INTEGRATION OF AS-BUILT BUILDING INFORMATION MODELING AND AUGMENTED REALITY IN CONSTRUCTION INDUSTRY: A CASE STUDY OF THE (UTM) ECO-HOME

ABDUL RAHMAN AHSAN USMANI

A project report submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Construction Management)

Faculty of Civil Engineering
Universiti Teknologi Malaysia

JANUARY 2018

Thank You "ALLAH" for Everything ...

ACKNOWLEDGEMENT

In accomplishing to completion of this project report, I had interfered with many generous people who willing to provide me a lending hand. Undoubtedly, they have contributed significantly in expanding my comprehensions and thoughts.

Foremost, my thanks and gratitude go to my mother and father, who bestowed on me the gift of life, and to my wife, whose love and affection inspired me along the way.

Besides my family, I would like to express my sincere gratitude to my present and previous supervisors Dr. Chai Chang Sa'ar, Dr. Eeydzah Aminudin, Dr. Masoud Gheisari and Dr. Ali Keyvanfar for the continuous support of my Master study and research, for their patience, motivation, enthusiasm, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better team of supervisors and mentors for my Master study.

My sincere gratitude also extends to all my friends and others who have provided assistance at various occasions. Their willingness and lending hands are cherished.

Last but not the least, I would like to thank Nesma and Partners Co. Ltd. for giving me this exceptional opportunity to do my master degree, specially my line managers and colleagues for their motivation and prayers.

ABSTRACT

Building Information Modeling (BIM) is becoming increasingly popular in architectural documentation processes in which various stakeholders share data through consistent digital models, keeping workflow up to date to maximize reliability and quality throughout the construction cycle. Most of the constructed buildings might not be built as-designed exactly and 2D drawings are not functional to aid facility managers, viral reliance is on the traditional method to develop as-built drawings leads to greater need of developing accurate and functional 3D as-built BIM through smart workflow. 3D laser scanners are rarely used in construction industry and rarely integrated and practiced with BIM. Moreover, due to less efforts exploring the integration of the digital virtual BIM on site activities, it is predicted that Augmented Reality (AR) can fulfill this vision effectively through visualizing BIM right into the reality. However, some research studies developed workflows using 3D laser scanner to come up with 3D model, as well as workflows to adopt the 3D model into AR platforms separately. Therefore, the aim of this research is to integrate "Scan-BIM" workflow with "BIM-AR" workflow developing newly single integrated workflow. This qualitative case study investigates the current practice of as-built data development based on interviews and practice a modern method of 3D as-built BIM development through an experiment. In this study the integration between SCENE, Revit and Unity3D softwares supported with some extension softwares unveiled the possibility of integrating laser scanning, as-built BIM and AR. This research resulted in an efficient solution in developing "Scan-As-Built BIM-AR" integrated workflow that Architecture, Engineering, Construction and Operation (AECO) industries' practitioners can use to consolidate, optimize and visualize their models in a real-time AR environment.

ABSTRAK

Building Information Modeling (BIM) menjadi semakin popular dalam proses mendokumentasi kerja seni bina di mana pelbagai pihak berkepentingan boleh berkongsi data melalui model digital yang konsisten, dapat menjaga aliran kerja agar sentiasa seiring dengan perkembangan semasa untuk meningkatkan kebolehpercayaan dan kualiti sepanjang proses pembinaan. Kebanyakan bangunan yang dibina mungkin tidak setepat yang direka dan lukisan 2D pula tidak membantu pengurus fasiliti, pergantungan terhadap kaedah tradisional untuk membangunkan lukisan yang direka menyebabkan perlunya penggunaan 3D BIM yang tepat dan mempunyai pelbagai fungsi. Pengimbas laser 3D jarang digunakan dalam industri pembinaan dan kurang diintegrasikan dan dipraktikkan dalam BIM. Tambahan lagi, disebabkan kurangnya usaha untuk menerokai integrasi BIM dalam alam maya digital bagi aktiviti di tapak pembinaan, dijangkakan bahawa Augmented Reality (AR) dapat memenuhi visi ini secara berkesan dengan menggambarkan BIM terus ke realiti. Namun, beberapa kajian tentang aliran kerja menggunakan pengimbas laser 3D untuk menghasilkan model 3D serta aliran kerja untuk mengadaptasi model 3D ke platform AR telah dilakukan secara berasingan. Oleh itu, matlamat penyelidikan ini adalah untuk mengintegrasikan aliran kerja "Scan-BIM" dengan aliran kerja "BIM-AR" mmjadi satu elemen. Kajian kes kualitatif ini mengkaji amalan terkini dalam merekod data sesuatu projek berdasarkan temubual dan mempraktikkan BIM 3D melalui satu eksperimen. Dalam kajian ini integrasi beberapa perisian seperti SCENE, Revit dan Unity3D dibantu dengan beberapa perisian lain dilakukan untuk menghasilkan suatu kemungkinan integrasi antara pengimbas laser, BIM dan AR. Dapatan kajian ini adalah suatu penyelesaian yang efisien dalam membangunkan “Scan-As-Built BIM-AR” yang boleh digunakan untuk industri seperti Arkitek, Kejuruteraan, Pembinaan dan Operasi (AECO) untuk menggabungkan, mengoptimumkan dan memvisualisasikan model mereka dalam alam nyata.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BIM	-	Building Information Modeling
AR	-	Augmented Reality
MAR	-	Mobile Augmented Reality
VR	-	Virtual Reality
3D	-	Three Dimensional
2D	-	Two Dimensional
4D	-	Four Dimensional
AECO	-	Architecture, Engineering, Construction, Operation
O&M	-	Operation and Maintenance
MEP	-	Mechanical, Electrical and Plumping
FM	-	Facility Management
GDP	-	Gross Domestic Product
IT	-	Information Technology
ICT	-	Information and Communication Technology
LCA	-	Life Cycle Assessment
GPS	-	Global Positioning System
GIS	-	Geographic Information System
CAD	-	Computer-aided Design
RFID	-	Radio-Frequency Identification
LiDAR	-	Light Detection and Ranging
HMD	-	Head Mounted Display
PC	-	Personal Computer
IFC	-	Industry Foundation Class
API	-	Application Programming Interface
PCD	-	Point Cloud Data

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Construction industry is one of the most important industries that contribute to socio-economic growth specially in developing countries. Most importantly, construction industry contributes remarkably to the Gross Domestic Product (GDP) of Malaysia's economy as well as most of the developing countries. The nature of the construction industry is unique, fragmented and complex which mostly face numerous problems like time overrun, cost overrun and waste generation. Those problems need to be solved through many research studies in different related fields integrated to the construction industry (Hussin *et al.*, 2013)

Nowadays, the construction industry is facing new challenges. The demand is increasing for new infrastructure, mitigation in the consumption of resources and energy, and a real advancement towards sustainable environmental built. The construction industry is turning increasingly towards sustainability. In the construction industry, sustainability relies upon accomplishing the most reduced conceivable ecological effect while empowering economic and social improvement (Diaz & Anton, 2014). According to Farzad & Ahmad, (2014) during conceptual stage, different design alternatives can be assessed through BIM assist by designers, so that effective energy strategies can be attained within the green building constraints. In addition, designers can choose appropriate types of building materials which have considerable impact on the cost of the building overall and its life cycle.

BIM is an Information Technology (IT) enabled approach. It is implementing and maintaining digital representation dynamically for the information of a facility indifferent phases of the project lifecycle. Moreover, it forms a warehouse of the data. The infrastructure's data includes non-geometric and, geometric data (Ellis, 2006). Kim *et al*, (2013) defined BIM as the whole construction information and the overall life-cycle of a construction project, including all phases; design, construction and maintenance, which is managed through Three Dimensional (3D) objects. BIM is one of the increasing demanded fields nowadays as many international organizations and government is taking the initiative to support BIM in project life-cycle (Aziz *et al*., 2016). In project life-cycle, BIM provides benefits overlap, reduce real project risks; irrelevant documents eliminated; waste reduces; productivity increases; cost decreases; profit increases as improves product, improve services delivered, or expand market share (Smith & Tardif, 2009).

Eastman *et al*., (2008) explained that, the modern approach to collecting, organizing and integrating as-built data of a building into a data structure is to develop an as-built BIM. As-built models and depictions are crucial documents used during operations and maintenance as well as in construction of buildings for a variety of purposes. These documents are continuously verified, and the procedures are frequently updated, especially in the initial handover process so that changes made during the project's lifespan are reflected. As a result of this, as-built documents are highly valuable to building owners and managers (Gallaher *et al*., 2004).

According to Williams *et al*., (2014), BIM technologies are vastly embraced by the Architecture, Engineering, Construction and Operation (AECO) industries. Mobile devices have become a useful and reactive interface for AECO industry. With the mobility and the accessibility to the desired data, it is popular to move among various locations during accessing specific data. However, accessing the different levels of data during normal interaction with Mobile devices by AECO industry, users are provided by integrating AR, mobile devices and developing an incorporated MAR medium.

The Augmented Reality (AR) is a live direct or indirect view of a physical real-world environment (Siddhant Agarwal, 2016). The 3D and 4D objects are made by computer graphics using virtual reality (VR) technology. The practical engineers in construction site do not pay attention to those objects because they use to think that the graphic objects cannot be used in real construction site and they are just virtual objects. For this reason, AR technology can be a useful tool for the construction project. So, AR environment can be achieved when VR object is merged with real image, can reduce the difference between the object by computer graphic and the object by real image. If project engineers use only VR object for virtual construction of bridge facility, they do not feel interested in those objects. However, if they use the AR objects merged with real image, they can have an interest because the image includes real construction status (Kim *et al*., 2013).

Conveying AR to the handheld mobile devices and building up an incorporated mobile augmented reality (MAR) environment can furnish users in the AECO industries with the chance to effectively get to their augmented layers of data through common communication with their cell phones. MAR has been the subject of research for quite a long time in recent years, and it has evolved in complexity, not only in terms of software but also hardware. From HMDs to handheld mobile devices or glasses , the field of MAR is constantly changing as technology rapidly improves and makes AR more accessible to the consumer (Williams *et al*. 2014).

By connecting different information technologies, AR can be widely utilized in construction. Smartphone users can recognize the GPS information for the holder position by a certain key on the phone. The position information can be forwarded to 4D simulation server and real components can be viewed via AR. This procedure will ease the understanding of the advances statutes for the construction manager on time. The provided technique is predicted to provide ease in minimizing the construction and design mistakes beforehand, as well as minimize the time required to choose an improved construction technique and structure units (Kim *et al.*, 2013).

The construction industry has started to embrace BIM, however, the usage of it through the project lifecycle is still limited to the design phase. AR, is a new and rising technology in the industry which is considered to fill the gap that BIM has for on-site use in the construction industry. BIM is used for the enhancement of the effectiveness of design coordination. However, in complex projects BIM is unable to consider the uncertainty related to the design modifications and rework that occurs during the construction. The utilization of an inbuilt context awareness and intelligence layer provides a system which can handle the integration between BIM and AR. Therefore, the data related to 'as-built and as-planned progress' and 'current and future progress' can be acquired and presented visually. Finally, BIM and AR use and their integration for AECO practices are still new and there are a few empirical research studies and data on these topics.

1.2 Problem Statement

BIM is quite widely used in the design phase as it is significantly less used by site workers in the construction phase which is still dominated by paper in the form of drawings (Bråthen & Moum, 2015). Berlo & Natrop (2015) stated *"In a BIM data collection much more information is available, but this information stays hidden for construction workers on site. With a raising complexity and fragmentation of experts on a construction site, most drawings don't seem to provide enough information, and are not specific enough for specialized tasks"*. Moreover, the practical engineers in construction site do not pay attention to those objects because they to think the graphic objects cannot be used in real construction site and they are just virtual objects. For this reason, augmented reality technology can be a useful tool for construction project. If project engineers use only VR object for virtual construction of bridge facility, they do not feel interested in those objects. However, if they use the AR objects merged with real image, they can have an interest because the image includes real construction status

(Kim *et al.*, 2013). According to Wang & Love, (2012), there was a lack of investigation and exploration of the real-time communication and combination of BIM to the site activity conditions and the integration of BIM with the site staff. Therefore, it is imagined that AR can fulfill the sight effectively by visualizing BIM onto the physical frame of each site task.

As mentioned in the first place, by all known project data; BIM+AR both can supply by all known project data an integrated computer based collections. BIM includes design data, management data, geometric and non-geometric data. The management data such as supplier information, material cost and properties along with schedule and organizational data. However, via AR, these data can be easily visualized, as it can guide and monitor site workers over the construction of actual buildings. Additionally, it enhances the quality of the work. Certain designs might be more adequately grasped by enlisting virtual models including objects in the real scene. Consequently, particularly in case of complex designs in compelled spaces, it can be uncomplicated to build quickly and accurately as planned. (Wang & Love, 2012).

BIM is a tool with great potential for achieving sustainable design but currently this potential is still underused. One of the main reasons for this is the lack of interoperability (Nisbet & Dinesen, 2010). BIM's potential for sustainability could be enhanced by creating synergies with other existing tools such as Life Cycle Assessment (LCA) (Diaz & Anton, 2014).

In data transferring and editing area, during the duplication of the data or registering new data within construction phase, it is crucial to eliminate the need of reentering the same data. The utilization of BIM helps to prevent useless waste of resources and time affected by wasteful data management. It has been estimated that at present, similar information might be entered up to seven times in the construction industry, (Sjogren, 2011). BIM has the ability to improve the quality and accuracy of financial estimations, which was resulting in mistakes, regardless of the competence and diligence of everyone involved (Smith & Tardif, 2009).

All planning and design activities work with data on behalf of physical assets. Architects, planners, and directors generally collaborate with the stakeholders through different data models, so their mental models are associated with this present reality through different Personal Computer (PC) applications and documents. The PC applications used to aid the different work activities, as well as the documents (soft copy or hard copy) that present the majority of the data from which participants build their mental models. This is the issue since site work requires working with data as well as changing physical assets to a built facility. Much time is squandered of the fact that designs or drawings are misjudged, or the data is being followed and built imprecisely. (Froese, 2010). There is evidently a need for a data linkage that can empower users to be undependable to data and guide users to a higher standard in order to link data with the physical assets in a more clear and effective way. (Wang & Love, 2012).

The greatest capacity of BIM is its nature of integration, among the building disciplines, and different stages of the building life-cycle as it relates to a sustainable world at the front end of a project during design, construction, and operation phases (Krygiel & Nies, 2008). The incorporation of sustainable design strategies and BIM technologies have the power to change the traditional design practices and to produce a high-performing building efficiently (Azhar *et al.*, 2010). BIM has a numerous softwares which are capable to analyze in detail several environmental sustainable categories such as; sustainable site development; embodied energy and thermal analysis; optimum orientation of the building analysis; energy consumption, savings and cost analysis; water harvesting and consumption analysis; indoor air quality analysis; natural ventilation analysis; and indoor day lightening analysis. Those features in softwares that BIM provided can trigger the whole construction industry as the existing facilities and buildings work towards a sustainable globe.

Finally, without a doubt there is a lack of research which has been done in adoption of BIM and AR through the whole life-cycle of a project. However, adopting a new method such as using 3D laser scanners to scan a building or a facility interiorly and exteriorly need to be examined, studied, evaluated and to discover up to what extent it can be beneficial to the construction industry under this experimental study. Additionally, proposing a conceptual workflow to ease the adoption of BIM in real-time, AR environment aiding the construction industry will be a contribution to the knowledge.

1.3 Aim and Objectives

This study aimed to develop a comprehensive integrated workflow "Scan - As-built BIM - AR" based on an extensive case study. In order to achieve the aim; therefore, three objectives formulated accordingly as follows;

1. To investigate the current practice of as-built model development.

2. To examine the integration of BIM in as-built drawing development

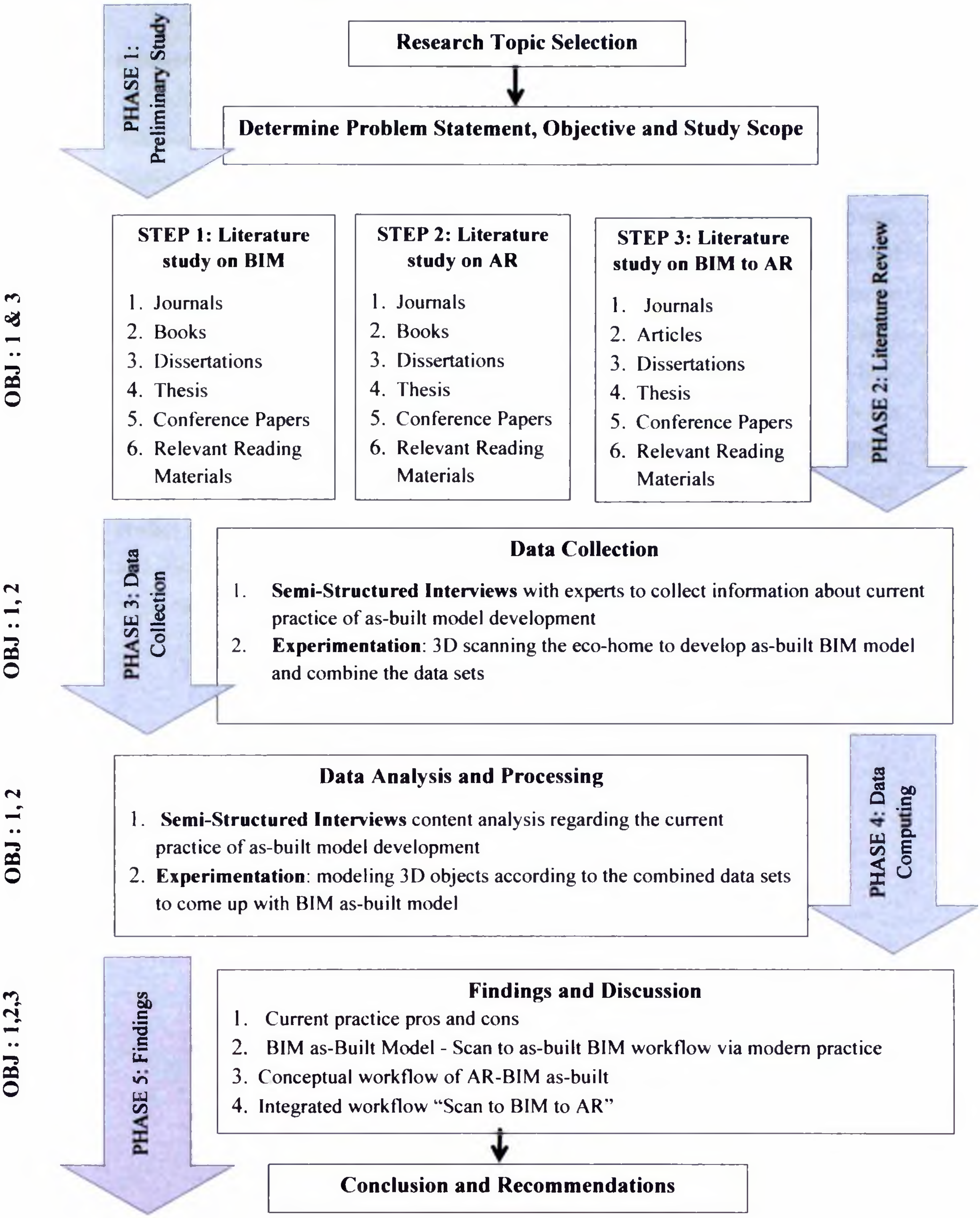
3. To develop a conceptual workflow AR-BIM as-built

1.4 Scope of Study

This research is a case study focusing on developing a workflow starting from 3D laser scanning the Eco-home in UTM, ending with a BIM as-built model. Afterwards, it aims to develop a conceptual workflow to adopt the outcome as-built model into AR platform. However, it will be focusing on the adoptability, reliability, accuracy, compatibility and easiness in achieving the outcome of the developed workflows. Furthermore, it will discuss the practitioners' usability of the workflow as well as the end-users' usage of the outcome ideal sample.

1.5 Research Methodology

Figure 1.1: Flow Chart of Research Methodology



1.6 Significance of the Study

This thesis is going to be an applied research project, leading the author through a unique experiment considered new in Malaysia and most of the developing countries. The building which is going to be scanned and experimented is a unique Eco-home, and most probably this might be one of the first experiments over the world. Utilizing highly technological devices to benefit the Eco-home facility can aid to offer many opportunities for further research case studies. So, by utilizing 3D laser scanner to scan the building and come up with an as-built 3D model. Afterward, several practical and theoretical research studies can be conducted on the model supplied which can be modified, tested, set for environmental analysis or adopted in AR field. Two workflows are going to be integrated; the first is scanning the building and coming up with as-built 3D BIM model; the second is adopting that model in AR environment. This can be the most significant part in this research combining "scan-to-BIM" workflow with "BIM-to-AR" conceptual workflow, which is considered as one of the very first research studies conducted in this field. Scan-to-BIM-to-AR workflow is able to close the gap and contribute to the body of knowledge in this field. Therefore, this will give this research an added value to all similar research studies conducted in the relative fields.

REFERENCES

Agarwal, S. (2016). Review on application of augmented reality in civil engineering. International Conference on Inter Disciplinary Research in Engineering and Technology.

Akcamete, A., et al. (2010). Potential utilization of building information models for planning maintenance activities. Proceedings of the international conference on computing in civil and building engineering, June.

Altheide, D. L. (1987). "Reflections: Ethnographic content analysis." Qualitative sociology 10(1): 65-77.

Ani, A. I. C., et al. (2015). "Building Information Modeling (BIM)-based building condition assessment: a survey of water ponding defect on a flat roof." Jurnal Teknologi 75(9): 25-31.

Aouad, G., et al. (2006). Constructing the future: nD modelling, Routledge.

Arayici, Y. (2008). "Towards building information modelling for existing structures." Structural Survey 26(3): 210-222.

Arayici, Y., et al. (2011). "Technology adoption in the BIM implementation for lean architectural practice." Automation in construction 20(2): 189-195.

Arayici, Y., et al. (2012). "Building information modelling (BIM) for facilities management (FM): The MediaCity case study approach." International Journal of 3D Information Modelling 1(1): 55-73.

Armbrust, M., et al. (2010). "A view of cloud computing." Communications of the ACM 53(4): 50-58.

Axelsson, P. (1999). "Processing of laser scanner data—algorithms and applications." ISPRS Journal of Photogrammetry and Remote Sensing 54(2): 138-147.

Azhar, S., et al. (2015). "Building information modelling (BIM): now and beyond." Construction Economics and Building 12(4): 15-28.

Aziz, N. D., et al. (2016). "Building Information Modelling (BIM) in Facilities Management: Opportunities to be Considered by Facility Managers." Procedia-Social and Behavioral Sciences 234: 353-362.

Azuma, R. T. (1997). "A survey of augmented reality." Presence: Teleoperators and virtual environments 6(4): 355-385.

Babič, N. Č., et al. (2010). "Integrating resource production and construction using BIM." Automation in construction 19(5): 539-543.

Bae, H., et al. (2014). "Image-based localization and content authoring in structure-from-motion point cloud models for real-time field reporting applications." Journal of Computing in Civil Engineering 29(4): B4014008.

Bahl, P. and V. N. Padmanabhan (2000). RADAR: An in-building RF-based user location and tracking system. INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE, Ieee

Baik, A. (2017). "From Point Cloud to Jeddah Heritage BIM Nasif Historical House–case study." Digital Applications in Archaeology and Cultural Heritage.

Baillot, Y., et al. (2001). "A survey of tracking technology for virtual environments." Fundamentals of wearable computers and augumented reality: 67.

Bajura, M. and U. Neumann (1995). "Dynamic registration correction in video-based augmented reality systems." IEEE Computer Graphics and Applications 15(5): 52-60.

Bargh, M. S. and R. de Groote (2008). Indoor localization based on response rate of bluetooth inquiries. Proceedings of the first ACM international workshop on Mobile entity localization and tracking in GPS-less environments, ACM.

Becerik-Gerber, B., et al. (2011). "Application areas and data requirements for BIM-enabled facilities management." Journal of construction engineering and management 138(3): 431-442.

Behzadan, A. H. (2008). ARVISCOPE: Georeferenced visualization of dynamic construction processes in three-dimensional outdoor augmented reality, University of Michigan.

Behzadan, A. H. and V. R. Kamat (2005). Visualization of construction graphics in outdoor augmented reality. Proceedings of the 37th conference on Winter simulation, Winter Simulation Conference.

Behzadan, A. H. and V. R. Kamat (2007). "Georeferenced registration of construction graphics in mobile outdoor augmented reality." Journal of Computing in Civil Engineering 21(4): 247-258.

Bernardini, F. and H. Rushmeier (2002). The 3D model acquisition pipeline. Computer graphics forum, Wiley Online Library.

Billinghurst, M. and A. Duenser (2012). "Augmented reality in the classroom." Computer 45(7): 56-63.

BIM Task Group (2013), Government Soft Landings: Departmental Implementation Brief, BIM Task Group, London.

Bosché, F. (2010). "Automated recognition of 3D CAD model objects in laser scans and calculation of as-built dimensions for dimensional compliance control in construction." Advanced Engineering Informatics 24(1): 107-118.

Bosché, F. and E. Guenet (2014). "Automating surface flatness control using terrestrial laser scanning and building information models." Automation in construction 44: 212-226.

Botella, C., et al. (2011). "Treating cockroach phobia using a serious game on a mobile phone and augmented reality exposure: A single case study." Computers in Human Behavior 27(1): 217-227.

Bouchard, T. J. (1976). "Field research methods: Interviewing, questionnaires, participant observation, systematic observation, unobtrusive measures." Handbook of industrial and organizational psychology 1: 363.

Bouvier, D. J., et al. (2011). An approach for occlusion detection in construction site point cloud data. Computing in Civil Engineering (2011): 234-241.

Bråthen, K., et al. (2016). "Bridging the gap: bringing BIM to construction workers." Engineering, Construction and Architectural Management 23(6): 751-764.

Bråthen, K. and A. Moum (2015). Bridging the gap: taking BIM to the construction site. Proceedings of the 32nd CIB W78 Conference.

Brilakis, I., et al. (2010). "Toward automated generation of parametric BIMs based on hybrid video and laser scanning data." Advanced Engineering Informatics 24(4): 456-465.

British Institute of Facilities Management (2012), BIM and FM: Bridging the Gap for Success, Bishop's Stortford, Hertfordshire

Brown, R. and A. Barros (2013). Towards a service framework for remote sales support via augmented reality. Web Information Systems Engineering–WISE 2011 and 2012 Workshops, Springer.

Burke, J. W., et al. (2010). Augmented reality games for upper-limb stroke rehabilitation. Games and Virtual Worlds for Serious Applications (VS-GAMES), 2010 Second International Conference on, IEEE.

Campbell, D. T. and D. W. Fiske (1959). "Convergent and discriminant validation by the multitrait-multimethod matrix." Psychological bulletin 56(2): 81.

Castle, R., et al. (2008). Video-rate localization in multiple maps for wearable augmented reality. Wearable Computers, 2008. ISWC 2008. 12th IEEE International Symposium on, IEEE.

Chantawit, D., et al. (2005). "4DCAD-Safety: visualizing project scheduling and safety planning." Construction Innovation 5(2): 99-114.

Chen, H.-M. and P.-H. Huang (2013). "3D AR-based modeling for discrete-event simulation of transport operations in construction." Automation in construction 33: 123-136.

Chen, J., et al. (2012). KinÊtre: animating the world with the human body. Proceedings of the 25th annual ACM symposium on User interface software and technology, ACM.

Chen, Y. C., et al. (2011a). A lightweight imaged based bridge inspection system using fishing pole, fishing line and fisheye camera. Proceedings of 28th International Symposium on Automation and Robotics in Construction (ISARC), Seoul, Korea.

Chen, Y.-C., et al. (2011b). A smart crane operations assistance system using augmented reality technology. Proceedings of 28th International Symposium on Automation and Robotics in Construction, Seoul, Korea.

Chi, H.-L., et al. (2013). "Research trends and opportunities of augmented reality applications in architecture, engineering, and construction." Automation in construction 33: 116-122.

Chong, W. K., et al. (2009). "Understanding and interpreting baseline perceptions of sustainability in construction among civil engineers in the United States." Journal of Management in Engineering 25(3): 143-154.

Claerbout, J. F. (1985). "Fundamentals of geophysical data processing."

Cohen, D. and B. Crabtree (2006). Qualitative research guidelines project.

Comport, A. I., et al. (2006). "Real-time markerless tracking for augmented reality: the virtual visual servoing framework." IEEE transactions on visualization and computer graphics 12(4): 615-628.

Construction, M. H. (2010). "SmartMarket Report. Green BIM." How Building Information Modeling is Contributing to Green Design and Construction.

Council, U. G. B. (2014). "LEED V4 Reference Guide for Homes Design and Construction." US Green Building Council, Washington DC.

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches, Sage publications.

Deak, G., et al. (2012). "A survey of active and passive indoor localisation systems." Computer Communications 35(16): 1939-1954.

Demchak, G., et al. (2009). Introducing Revit architecture 2009: BIM for beginners, John Wiley and Sons.

Denzin, N. K. (1973). The research act: A theoretical introduction to sociological methods, Transaction publishers.

Díaz, J. and L. Á. Antón (2014). Sustainable construction approach through integration of LCA and BIM tools. Computing in Civil and Building Engineering (2014): 283-290.

Dickinson, J., et al. (2009). A survey of automation technology for realising as-built models of services. 1st International Conference on Improving Construction and Use Through Integrated Design Solutions, CIB IDS.

Dore, C. and M. Murphy (2014). "Semi-automatic generation of as-built BIM façade geometry from laser and image data." Journal of Information Technology in Construction (ITcon) 19(2): 20-46.

Dunston, P., et al. (2003). "Mixed reality benefits for design perception." NIST SPECIAL PUBLICATION SP: 191-196.

Dunston, P. S. (2008). "Identification of application areas for Augmented Reality in industrial construction based on technology suitability." Automation in construction 17(7): 882-894.

Dunston, P. S. (2009). Key areas and issues for augmented reality applications on construction sites. Mixed Reality in Architecture, Design and Construction, Springer: 157-170.

Eastman, C. M., et al. (2011). BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors, John Wiley & Sons.

FARO PointSense, "https://www.faro.com/products/construction-bim-cim/faro-pointsense/".

FARO Scanner, "https://www.faro.com/products/construction-bim-cim/faro-focus/".

FARO SCENE, 3D Documentation Software "https://www.faro.com/products/product-design/faro-scene/".

Feng, C.-W., et al. (2010). "Using the MD CAD model to develop the time–cost integrated schedule for construction projects." Automation in construction 19(3): 347-356.

Fischer, M. and J. Kunz (2004). The scope and role of information technology in construction. Proceedings-Japan Society of Civil Engineers, DOTOKU GAKKAI.

Flick, U. (2004). "Triangulation in qualitative research." A companion to qualitative research: 178-183.

Forgues, D. and B. Becerik-Gerber (2013). "Integrated project delivery and building information modeling: redefining the relationship between education and practice." International Journal of Design Education 6(2): 47-56.

Freedman, B., et al. (2012). Depth mapping using projected patterns, Google Patents.

Froese, T. M. (2005). Impact of emerging information technology on information management. Computing in Civil Engineering (2005): 1-10.

Froese, T. M. (2010). "The impact of emerging information technology on project management for construction." Automation in construction 19(5): 531-538.

Fuchs, C., et al. (2011). "Indoor tracking for mission critical scenarios: A survey." Pervasive and Mobile Computing 7(1): 1-15.

Furukawa, Y., et al. (2009). Reconstructing building interiors from images. Computer Vision, 2009 IEEE 12th International Conference on, IEEE.

Gallaher, M. P., et al. (2004). "Cost Analysis of Inadequate Interoperability in the US Capital Facilities Industry. National Institute of Standards and Technology, Gaithersburg, Md., August 2004." About the Authors.

Gao, T., et al. (2015). "An approach to combine progressively captured point clouds for BIM update." Advanced Engineering Informatics 29(4): 1001-1012.

Gao, T., et al. (2014). "Evaluation of different features for matching point clouds to building information models." Journal of Computing in Civil Engineering 30(1): 04014107.

Garagnani, S. (2013). Building Information Modeling and real world knowledge: A methodological approach to accurate semantic documentation for the built environment. Digital Heritage International Congress (DigitalHeritage), 2013, IEEE.

Gheisari, M., et al. (2014). Exploring BIM and mobile augmented reality use in facilities management. Construction Research Congress 2014: Construction in a Global Network.

Gheisari, M. and J. Irizarry (2016). "Investigating human and technological requirements for successful implementation of a BIM-based mobile augmented reality environment in facility management practices." Facilities 34(1/2): 69-84.

Gheisari, M., et al. (2014). Locating Building Components in a Facility Using Augmented Reality Vs. Paper-based Methods: A User-centered Experimental Comparison. Computing in Civil and Building Engineering (2014): 850-857.

Golabchi, A., et al. (2013). "Leveraging BIM for automated fault detection in operational buildings." 2013 Proceedings of the 30th ISARC, Montréal.

Golparvar-Fard, M., et al. (2011). "Evaluation of image-based modeling and laser scanning accuracy for emerging automated performance monitoring techniques." Automation in construction 20(8): 1143-1155.

Golparvar-Fard, M., et al. (2009). "Visualization of construction progress monitoring with 4D simulation model overlaid on time-lapsed photographs." Journal of Computing in Civil Engineering 23(6): 391-404.

Golparvar-Fard, M., et al. (2009a). "D4AR–a 4-dimensional augmented reality model for automating construction progress monitoring data collection, processing and communication." Journal of information technology in construction 14(13): 129-153.

Grounded Theory Institute (2013). What is grounded theory? Retrieved from http://www.groundedtheory.com/what-is-gt.aspx

Gu, N. and K. London (2010). "Understanding and facilitating BIM adoption in the AEC industry." Automation in construction 19(8): 988-999.

He, Y. and Y. Zheng (2016). Making series of achievements for building entity measured by terrestrial laser scanning. Earth Observation and Remote Sensing Applications (EORSA), 2016 4th International Workshop on, IEEE.

Henderson, S. and S. Feiner (2011). "Exploring the benefits of augmented reality documentation for maintenance and repair." IEEE transactions on visualization and computer graphics 17(10): 1355-1368.

Henderson, S. J. and S. Feiner (2009). Evaluating the benefits of augmented reality for task localization in maintenance of an armored personnel carrier turret. Mixed and Augmented Reality, 2009. ISMAR 2009. 8th IEEE International Symposium on, IEEE.

Hendricks, 2016, https://www.inc.com/drew-hendricks/as-virtual-reality-grows-augmented-reality-hits-the-spotlight.html

Henrysson, A. and M. Ollila (2004). UMAR: Ubiquitous mobile augmented reality. Proceedings of the 3rd international conference on Mobile and ubiquitous multimedia, ACM.

Hichri, N., et al. (2013). From point cloud to BIM: a survey of existing approaches. XXIV International CIPA Symposium, Proceedings of the XXIV International CIPA Symposium.

Hightower, J., et al. (2000). "SpotON: An indoor 3D location sensing technology based on RF signal strength."

Hoppe, H., et al. (1992). Surface reconstruction from unorganized points, ACM.

Hou, L. and X. Wang (2013). "A study on the benefits of augmented reality in retaining working memory in assembly tasks: A focus on differences in gender." Automation in construction 32: 38-45.

Hou, L., et al. (2013). "Using animated augmented reality to cognitively guide assembly." Journal of Computing in Civil Engineering 27(5): 439-451.

Hou, L., et al. (2014). "An integration framework of advanced technologies for productivity improvement for LNG mega-projects." Journal of Information Technology in Construction (ITcon) 19(22): 360-382.

Hou, L., et al. (2014a). "Combining photogrammetry and augmented reality towards an integrated facility management system for the oil industry." Proceedings of the IEEE 102(2): 204-220.

Hove, S. E. and B. Anda (2005). Experiences from conducting semi-structured interviews in empirical software engineering research. Software metrics, 2005. 11th ieee international symposium, IEEE.

Hsiao, K.-F., et al. (2012). "Learning while exercising for science education in augmented reality among adolescents." Interactive Learning Environments 20(4): 331-349.

Huber, D., et al. (2010). Using laser scanners for modeling and analysis in architecture, engineering, and construction. Information Sciences and Systems (CISS), 2010 44th Annual Conference on, IEEE.

Hussin, J. M., et al. (2013). "The way forward in sustainable construction: issues and challenges." International Journal of Advances in Applied Sciences 2(1): 15-24.

Huynh, D.-N. T., et al. (2009). Art of defense: a collaborative handheld augmented reality board game. Proceedings of the 2009 ACM SIGGRAPH symposium on video games, ACM.

Innovation, C. C. (2007). "Adopting BIM for facilities management: Solutions for managing the Sydney Opera House." Cooperative Research Center for Construction Innovation, Brisbane, Australia.

Irizarry, J., et al. (2014). "Ambient intelligence environments for accessing building information: A healthcare facility management scenario." Facilities 32(3/4): 120-138.

Irizarry, J., et al. (2013). "InfoSPOT: A mobile Augmented Reality method for accessing building information through a situation awareness approach." Automation in construction 33: 11-23.

Jalaei, F. and A. Jrade (2014). Integrating BIM with green building certification system, energy analysis, and cost estimating tools to conceptually design sustainable buildings. Construction Research Congress 2014: Construction in a Global Network.

Jang, W.-S. (2009). "Utilization of ubiquitous computing for construction AR technology." Automation in construction 18(8): 1063-1069.

Jardim-Goncalves, R. and A. Grilo (2010). "SOA4BIM: Putting the building and construction industry in the Single European Information Space." Automation in construction 19(4): 388-397.

Jiao, Y., et al. (2013). "A cloud approach to unified lifecycle data management in architecture, engineering, construction and facilities management: Integrating BIMs and SNS." Advanced Engineering Informatics 27(2): 173-188.

Juang, J., et al. (2011). Kinesthetic and stereoscopic vision for crane training systems. Proceedings of 11th International Conference on Construction Applications of Virtual Reality (CONVR) Conference, Weimar, Germany.

Jung, Y. and M. Joo (2011). "Building information modelling (BIM) framework for practical implementation." Automation in construction 20(2): 126-133.

Kalantari, M. and M. Nechifor (2016). "Accuracy and utility of the Structure Sensor for collecting 3D indoor information." Geo-spatial Information Science 19(3): 202-209.

Kamarainen, A. M., et al. (2013). "EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips." Computers & Education 68: 545-556.

Kamat, V. R., et al. (2010). "Research in visualization techniques for field construction." Journal of construction engineering and management 137(10): 853-862.

Kang, Z., et al. (2009). "Automatic registration of terrestrial laser scanning point clouds using panoramic reflectance images." Sensors 9(4): 2621-2646.

Kans, M. (2008). "An approach for determining the requirements of computerised maintenance management systems." Computers in Industry 59(1): 32-40.

Karlekar, J., et al. (2010). Model-based localization and drift-free user tracking for outdoor augmented reality. Multimedia and Expo (ICME), 2010 IEEE International Conference on, IEEE.

Kassem, M., et al. (2015). "BIM in facilities management applications: a case study of a large university complex." Built Environment Project and Asset Management 5(3): 261-277.

Kato, H. and M. Billinghurst (1999). Marker tracking and hmd calibration for a video-based augmented reality conferencing system. Augmented Reality, 1999.(IWAR'99) Proceedings. 2nd IEEE and ACM International Workshop on, IEEE.

Kawazu, Y., et al. (2005). Comparison of the assessment results of BREEAM, LEED, GBTool and CASBEE. Proc. of Int. Conf. on the Sustainable Building (SB05).

Kelly, M. (2010). "Energy efficiency, resilience to future climates and long-term sustainability: the role of the built environment." Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences 368(1914): 1083-1089.

Khemlani, L. (2011). "BIM for facilities management." AEC Bytes 30.

Khoury, H. M. and V. R. Kamat (2009). "Evaluation of position tracking technologies for user localization in indoor construction environments." Automation in construction 18(4): 444-457.

Kim, H.-s., et al. (2013). Application of augmented reality object in construction project. Information and Communication Technologies (WICT), 2013 Third World Congress on, IEEE.

Kim, S. L., et al. (2014). Using Unity 3D to facilitate mobile augmented reality game development. Internet of Things (WF-IoT), 2014 IEEE World Forum on, IEEE.

Klatzky, R. L., et al. (2008). "Effectiveness of augmented-reality visualization versus cognitive mediation for learning actions in near space." ACM Transactions on Applied Perception (TAP) 5(1): 1.

Klein, L., et al. (2012). "Imaged-based verification of as-built documentation of operational buildings." Automation in construction 21: 161-171.

Krygiel, E. and B. Nies (2008). Green BIM: successful sustainable design with building information modeling, John Wiley & Sons.

Kuo, C., et al. (2013). "An invisible head marker tracking system for indoor mobile augmented reality." Automation in construction 33: 104-115.

LaMarca, A., et al. (2005). "Place lab: Device positioning using radio beacons in the wild." Pervasive computing: 301-306.

Lamounier, E., et al. (2010). On the use of Augmented Reality techniques in learning and interpretation of cardiologic data. Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE, IEEE.

Lee, S. and Ö. Akin (2011). "Augmented reality-based computational fieldwork support for equipment operations and maintenance." Automation in construction 20(4): 338-352.

Lee, S.-K., et al. (2012). An extension of the technology acceptance model for BIM-based FM. Construction Research Congress 2012: Construction Challenges in a Flat World.

Lertlakkhanakul, J., et al. (2008). "Building data model and simulation platform for spatial interaction management in smart home." Automation in construction 17(8): 948-957.

Liu, H., et al. (2007). "Survey of wireless indoor positioning techniques and systems." IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews) 37(6): 1067-1080.

Livingston, M. A., et al. (2011). Military applications of augmented reality. Handbook of augmented reality, Springer: 671-706.

Ma, Z., et al. (2005). "Application of 4D for dynamic site layout and management of construction projects." Automation in construction 14(3): 369-381.

Malkawi, A. M. and R. S. Srinivasan (2005). "A new paradigm for Human-Building Interaction: the use of CFD and Augmented Reality." Automation in construction 14(1): 71-84.

Markley, J. D., et al. (2008). Hybridization of photogrammetry and laser scanning technology for as-built 3D CAD models. Aerospace Conference, 2008 IEEE, IEEE.

Marotzki, W. and S. Tiefel (1995). Qualitative Bildungsforschung, na.

Matsutomo, S., et al. (2012). "Real-time visualization system of magnetic field utilizing augmented reality technology for education." IEEE transactions on magnetics 48(2): 531-534.

Meža, S., et al. (2014). "Component based engineering of a mobile BIM-based augmented reality system." Automation in construction 42: 1-12.

Mistry, P. and P. Maes (2009). SixthSense: a wearable gestural interface. ACM SIGGRAPH ASIA 2009 Sketches, ACM.

Møller, A. and M. I. Schwartzbach (2006). An introduction to XML and Web technologies, Pearson Education.

Moretti, F., et al. (2011). "A standardized approach to qualitative content analysis of focus group discussions from different countries." Patient education and counseling 82(3): 420-428.

Moum, A. (2010). "Design team stories: Exploring interdisciplinary use of 3D object models in practice." Automation in construction 19(5): 554-569.

Neumann, U. and S. You (1999). "Natural feature tracking for augmented reality." IEEE Transactions on Multimedia 1(1): 53-64.

Newcombe, R. A., et al. (2011). KinectFusion: Real-time dense surface mapping and tracking. Mixed and augmented reality (ISMAR), 2011 10th IEEE international symposium on, IEEE.

Ni, L. M., et al. (2004). "LANDMARC: indoor location sensing using active RFID." Wireless networks 10(6): 701-710.

Knowledge Autodesk, Revit Products, https://knowledge.autodesk.com/support/revit-products

Occipital. 2014. Inside the Structure Sensor By Occipital. Accessed May 10, 2016. https://www.youtube.com/watch?v=y6UE61ekF34

Ohta, Y. and H. Tamura (2014). Mixed reality: merging real and virtual worlds, Springer Publishing Company, Incorporated.

Omar, T. and M. L. Nehdi (2016). "Data acquisition technologies for construction progress tracking." Automation in construction 70: 143-155.

Papagiannakis, G. and N. Magnenat-Thalmann (2007). "Mobile augmented heritage: Enabling human life in ancient pompeii." International Journal of Architectural Computing 5(2): 395-415.

Park, C.-S., et al. (2013). "A framework for proactive construction defect management using BIM, augmented reality and ontology-based data collection template." Automation in construction 33: 61-71.

Park, Y., et al. (2008). Multiple 3D object tracking for augmented reality. Mixed and Augmented Reality, 2008. ISMAR 2008. 7th IEEE/ACM International Symposium on, IEEE.

Pereira, F., et al. (2011). "Virtual fitting room augmented reality techniques for e-commerce." ENTERprise Information Systems: 62-71.

Petrie, G. and C. K. Toth (2009). "Terrestrial laser scanners." Topographic Laser Ranging and Scanning Principles and Processing: 87-128.

Popa, M., et al. (2008). Combining cricket system and inertial navigation for indoor human tracking. Wireless Communications and Networking Conference, 2008. WCNC 2008. IEEE, IEEE.

Prakhya, S. M., et al. (2016). "Detecting keypoint sets on 3d point clouds via histogram of normal orientations." Pattern Recognition Letters 83: 42-48.

Pressigout, M. and E. Marchand (2006). Hybrid tracking algorithms for planar and non-planar structures subject to illumination changes. Mixed and Augmented Reality, 2006. ISMAR 2006. IEEE/ACM International Symposium on, IEEE.

Rabbani, T., et al. (2007). "An integrated approach for modelling and global registration of point clouds." ISPRS Journal of Photogrammetry and Remote Sensing 61(6): 355-370.

Rackham, J., et al. (2009). Composite slabs and beams using steel decking: best practice for design and construction, Metal Cladding & Roofing Manufacturers Association in partnership with the Steel Construction Institute.

Ragin, C. C. (2014). The comparative method: Moving beyond qualitative and quantitative strategies, Univ of California Press.

Razavi, S. N. and C. T. Haas (2011). "Reliability-based hybrid data fusion method for adaptive location estimation in construction." Journal of Computing in Civil Engineering 26(1): 1-10.

Rebolj, D., et al. (2008). "Automated construction activity monitoring system." Advanced Engineering Informatics 22(4): 493-503.

Redmond, A., et al. (2012). "Exploring how information exchanges can be enhanced through Cloud BIM." Automation in construction 24: 175-183.

Reitmayr, G. and T. Drummond (2006). Going out: robust model-based tracking for outdoor augmented reality. Proceedings of the 5th IEEE and ACM International Symposium on Mixed and Augmented Reality, IEEE Computer Society.

Riessman, C. K. (2005). Narrative analysis, University of Huddersfield.

Ritchie, J., et al. (2013). Qualitative research practice: A guide for social science students and researchers, Sage.

Russell, A., et al. (2009). "Visualizing high-rise building construction strategies using linear scheduling and 4D CAD." Automation in construction 18(2): 219-236.

Sandelowski, M. (2000). "Focus on research methods-whatever happened to qualitative description?" Research in nursing and health 23(4): 334-340.

Schall, G., et al. (2009). "Handheld augmented reality for underground infrastructure visualization." Personal and ubiquitous computing 13(4): 281-291.

Schlueter, A. and F. Thesseling (2009). "Building information model based energy/exergy performance assessment in early design stages." Automation in construction 18(2): 153-163.

Schründer-Lenzen, A. (1997). Triangulation und idealtypisches Verstehen in der (Re-) Konstruktion subjektiver Theorien, na.

Schwartz, Y. and R. Raslan (2013). "Variations in results of building energy simulation tools, and their impact on BREEAM and LEED ratings: A case study." Energy and Buildings 62: 350-359.

Shahi, A., et al. (2012). Activity-Based Data Fusion for Automated Progress Tracking of Construction Projects. Construction Research Congress 2012: Construction Challenges in a Flat World.

Shekhar, R., et al. (2010). "Live augmented reality: a new visualization method for laparoscopic surgery using continuous volumetric computed tomography." Surgical endoscopy 24(8): 1976-1985.

Sheng, Y., et al. (2011). "A spatially augmented reality sketching interface for architectural daylighting design." IEEE transactions on visualization and computer graphics 17(1): 38-50.

Simpfendörfer, T., et al. (2011). "Augmented reality visualization during laparoscopic radical prostatectomy." Journal of endourology 25(12): 1841-1845.

Sjøgren, J. (2011). A Norwegian IFC story and lessons learned." buildingSMART in Norway.

Smith, D. K. and M. Tardif (2009). Building information modeling: a strategic implementation guide for architects, engineers, constructors, and real estate asset managers, John Wiley & Sons.

Son, H., et al. (2010). "Rapid 3D object detection and modeling using range data from 3D range imaging camera for heavy equipment operation." Automation in construction 19(7): 898-906.

Spearpoint, M. (2007). "Transfer of architectural data from the IFC building product model to a fire simulation software tool." Journal of Fire Protection Engineering 17(4): 271-292.

Staiger, R. (2003). Terrestrial laser scanning technology, systems and applications. 2nd FIG Regional Conference Marrakech, Morocco.

Stein, M. (2012). ARCADE: a system for augmenting gesture-based computer graphic presentations. ACM SIGGRAPH 2012 Computer Animation Festival, ACM.

Strauss, A. and J. Corbin (1994). "Grounded theory methodology." Handbook of qualitative research 17: 273-285.

Su, X., et al. (2013). "Uncertainty-aware visualization and proximity monitoring in urban excavation: a geospatial augmented reality approach." Visualization in engineering 1(1): 2.

Sun, J., et al. (2016). "An automatic 3D point cloud registration method based on regional curvature maps." Image and Vision Computing 56: 49-58.

Talmaki, S. A., et al. (2010). Geospatial databases and augmented reality visualization for improving safety in urban excavation operations. Construction Research Congress 2010: Innovation for Reshaping Construction Practice.

Tang, A., et al. (2003). Comparative effectiveness of augmented reality in object assembly. Proceedings of the SIGCHI conference on Human factors in computing systems, ACM.

Tang, P., et al. (2010). "Automatic reconstruction of as-built building information models from laser-scanned point clouds: A review of related techniques." Automation in construction 19(7): 829-843.

Tonkiss, F. (2012). Discourse analysis, Sage.

Tonn, C., et al. (2008). Put on your glasses and press right mouse button AR-based user interaction using laser pointer tracking. Proceeding of the 26th conference on education in computer aided architectural design in Europe. Antwerp, Belgium.

Turk, G. and M. Levoy (1994). Zippered polygon meshes from range images. Proceedings of the 21st annual conference on Computer graphics and interactive techniques, ACM.

Unity User Manual, 2017 "https://docs.unity3d.com/Manual/UnityManual.html"

Vacchetti, L., et al. (2004). Combining edge and texture information for real-time accurate 3d camera tracking. Proceedings of the 3rd IEEE/ACM International Symposium on Mixed and Augmented Reality, IEEE Computer Society.

van Berlo, L. A. and M. Natrop (2015). "BIM on the construction site: providing hidden information on task specific drawings." Journal of Information Technology in Construction (ITcon) 20(7): 97-106.

van Treeck, C. and E. Rank (2007). "Dimensional reduction of 3D building models using graph theory and its application in building energy simulation." Engineering with Computers 23(2): 109-122.

VirtuSurv Manual, "https://www.sccssurvey.co.uk/downloads/kubit/What-is-new_VirtuSurv.pdf".

Vuforia Developer Portal, 2017, https://developer.vuforia.com/.

Wagner, D., et al. (2010). "Real-time detection and tracking for augmented reality on mobile phones." IEEE transactions on visualization and computer graphics 16(3): 355-368.

Wagner, D. and D. Schmalstieg (2003). First steps towards handheld augmented reality, IEEE.

Wakeman, I., et al. (2011). Deploying pervasive advertising in a farmers' market. Pervasive Advertising, Springer: 247-267.

Wang, C. and Y. K. Cho (2014). Automatic as-is 3d building models creation from unorganized point clouds. Construction Research Congress 2014: Construction in a Global Network.

Wang, J., et al. (2015). "Integrating BIM and LiDAR for real-time construction quality control." Journal of Intelligent & Robotic Systems 79(3-4): 417.

Wang, J., et al. (2014a). "Integrating BIM and augmented reality for interactive architectural visualisation." Construction Innovation 14(4): 453-476.

Wang, L., et al. (2016). "Energy-based automatic recognition of multiple spheres in three-dimensional point cloud." Pattern Recognition Letters 83: 287-293.

Wang, X. (2007). "Using augmented reality to plan virtual construction worksite." International Journal of Advanced Robotic Systems 4(4): 42.

Wang, X. (2009). "Augmented reality in architecture and design: potentials and challenges for application." International Journal of Architectural Computing 7(2): 309-326.

Wang, X. and H.-Y. Chong (2015). "Setting new trends of integrated Building Information Modelling (BIM) for construction industry." Construction Innovation 15(1): 2-6.

Wang, X. and P. S. Dunston (2006). "Compatibility issues in Augmented Reality systems for AEC: An experimental prototype study." Automation in construction 15(3): 314-326.

Wang, X. and P. S. Dunston (2007). "Design, strategies, and issues towards an augmented reality-based construction training platform." Journal of Information Technology in Construction (ITcon) 12(25): 363-380.

Wang, X. and P. S. Dunston (2008). "User perspectives on mixed reality tabletop visualization for face-to-face collaborative design review." Automation in construction 17(4): 399-412.

Wang, X., et al. (2008). "An empirical case study on designer's perceptions of augmented reality within an architectural firm." Journal of Information Technology in Construction (ITcon) 13(33): 536-552.

Wang, X. and P. E. Love (2012). BIM+ AR: Onsite information sharing and communication via advanced visualization. Computer Supported Cooperative Work in Design (CSCWD), 2012 IEEE 16th International Conference on, IEEE.

Wang, X., et al. (2012). BIM+ AR: a framework of bringing BIM to construction site. Construction Research Congress 2012: Construction Challenges in a Flat World.

Wang, X., et al. (2013). "A conceptual framework for integrating building information modeling with augmented reality." Automation in construction 34: 37-44.

Wang, X., et al. (2013b). Application of collaborative mobile system in ar-based visualization, data storage and manipulation. International Conference on Cooperative Design, Visualization and Engineering, Springer.

Wang, X., et al. (2014b). "Integrating Augmented Reality with Building Information Modeling: Onsite construction process controlling for liquefied natural gas industry." Automation in construction 40: 96-105.

Wang, Y., et al. (2013a). "Engagement of facilities management in design stage through BIM: framework and a case study." Advances in Civil Engineering 2013.

Want, R., et al. (1992). "The active badge location system." ACM Transactions on Information Systems (TOIS) 10(1): 91-102.

White, S., et al. (2007). Visual hints for tangible gestures in augmented reality. Mixed and Augmented Reality, 2007. ISMAR 2007. 6th IEEE and ACM International Symposium on, IEEE.

Williams, G., et al. (2014). "BIM2MAR: an efficient BIM translation to mobile augmented reality applications." Journal of Management in Engineering 31(1): A4014009.

Woo, J., et al. (2010). Use of as-built building information modeling. Construction Research Congress 2010: Innovation for Reshaping Construction Practice.

Woo, S., et al. (2011). "Application of WiFi-based indoor positioning system for labor tracking at construction sites: A case study in Guangzhou MTR." Automation in construction 20(1): 3-13.

Woodward, C., et al. (2010). Mixed reality for mobile construction site visualization and communication. Proc. 10th International Conference on Construction Applications of Virtual Reality (CONVR2010).

Yin, R. (1994). Case study research: Design and methods . Beverly Hills, CA: Sage publishing.

Yin, R. K. (2003). "Case study research: design and methods, Applied social research methods series." Thousand Oaks, CA: Sage Publications, Inc. Afacan, Y., & Erbug, C.(2009). An interdisciplinary heuristic evaluation method for universal building design. Journal of Applied Ergonomics 40: 731-744.

Yin, R. K. (2013). Case study research: Design and methods, Sage publications.

Yun, D. H., et al. (2017). "Registration of multiview point clouds for application to ship fabrication." Graphical Models 90: 1-12.

Zhang, Z., et al. (2006). "BEPAS—a life cycle building environmental performance assessment model." Building and Environment 41(5): 669-675.

Zhou, F., et al. (2008). Trends in augmented reality tracking, interaction and display: A review of ten years of ISMAR. Proceedings of the 7th IEEE/ACM International Symposium on Mixed and Augmented Reality, IEEE Computer Society.

Zhu, W., et al. (2004). "Personalized in-store e-commerce with the promopad: an augmented reality shopping assistant." Electronic Journal for E-commerce Tools and Applications 1(3): 1-19.