# Importance of BIM modelling of seismic supports on Non-structural Components for construction compliance

Arash Nazari Rad[1] and Peter Sharifi[2]

*1. Director, Structural/Seismic Engineer, MSc, MIEAust, CPEng, NER, RPEQ, PE, BLA, SeismicPro Pty Ltd, Sydney, NSW 2067, Australia. Email: Arash.nr@SeismicPro.com.au*

*2. Director, Structural/Seismic Engineer, MIEAust, SeismicPro Pty Ltd, Sydney, NSW 2067, Australia. Email: Peter.sh@SeismicPro.com.au*

## Abstract

BIM (Building Information Modelling) modelling of seismic supports for non-structural components is of paramount importance for construction compliance. Non-structural components refer to building elements that are not part of the structural system, such as partitions, ceilings, lighting fixtures, HVAC systems, and equipment. Through the application of BIM Modelling of the seismic supports for MEP-F (Mechanical, Electrical, Plumbing and Fire components), enhanced adherence to construction compliance standards can be achieved.

BIM modelling especially for seismic supports for non-structural components enhances safety and risk mitigation, ensures code compliance, facilitates coordination, saves costs and time, and promotes effective collaboration. By accurately analysing and designing seismic supports through BIM, construction professionals can mitigate risks, optimise construction processes, and create safer built environments. This paper reviewes the BIM modelling procedures, different types of seismic restraints and the portion of BIM modelling in design. Furthermore, examples of modelling output and recommendations will be provided based on real cases.

**Keywords:** BIM (Building Information Modelling), non-structural components, construction compliance, MEP-F (Mechanical, electrical, plumbing, fire), Seismic restraints

## 1 Introduction

Recent earthquakes have highlighted the susceptibility of non-structural elements to the accelerations and displacements generated by a building's seismic response. A significant portion of the earthquake-related losses observed in recent global seismic events can be traced back to non-structural component damage. NSEs (Non-structural components) typically show signs of damage even under relatively low seismic intensities, which can substantially disrupt a building's immediate functionality. This issue takes on critical importance for essential facilities like hospitals that must remain serviceable for emergency responses after the earthquake.

During the recent 2010 Chile earthquake, the Santiago International Airport was closed for several days following the significant damage to the piping systems interacting with ceiling systems (E. Miranda et al., 2010). During the same earthquake, four hospitals completely lost their functionality and over 10 lost 75% of their functionality due to damage to fire sprinklers (E. Miranda et al., 2010). Following the 2001 Nisqually earthquake in the Seattle region in the United States (US), considerable damage was observed to suspended ceiling systems and interior partition walls (A. Filiatrault et al., 2001). Significant damage to non-structural elements has been also observed during the 2012 Emilia earthquake in Italy. In this seismic event, industrial facilities reported large economic losses often related to the failure of racking systems (M. Ercolino et al., 2012). Recent earthquake sequences in Canterbury and Wellington have highlighted that losses from damage to overhead NSEs can be significant. With architectural and building services components accounting for up to 70% of a building's value (M. Ercolino et al., 2012), costs of NSE earthquake damage exceed costs from primary structural damage in some cases. Furthermore, the failure of overhead NSEs can become a significant safety hazard to building occupants during an earthquake and can inhibit business continuity (M. Ercolino et al., 2012).

The term Building Information Modelling (BIM) can be defined as a process producing and utilising a digital representation of a built entity that allows physical and functional information to be shared amongst multiple parties; in a manner that supports decision making throughout the life of a facility (ISO 29481-1, 2010 and ISO 19650, 2018). Conceptually, BIM has been discussed in the literature since the 1970s (Eastman et al., 2011), yet it wouldn't be until the 1990s that the term was actually used when, seemingly, computing capabilities were able to coalesce with the clear and present demand for integrated building information within the Architecture, Engineering and Construction (AEC) community (Van Nederveen et al. 1992 and Eastman, C. et al., 1993). Advancements in BIM technology have allowed for the synchronisation of spatial data between design and construction processes in order to enhance the following: preplanning and early collaboration, consistency of design throughout the construction life cycle as well as prevention of geometrical conflicts (clash detection) and change orders (Eastman et al., 2011 and Volk, R. et al., 2014). Further, the real-time, object-oriented, capabilities of using BIM data extend beyond three-dimensional (3D) functions to assist in numerous aspects of project management such as: quantity surveying, process visualisation and scheduling (4D) and cost estimation (5D) enabling integrated project delivery (Eastman et al., 2011 and Sacks, R., et al., 2009 and Cheung, F. et al., 2012 and Campbell, A.D. 2007).

The use of BIM can also provide records regarding the installation costs at the time of construction as well as manufacturer details (Bercerik-Gerber, B. et al., 2012 and Azhar, S. et al, 2008) of mechanical and service equipment. Furthermore, from a non-structural intervention standpoint, the typical design-construction sequence, in the interests of efficiency, rarely allows for structural engineers (or seismic consultants) to become involved in the phases that include the design and installation of architectural and mechanical contents (Hamburger, R.O. et al., 2000). However, the use of BIM could allow for real-time cost estimates and feasibility of implementation of various changes in the seismic detailing of non-structural systems (Eastman et al., 2011)

Understanding a building's details is crucial to reduce uncertainties and enhance analysis quality, especially for non-structural elements. Better coordination between consultants and contractors aims to reduce non-compliant installations, improve seismic performance, lower seismic risk, and increase the chances of business continuity after a major earthquake. Using Building Information Modelling (BIM) can greatly improve seismic assessment accuracy. Building Information modelling is defined by international standards as "a shared digital representation of physical and functional characteristics of any built object which forms a reliable basis for decision" (AUS and NZ BIM best practice, 2016). BIM is a tool to manage accurate building information over the whole lifecycle of a facility and is able to support data beyond the design and construction phases, such as the management, maintenance and deconstruction processes (J. Cheng et al., 2013 and X. Liu et al, 2012).

In the context of seismic assessment and mitigation, the utilization of BIM technology holds immense promise. By harnessing the power of BIM, engineers and researchers can access a wealth of data that was previously difficult to obtain or scattered across various sources. This paper delves into the potential benefits of employing BIM in seismic assessments, illustrating how it can significantly enhance the accuracy of our analyses. In this paper, we want to show how Building Information Modelling (BIM) can greatly improve earthquake engineering and help make buildings more resilient to earthquakes.

# 2 Seismic Restraints Solutions

Various seismic bracing systems are available for securing suspended components against seismic forces. Selecting the most suitable system for a particular project depends on several factors, including potential conflicts with other disciplines, labour and material costs, the type of supporting structure, and the nature of the non-structural components (NSCs) involved.

While standard seismic restraints for Mechanical, Electrical, and Plumbing - Fire Protection (MEP-F) supports are readily accessible, some projects possess greater complexities that necessitate a degree of customization in the seismic restraint approach. Under such circumstances, either novel restraint solutions must be devised, or a combination of standard and customized restraints must be implemented.

It is worth noting that this paper specifically focuses on typical seismic restraint systems commonly found in the Australian market.

## *2.1 Wire Bracing System*

Wire bracing is a commonly used seismic restraint system designed to secure non-structural components (NSCs) within buildings, ensuring their stability and functionality during seismic events (see Figure 1). Wire bracing operates on the principle of tension. It relies on wires or cables, typically made of steel, to restrain the movement of non-structural components during seismic events. These wires are anchored to the building's structure and are tensioned to prevent excessive swaying or displacement.

Proper arrangement of restraint wires is critical to ensure effective restraint in the desired direction. The configuration of wires is adjusted to prevent movement that could potentially damage or dislodge non-structural components.

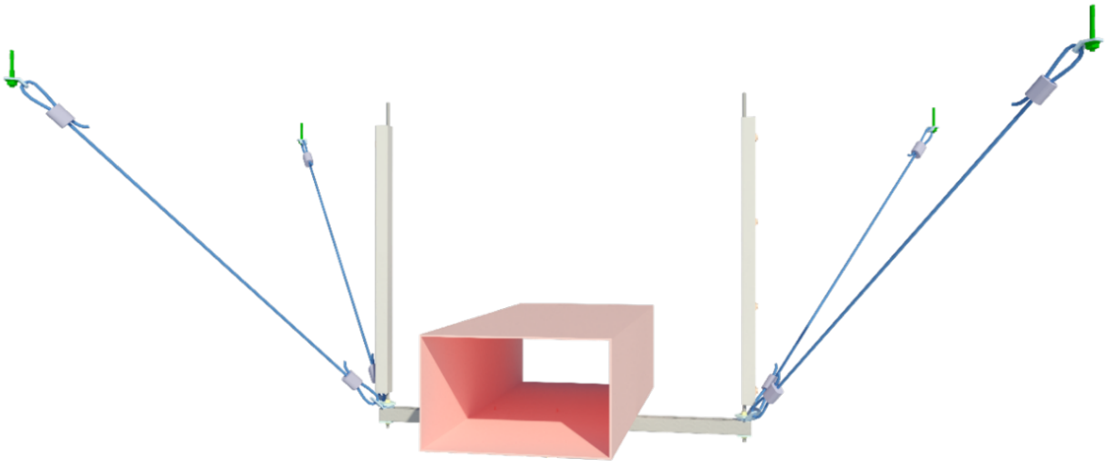

*Figure 1. 4-way wire System (SeismicPro typical detail drawing, DWG. No. SP-DW1-D.1).*

## *2.2 Strut Rigid system*

Unlike some other restraint systems that primarily operate under tension, strut rigid bracing is designed to handle both compression and tension loads (see Figure 2). This versatility allows it to effectively secure NSCs in various directions. The name "strut" comes from the solid bracing element used in this system. This bracing element connects the gravity support points of the NSCs to the building's supporting structure. Its robust design ensures it can withstand the forces generated during seismic events.

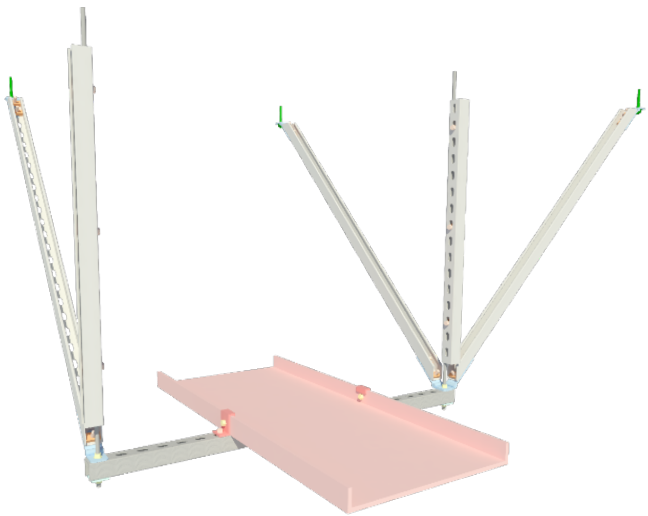

Figure 2. 3-way rigid System (SeismicPro typical detail drawing, DWG. No. SP-DH6-C.1)

### 2.3 Vertical Post

Vertical post bracing is relatively easy to install, making it a practical choice, especially in congested areas where space constraints might limit other bracing options (see Figure 3). It typically involves the use of one or two vertical posts designed to transfer loads from NSCs to the building's structure. The primary function of vertical posts is to provide moment-resistant support. This means they can effectively resist both horizontal and vertical forces during seismic events. Moment-resistant vertical posts are strategically positioned to bear the seismic loads and ensure NSCs remain stable.

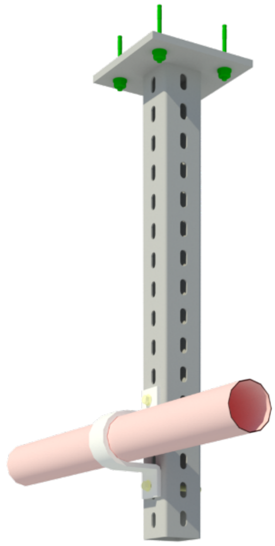

*Figure 3. Vertical Post (SeismicPro typical detail drawing, DWG. No. SP-DH5-P)*

## 3 BIM modelling advantages in NSCs seismic design

BIM modelling provides a powerful set of tools and advantages for the seismic bracing of non-structural components. It enhances accuracy, collaboration, visualization, and performance analysis, ultimately contributing to safer and more resilient buildings in seismic-prone regions. Here are summary of several advantages of incorporating BIM into the seismic bracing design.

1 **Accurate Representation:** BIM provides a highly accurate digital representation of the building, including both structural and non-structural components. This comprehensive model enables engineers and designers to assess how different seismic bracing systems will interact with the entire building, ensuring precise placement and configuration of restraints for non-structural components.

2 **Collision Detection:** BIM software includes collision detection capabilities, allowing professionals to identify clashes or conflicts between seismic bracing elements and other building components early in the design phase. This early detection helps prevent installation issues and costly modifications during construction.

3 **Enhanced Visualization:** BIM models offer 3D visualization, allowing stakeholders to visualize the placement of seismic bracing elements and their impact on non-structural components. This visual representation aids in making informed decisions about bracing locations and configurations.

4 **Parametric Modelling:** BIM allows for parametric modelling, which means that changes made to one part of the model automatically update related components. This dynamic modelling capability ensures that alterations to the seismic bracing system propagate throughout the model, maintaining consistency and accuracy.

5 **Seamless Collaboration:** BIM facilitates collaboration among multidisciplinary teams involved in the design and construction process. Engineers, architects, contractors, and other stakeholders can work together within a shared BIM environment, streamlining communication and ensuring that seismic bracing solutions align with overall project goals.

6 **Performance Analysis:** BIM software can perform structural analysis and simulate the behavior of seismic bracing systems under different earthquake scenarios. Engineers can assess the performance of various bracing configurations and make data-driven decisions to optimize non-structural component restraints for seismic safety.

7 **Cost Optimization:** BIM aids in evaluating the cost implications of different seismic bracing options. By analysing material quantities, labor requirements, and installation complexities within the model, project teams can make cost-effective decisions while ensuring structural and non-structural component safety.

8 **Documentation and Reporting:** BIM generates detailed documentation and reports related to seismic bracing design and installation. This documentation can be used for compliance with building codes and standards, as well as for regulatory approvals and construction permits.

9 **Change Management:** BIM offers robust change management capabilities, enabling teams to track and manage revisions to the seismic bracing system throughout the project lifecycle. This ensures that design changes are well-documented and implemented correctly.

10 **Lifecycle Management:** Beyond construction, BIM models can be used for facility management and maintenance. Building owners and facility managers can access the BIM data to identify and maintain seismic bracing systems, ensuring their continued effectiveness over time.

# 4 BIM modelling procedures:

The Procedure of BIM Modelling for Seismic Braces in Non-Structural Components is explained in the below steps:

1 **Initial Assessment:** Seismic Specialist to Identify the non-structural components (NSCs) that require seismic bracing, determine the seismic risk and the level of seismic performance required for the project based on Australian Standards and relevant guidelines.

2 **Assemble BIM Team:** Form a multidisciplinary team, including architects, structural engineers, MEP-F engineers, and BIM specialists then assign roles and responsibilities within the team.

3 **Create BIM Model:** Develop a comprehensive BIM model of the entire building, including structural and non-structural components and use BIM software to create a 3D model of the NSCs.

4 **Identify Seismic Restraint Locations:** Collaborate with structural engineers and seismic specialists to identify suitable locations for seismic restraints and mark these locations in the BIM model.

5 **Select Seismic Bracing System** Choose appropriate seismic bracing systems based on the specific requirements of each NSC and site constraints around the components. In addition, ensure selected systems comply with building codes and standards.

6 **Model Seismic Bracing:** Within the BIM model, add the selected seismic bracing components to the NSCs, such as wires, cables, struts, or vertical posts and accurately represent the configuration and attachment points of the bracing.

7 **Clash Detection:** Utilize BIM software to perform clash detection between the seismic bracing and other building elements and resolve clashes to ensure a coordinated design.

8 **Analyse and Validate:** Engage structural engineers to perform structural analysis on the BIM model to ensure the integrity of seismic bracing and validate the design against seismic performance requirements and make necessary adjustments.

9 **Documentation:** Generate detailed documentation within the BIM model, including plans, sections, and schedules related to seismic bracing and maintain clear records of the selected bracing systems and their specifications.

10 **Collaboration:** Foster collaborative communication among team members to ensure everyone understands the seismic bracing design and seek feedback and input from relevant stakeholders.

11 **Review and Approval:** Conduct internal reviews and simulations to evaluate the effectiveness of the seismic bracing design and obtain approvals from regulatory authorities and structural engineers.

12 **Construction and Monitoring:** Use the BIM model as a reference during construction to ensure the proper installation of seismic bracing and continuously monitor and update the BIM model to reflect any design changes during construction.

# 5. Sample of BIM modelling in the projects:

Here, we've gathered some pictures that clearly show the big improvements made by using Building Information Modelling (BIM) in one of our recent projects (see Figure 4). These images compare how things were before we used BIM for seismic restraint systems on cable trays with the much better results we got after using it. In this specific project, the benefits were numerous. They included creating an accurate project representation, spotting and fixing issues early, making things look better, and more. These advantages helped the client make smarter decisions.

Creating an accurate project representation makes a digital version of the project look just like the real thing. It's like having a detailed map to follow, so you know what to expect.

Spotting and fixing issues early helps find and solve problems before they become big headaches. It's similar to fixing a small leak in a boat before it turns into a major flood.

All this modelling makes things look better and involves improving how the project appears visually. It's like giving a room a makeover to make it more attractive. This not only makes the project look nicer but also helps the client imagine the final result more clearly.

"Working closely with different teams was especially important in this busy place. As a result, the client now understands better what needs to happen during the installation phase, like having a clear and well-lit path in a dark forest, making the journey smoother and more confident.

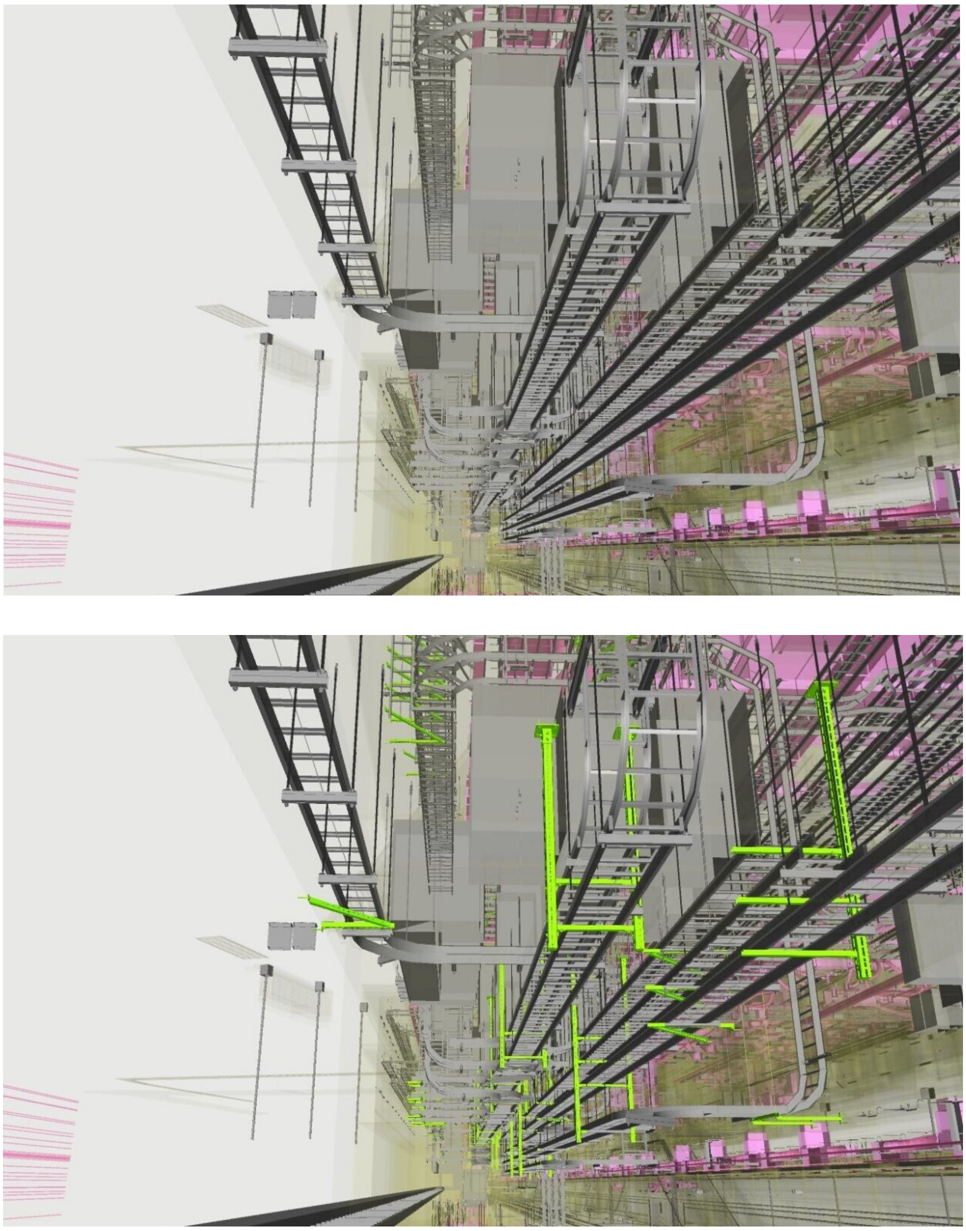

*Figure 4. Before and after BIM modelling seismic bracing for cable trays*

## 6. Recommendations:

We strongly recommend the adoption of Building Information Modelling (BIM) in the design of seismic bracing systems. BIM offers numerous advantages, including improved accuracy, early clash detection, enhanced visualization, streamlined collaboration, structural analysis capabilities, cost optimization, and comprehensive documentation. Integrating BIM into seismic bracing design processes leads to safer construction practices, reduced risks, and more resilient buildings with non-structural components by seismic design projects.

## 7. Conclusion

In conclusion, integrating Building Information Modelling (BIM) into seismic bracing design, specifically for non-structural components, is vital for ensuring compliance with construction standards. Non-structural components encompass elements like walls, ceilings, lighting fixtures, HVAC systems, and equipment, but it's especially crucial to emphasize the importance of modelling supports for Mechanical, Electrical, and Plumbing (MEP-F) systems within this context.

Leveraging BIM for seismic bracing design offers numerous advantages, including heightened safety and risk reduction, strict adherence to building codes, improved coordination among project stakeholders, cost and time savings, and more effective collaboration. Through meticulous analysis and design of seismic supports facilitated by BIM, construction professionals can effectively mitigate risks, streamline construction processes, and contribute to the creation of safer built environments.

This paper has provided a comprehensive overview of BIM modelling procedures, explored various types of seismic restraints, and underscored the integral role of BIM in the design phase of seismic bracing. Drawing upon real-life case studies, this paper has presented illustrative examples of BIM modelling outputs and formulated practical recommendations for the industry.

## 8. References

E. Miranda, G. Mosqueda, R. Retamales, G. Pekcan, Performance of non-structural components during the 27 February 2010 Chile earthquake, Earthquake Spectra 28 (S1) (2012) S453–S471,

A.Filiatrault,C.M.Uang,B.Folz,C.Christopoulos,K.Gatto,Reconnaissance Report of the February 28, 2001 Nisqually (Seattle-Olympia) Earthquake, Structural Systems Research Project Report No. SSRP-2000/15, Department of Structural Engineering, University of California, San Diego, La Jolla, CA, 2001 (62 pp.).

M. Ercolino, C. Petrone, O. Coppola, G. Magliulo, Report sui danni registrati a San Felice sul Panaro (Mo)inseguitoaglieventisismicidel20e29maggio2012 – v1.0,

Ferner, H., Wemyss, M., Baird,A., Beer, A., & Hunter, D. (2014). Seismic Performance of Non-structural Elements within Buildings. (NZSEE).

ISO Standard. (2010) "Building Information Modelling – Information Delivery Manual – Part 1: Methodology and Format". ISO 29481-1:2010(E).

ISO 19650 - Building Information Modelling (BIM) | BSI Australia

Associated General Contractors of America. (2005) The Contractors Guide to BIM, 1st ed. AGC Research Foundation. Las Vegas, NV.

Eastman, C., Teicholz, P., Sacks, R., Liston, K. (2011) BIM Handbook: A guide to building information modelling for owners, managers, designers, engineers and contractors – 2nd Edition. Wiley, Hoboken, New Jersey.

Van Nederveen, G.A., Tolman, F.P. (1992) "Modelling multiple views on buildings". Automation in Construction 1 (3): 215-224.

Eastman, C., Chase, S., Assal, H. (1993) "System architecture for computer integration of design and construction knowledge". Automation in Construction 2 (2): 95-107.

Volk, R., Stengel, J., Schultmann, F. (2014) "Building Information Modelling (BIM) for existing buildings – Literature review and future needs". Automation in Construction 38: 109–127.

Sacks, R., Treckmann, M., Rozenfeld, O. (2009) "Visualization of work flow to support lean construction". Journal of Construction Engineering and Management 135 (12): 1307-1315.

Cheung, F., Rihan J., Tah, J., Duce, D., Kurul, E. (2012) "Early stage multi-level cost estimation for schematic BIM models". Automation in Construction 27: 67-77.

Campbell, A.D. (2007) "Building Information Modelling: The Web3D Application for AEC". Proceedings of the 12th international conference on 3D web technology (Web3D '07). New York, USA.

Bercerik-Gerber, B., Jazizadeh, F., Li, N., Calis, G. (2012) "Application areas and data requirements for BIM-enabled facilities management". Journal of Construction Engineering and Management 138 (3): 431-442.

Azhar, S., Hein, M., Sketo, B. (2008) "Building Information Modelling (BIM): Benefits, Risks, Challenges". Associated Schools of Construction (ASC) 44th Annual Conference. Auburn, Alabama.

Hamburger, R.O., Moehle, J.P. (2000) "State of performance-based engineering in the United States". Proceedings of the 2nd US-Japan Workshop on Performance-Based Design Methodology for Reinforced Concrete Building Structures. Sapporo, Japan.

Australia and New Zealand BIM best practice guideline (2016), "Australian Institute of Quantity Surveyors and New Zealand Institute of Quantity Surveyors" (2016).

J. Cheng, I. Ma, A BIM-based system for demolition and renovation waste quanti-fication and planning, Waste Manag. 33 (6) (2013) 1539–1551. [19] Eastman, C., Chase, S., Assal, H. (1993) "System architecture for computer integration of design and construction knowledge". Automation in Construction 2 (2): 95-107.

X. Liu, E.B. Akinci, Developing As-built building information model using construction process history captured by a laser scanner and a camera, Proceeding Construction Research Congress 2012: Construction Challenges in a Flat World, West Lafayette, USA, 2012