proses selepas pembinaan bangunan, proses ini meningkat agak perlahan, berbanding dalam proses sebelum dan semasa pembinaan yang telah pun matang. Kertas penyelidikan ini akan menekankan kelebihan ini dengan membincangkan manfaat daripada menggunakan *3D as-built* kepada bangunan sedia ada dan mengetengahkan beberapa kajian kes berdasarkan projek-projek yang dijalankan oleh Geodelta Systems Sdn. Bhd. terhadap beberapa bangunan di Malaysia. Didapati bahawa penggunaan pengimbas laser daratan 3D banyak membawa peningkatan dalam menguruskan bangunan untuk beberapa sebab, dari fabrikasi, pengubahsuaian, kepada penyelenggaraan. Cabaran dalam menggunakan BIM

dalam proses selepas pembinaan bangunan turut dikupas di sini, bagi menunjukkan mengapa pembangunannnya agak lewat, berbanding dalam proses sebelum dan semasa pembinaan.

Kata kunci: Pengimbas laser daratan, *building information modelling*, *3D as-built*

1.0 INTRODUCTION

3D visualization of existing buildings has gained a lot of interest since the late 1990s, due to the growth of Building Information Modeling (BIM), as well as the rapid development of 3D laser scanners. BIM, which is a process developed to assist prior to and during construction stages of new buildings that combines visualization technologies (3D modelling) with related information such as cost, materials and timing, was introduced by American architects and engineers. 3D visualization / modelling is used to illustrate how the building will look like to the owner and contractors before the construction start. Contractors will be using the same model to build up the building, and later, building owners and managers can use the same model as the as-built drawings for maintenance purposes. The continuous use of the same 3D model in BIM, is being referred to as building lifecycle and is very functional as all related people are only using and depending on the same 3D model to design, construct, use and manage the building, compared to the current method where different drawings and platforms are used.

Due to its benefits, this 3D visualization is then extended further for currently in-use buildings. Current conventional approach in managing existing building is by using 2D as-built. However, the aspect of visualization is missing and almost unappreciated by people like the building owners, as they usually have problems to understand the drawings.

To develop this 3D model for existing buildings, 3D measurement systems such as the 3D laser scanner have been used to collect 3D data representing the exteriors and its interiors. 3D laser scanners have the advantages of high point density, rapid acquisition of 3D data and good accuracy, making it the preferred hardware in collecting 3D data of buildings. Despite this growth, developing 3D modelling of in-use buildings, however, is challenging. Quoting Smith and Tardif in their book about BIM, although BIM has been implemented widely in developing new buildings, adapting BIM in existing buildings is 'continually improving' [1]. This is due to several reasons such as the existence of clutter, in terms of furniture, people, and the surroundings (e.g. trees), as well as its complex construction.

This paper will highlight on the usage of laser scanners in aiding the process of generating 3D model representing existing buildings. Currently, there are three types of laser scanners – terrestrial (TLS), aerial (ALS) and mobile (MLS) – which has laser scanner mounted on top of moving vehicle. All of these scanners can be used to collect and generate 3D point cloud data representing existing building for further modelling. However, the usage of ALS and MLS are limited to exterior data collection only, and thus, will not be covered in this paper. Case studies will be reviewed and discussed here to show that the TLS is capable in generating 3D model of present buildings.

Since 3D visualizations of buildings are getting more attention, a number of researches work have been done in reviewing its current status and conditions (problems, issues, challenges). Cignoni and Scopigno in [2] for example, have reviewed the usage of 3D scanning devices in presenting their capabilities in generating 3D models, but the scope is limited to cultural heritage applications, while Tang, *et al*. [3] have come out with an extensive review of all related techniques and methods use in generating similar models. Another paper by Volk, *et al*. [4] reviewed all related publications to highlights the challenges in adopting BIM into existing buildings. Here, we will highlights on advantage of using TLS in capturing 3D point cloud data to generate 3D models of existing buildings by emphasizing some case studies from projects that have been done locally in Malaysia, since the awareness on its importance is still low here. Similar paper has also being done by [5] but with the highlights of case studies worldwide.

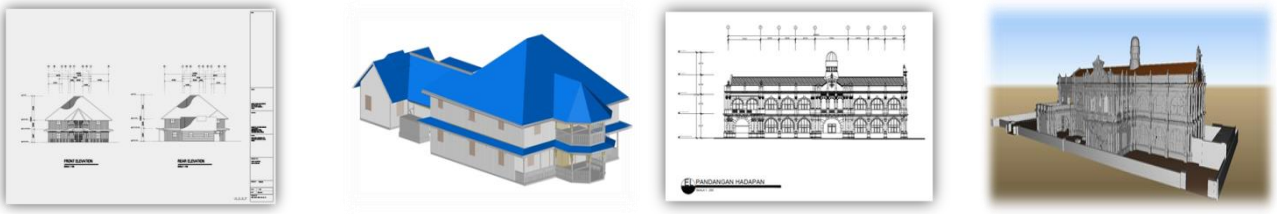
This paper will be organized as follows. Section 2.0 will highlights on the advantages of using terrestrial laser scanner in developing 3D as-built for existing building management purpose. Some case studies based on the projects done by Geodelta Systems Sdn. Bhd. will be discussed in Section 3.0 to support the benefits. Next, the challenges of applying 3D as-built for existing buildings, as part of BIM implementation for post-construction will be discussed in Section 4.0 before it ends with Section 5.0 for conclusion.

2.0 ADVANTAGES OF 3D AS-BUILT

3D as-built, being one of the elements from BIM, carries a lot of advantages, such as:

- Element of visualization – 3D drawings carry a better understanding compared to a 2D model. As seen in Figure 1, 3D models give more information about the behind / occluded scene, and is easier to be interpreted and understandable by everyone.

- Features and standardization – current practices in facilities management and maintenance have asked professionals to deal with different types of files and records, which are tedious. 3D modelling in BIM will allow all the records to be kept in the same drawings, making the management process easier, not for just facilities management but can also be extended to building forensics analysis, as well as towards conflict and collision detection.
- Laboriousness – Existing method in developing 3D Computer Aided Drafting (CAD) drawings are tedious, time consuming and requires a lot of manual effort. By adopting TLS in collecting the data, the whole process can be shortened and easier to be performed, especially with the help of suitable software.



(a) (b)

Figure 1 The visual representation of 2D as-built and 3D as-built of: (a) OKK Sedomon Memorial House, and (b) Penang Museum

Conventional approach in developing 2D / 3D model for maintenance, record, facilities management as well as assisting renovation work are by transferring measurement data collected at the building into respective CAD software. Although the element of 3D exists, 3D CAD describes a building by independent views, and no semantic relationship occurs between them. By developing 3D modelling from BIM into existing buildings, these data are being defined in terms of building elements such as walls, spaces, and beams. It also carries all the information related to the building, from the materials cost, producers, to the information of asset and facilities management, which can overcome the issues of features and standardization carries by the conventional method.

3.0 CASE STUDIES

To indicate on the advantages of having as-built in 3D, several case studies will be referred to here. The rationale on emphasizing some case studies in this paper is to illustrate various tangible and intangible benefits achieved by utilizing 3D terrestrial laser scanner for managing existing buildings. The data for these case studies is provided by Geodelta Systems Sdn. Bhd., located in Petaling Jaya, Selangor. The 3D point cloud data is generated using Leica HDS6000 TLS from Leica Geosystems High Definition Surveying (HDS) Solution.

Geodelta Systems Sdn. Bhd. has been using TLS to generate the 3D modelling of existing buildings in Malaysia for three purposes – national heritage preservations, scan to BIM (LoD 200 / 300) as well as for 3D as-built emergency clash checking. Malaysia inherits a number of important buildings due to its previous historical background, however many of them still remain in poor conditions [6]. Previous study has mentioned that around 40% of the heritage buildings surveyed in Malaysia were in poor conditions and over 80% of them have signs of serious building defects [7]. These are due to lack of proper care and protection, as no building is maintenance-free. Therefore, actions have been taken to preserve these buildings from defects and deterioration which threaten their survivals by developing a 3D model representing them. The model, which develop using the data collected by TLS, will have a very high Level-of-Details (LoD) since the data captured by the TLS are very high density and accurate. These models can be used to represent the building as close as possible, and community can use it for education, preservation and informed infrastructure purposes.

Commercial as well as residential buildings are often facing renovation and modification work to maintain its operation. Conventional approach of using 2D as-built drawing in expanding the work is very tedious and time consuming. Here, TLS has also being used by Geodelta Systems Sdn. Bhd. to come out with a 3D model in assisting renovation and clash check process, which is more time and cost savings.

3.1 Case Study 1: Pudu Jail, Kuala Lumpur – 2012

- Client – Jabatan Warisan Negara
- Objective – national heritage preservation
- Project Scope – 3D laser scanning external, detail 3D modelling, 2D drawing sets
- Software – Leica Cyclone 8.0.3, AutoCAD 2012

(a)

(b)

Figure 2 Original scenes of Pudu Jail

Being one of the important buildings in the history of our country, 3D modelling of Pudu Jail in Kuala Lumpur is requested by Jabatan Warisan Negara to be developed for national heritage preservation. Figure 2(a) shows the actual scene of the building, while Figure 2(b) shows the location of TLS while scanning the date representing the building.

Figure 3 shows the 3D point cloud data of the building exterior collected by the TLS with its 3D model. As shown here, the visualization aspect is more appreciated and valued using this model which suits with the aim of building preservation.

Figure 3 3D point cloud data gathered by the terrestrial laser scanner with its model

3.2 Case Study 2: OKK Sedomon Memorial House – 2012

- Client – Sabah Land Surveys
- Objective – national heritage preservation
- Project Scope – 3D laser scanning external, detail 3D modelling, 2D drawing sets
- Software – Leica Cyclone 8.0.3, AutoCAD 2012

Another project with the purpose of preserving national heritage was requested by Sabah Land Surveys for OKK Sedomon Memorial House, located in Keningau, Sabah. As shown previously in Figure 1, the visualization feature is more predominate in the 3D model compared to the 2D. By having the TLS to collect the 3D data, details of the building can be included in the model as well. Figure 4 shows the 3D point cloud data representing the building from bird eye view as collected by the TLS.

Figure 4 3D point cloud data representing OKK Sedomon Memorial House

3.3 Case Study 3: Penang Museum – 2013

- Client – Urbanisma Architect Sdn. Bhd.
- Objective – national heritage preservation
- Project Scope – 3D laser scanning internal and external, detail 3D modelling internal and external, 2D drawing sets
- Software – Leica Cyclone 8.0.3, 3D Reshaper 7.1, AutoCAD 2012

This national heritage preservation project was requested by Urbanisma Architect Sdn. Bhd. and is slightly differ from other similar work as the resulting model needs to cover both exterior and interior of the building. Thus, collection of data needs to be done inside and outside the buildings. By using TLS, the work of data collection which may take days to be finished before has been shortened. Figure 5 shows the actual scene representing Penang Museum while Figure 6 is the 3D point cloud data of its exterior as collected by the TLS.

Figure 5 Original scene of Penang Museum

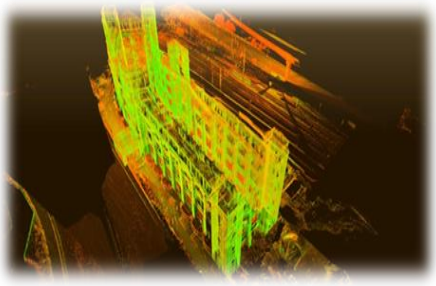
Figure 6 3D point cloud data of Penang Museum

3.4 Case Study 4: Syariah Court – 2013

- Objective – renovation purpose
- Project Scope – 3D laser scanning external, 2D drawing facade
- Software – Leica Cyclone 8.0.3, AutoCAD 2012

An example of how TLS is being used for renovation of existing building is highlighted here towards Syariah Court, Kuala Lumpur. In this case, the façade of the building needs to be renovated, hence data representing its exterior is collected to upkeep the existing façade condition as in the Historical Architectural Building Survey (HABS) report prior of renovation. Complete and detail 2D drawing for external façade were generated for reporting the conditions. Figure 7 shows the 3D point cloud data of Syariah Court as collected by the TLS.

(a)



(b)

Figure 7 3D point cloud data representing Syariah Court: (a) in colour, (b) multi hue

3.5 Case Study 4: Elite Pavillion – 2013

- Client – Juruukur Berjasa Sdn. Bhd.
- Objective – clash check for renovation
- Project Scope – 3D laser scanning, clash set, 2D drawing set
- Software – Leica Cyclone 8.0.3, AutoCAD 2012

Before any renovation procedure takes place, a clash check is being done to ensure any conflict between the mechanical, electrical and plumbing (MEP) works with the structural can be handled. These conflicts need to be identified and solved early prior to renovation. From the point cloud data collected by the TLS, an appropriate model can be generated. The model can be used to identify and resolve the conflicts quickly, avoiding additional cost and potential delays. All these improvement will not be achieved when using the incomplete design information inbuilt in a traditional 2D process.

Figure 8 shows the original scene representing the Elite Pavillion in Kuala Lumpur, which undergone a clash check for proposed roof renovation in 2013. Figures 9, 10 and 11 are the figures of the point cloud data, its model with the proposed renovation, as well as both point cloud with the model, respectively.

Figure 8 Original scene of Elite Pavillion

Figure 9 3D point cloud data of Elite Pavillion

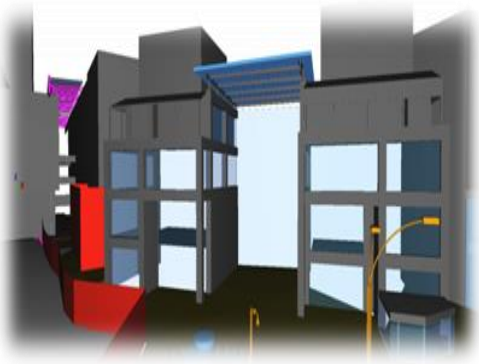


Figure 10 3D model representing the renovation (new design of the roof)

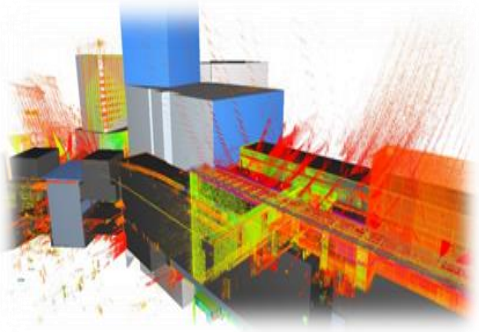


Figure 11 3D model of renovation with point cloud data

4.0 FUTURE CHALLENGE

Based on the above, it is clearly proven that the usage of 3D terrestrial laser scanner has given a lot of advantages in managing existing buildings. Table 1 supports these benefits by highlighting the duration of projects based on work when 3D terrestrial laser scanner is being adapted. As seen from the table, the duration of projects is rapid compared to months or years while adapting traditional methods.

Although the TLS provides a lot of benefits in collecting 3D data, this approach still has challenges that need to be addressed. One of them is the local acceptance of the technology implementation, which in this case, the usage of TLS and their appropriate software in generating 3D as-built. Developed countries like the US and Europeans are well adapting the technology; however, locals are still skeptical about the product produced by the TLS. Nevertheless, examples from the case studies shown here have proven Malaysia is not far away from others. Leading 3D TLS company like Geodelta Systems Sdn. Bhd. as described here has verified the technology could be adapted with the benefits offered especially in AEC application.

The accompanying software has its own limitations. Previous study has shown that 70% of the experts who involved in this area (3D modelling from laser scanners) agree that the software has some restrictions, which include manual processing as well as lack of ability in occlusion and clutter problems handling [8]. As the most natural conditions for 3D modelling applications, like building interiors and exteriors, will involve a great deal of occlusions and clutter, to have a software that is capable to handle these as well as large data capability and accessibility is required.

However, it was learned that not all point cloud are required to be modeled. Modelling our complex environment into a 3D model is depending on the project's objectives. Streaming good looking point for visualization purpose or performing complex 3D model will be the next pre-requisite prior to a TLS project when embarked.

Evolution of modelling methods toward automation will be much appreciated to handle the gigabyte of point cloud information. This will dictate a better and accurate LoD that could represent the real world concisely. A number of researches have been performed to provide alternative solutions in handling limitations of current software [9] [10]. However, more work are needed the model has to hold a higher the level-of-details (LoD) as possible.

Other important issues such as collaborative limitations, due to different TLS generates different data format and requires different processing software, as well as security and large data size concern when it comes to data sharing, need to be handled too as they could affect the usage of TLS in developing 3D model of buildings in the future.

Table 1 Duration of projects based on work

Project	Project duration / hours		
	Onsite scanning	Data processing	3D modelling
Pudu Jail, Kuala Lumpur	22	5	64
OKK Sodomon Memorial House	5	5	64
Penang Museum	48	12	120
Syariah Court	32	24	80
Elite Pavillion	32	16	96

5.0 CONCLUSION

This paper has discussed the advantages of using TLS in managing existing buildings, from various cases of national heritage preservation to clash detection for renovation work. Based from the case studies shown above, it can be seen that TLS has helped to shorten the overall process of collecting the data representing the scene, due to its ability in generating a high point density, rapid acquisition of 3D data and its good accuracy. With the help of suitable software available in the market, the process of developing such model to manage existing buildings has become easier. However, a number of challenges ahead as the adaptation of the elements of BIM, i.e. the 3D models are still deliberated compared to its usage towards pre-constructed buildings which has become mature. In order to rapidly increase the application, these challenges must be overcome as a lot of benefits have being shown here when 3D models are being adapted in existing buildings.

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References

[1] D. K. Smith and M. Tardiff. 2009. *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers.* New Jersey: John Wiley and Sons, Inc.

[2] P. Cignoni and R. Scopigno. 2008. Sampled 3D Models fro CH Applications: A Viable and Enabling New Medium or Just a Technological Exercise? *ACM Journal on Computing and Cultural Heritage.* 1(1): Article 2.

[3] P. Tang, *et al.* 2010. Automatic Reconstruction of As-Built Building Information Models from Laser-Scanned Point Clouds: A Review of Related Techniques. Automation in Construction, doi: 10.1016/j.autcon.2010.06.0007 [Accessed 13 July 2010].

[4] R. Volk, J. Stengel and F. Schultmann. 2014 .Building Information Modeling (BIM) for Existing Buildings–Literature Review and Future Needs. *Automation in Construction*. 38: 109-127.

[5] S. Azhar, A. Nadeem, J. Y. N. Mok and B. H. Y. Leung. 2008. Building Information Modeling (BIM): A New Paradigm for Visual Interactive Modeling and Simulation for Construction Projects. *Proceedings of the 1st International Conference on Construction in Developing Countries, August 2008, Karachi, Pakistan.*

[6] A. Idrus, F. Khamidi and M. Sodangi. 2010. Maintenance Management Framework for Conservation of Heritage Buildings in Malaysia. *Modern Applied Science*. 4(11): 66-77, November 2010.

[7] S. K. Kamarul, A. L. Wahab and G. A. Ahmad. 2008. Pilot Survey on the Conservation of Historical Buildings in Malaysia. *Proceedings of the 2nd International Conference on Built Environment in Developing Countries, December 2008, Penang, Malaysia.*

[8] S. A. Abdul Shukor and E. Rushforth. 2014. Towards 3D As-Built – What Say The Professionals?" *Proceedings of the FIG Congress, June 2014, Kuala Lumpur, Malaysia.*

[9] S. A. Abdul Shukor and E. Rushforth. 2014. Adapting SICK PLS 101 Laser Scanner for 3D Interior Modelling Data Collection. *Jurnal Teknologi.* 70(3): 29-33.

[10] S. A. Abdul Shukor, K. W. Young and E. J. Rushforth. 2011. 3D Modeling of Indoor Surfaces with Occlusion and Clutter. *Proceedings of the IEEE International Conference on Mechatronics, April 2011, Istanbul, Turkey.*