International Journal of 3-D Information Modeling

July-September 2013, Vol. 2, No. 3

Table of Contents

Guest Editorial Preface

Research Articles

The *International Journal of 3-D Information Modeling* is currently listed or indexed in: Bacon's Media Directory; Cabell's Directories; DBLP; Google Scholar; INSPEC; JournalTOCs; MediaFinder; ProQuest Advanced Technologies & Aerospace Journals; ProQuest Computer Science Journals; ProQuest Illustrata: Technology; ProQuest SciTech Journals; ProQuest Technology Journals; The Standard Periodical Directory; Ulrich's Periodicals Directory

Drivers and Barriers to the Use of Building Information Modelling in India

Anil Sawhney, FRICS, Department of Construction Project Management, RICS School of Built Environment, Amity University

Prateek Singhal, Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, Delhi, India

ABSTRACT

Building Information Modelling (BIM) is a remarkable development that has recently engulfed the construction sector globally. It has provided a catalytic means for "rethinking" the design, construction, and operation of our built environment. Fundamentally a technology driven concept, BIM when entwined with issues pertaining to people, processes and organizations has the potential to significantly impact the industry. Considering global adoption of BIM, a clear divide between developed economies and emerging economies can be seen. Significantly low adoption of BIM in the developing world has been reported. Paradoxically the need for BIM in the developing world is far more than the developed world. With this backdrop, this paper reports on the adoption of BIM in India. Finding the adoption rate in India low, this research aimed at finding out the drivers and barriers to the use of BIM. The research has been divided into two phases. The first phase involved interaction with industry professionals by conducting semi structured interviews so as to gather deeper and actual understanding of the subject under study. In the second phase, on the basis of this interaction and the literature review, a questionnaire was prepared and an online survey was conducted. As per the analysis of the collected data, it surfaced that the use of BIM is still in its nascent stage in India, although its adoption has seen an upward trend in the past three to four years. BIM adoption has still not reached a stage where the users can comment on the savings in cost due to BIM implementation as the majority of the respondents have not seen full cycle of successful implementation. Stakeholders remain sceptical about BIM adoption and its perceived benefits. However a majority of the users are intuitively convinced that there is savings in time and significant improvement in final quality. Moving forward a meaningful impact can be made on the state of education, research and practice pertaining to BIM in India via a meaningful collaboration between industry, government, and academia. Findings of this study can be compared and collated across other emerging economies to develop implementation strategies.

Keywords: *Building Information Modelling (BIM), Drivers and Barriers, Indian Construction Sector, Questionnaire Survey, Semi-Structured Interviews, Virtual Design and Construction*

DOI: 10.4018/ij3dim.2013070104

1. INDIAN CONSTRUCTION SECTOR AND USE OF TECHNOLOGY

The importance of the Indian construction sector to the Indian economy and the socio-economic development of the country is very high (Planning Commission 2011, Gupta et al., 2009). As an economic activity construction is the second largest activity after agriculture in India (Doloi et al., 2011, Planning Commission 2011). Statistics available in the public domain highlight the current contribution of the sector and the projected growth of the sector (Sawhney et al., 2011a). Regardless of the economic importance and employment generation of the sector, issues such as low productivity, limited mechanization and lack of professionally qualified employees plague the industry (Doloi et al., 2011, Sawhney et al., 2011a). Lack of standards and low use of technology across the construction supply chain is one of the weak points of the industry (Planning Commission 2011). There is strong evidence of less than optimum performance of Indian construction projects and this trend is growing. Projects are reportedly failing across the key performance measures including cost, time and quality performances (Doloi et al., 2011; Sawhney et al., 2011a). By earlier estimate, over 40% of Indian projects suffer from poor performance (Satyanarayana & Iyer 1996; Iyer and Jha, 2005). In a study comparing the performance of international development projects in India, China, Bangladesh, and Thailand, Ahsan and Gunawan (2010) reported that construction projects in India showed the worst schedule performance. A status report published by the Ministry of Statistics and Programme Implementation highlighted that out of the 951 projects being monitored 309 projects have cost overruns and 474 projects are behind schedule. Reasons for these problems range from land acquisition, improper planning and budgeting, to poor coordination and monitoring of the projects (Singh, 2010).

The Indian Planning Commission recently highlighting the importance of the sector recommended the use of "*modern management techniques and efficient technologies*" for the growth of the sector so as to fulfil the demands being placed on it by the economic development of the country (Planning Commission 2011). One such technology that can benefit the Indian construction sector is Building Information Modelling (BIM). Using the linkages between technology, process and people that BIM platform provides, this study is aimed at determining and understanding the drivers and barriers to its implementation in India. Teasing out these issues ultimately yields insights as to how the Indian construction sector can benefit from BIM in years to come.

2. LITERATURE REVIEW

Over the past few three decades, realizing that project delivery is an information intensive process, there has been rapid development of concepts and representations relating to how information is created and managed on projects. Tracing back in time, Mokhtar et al. (1998) developed an information model intended to replace drawings as the main repository of design information and main communication media. Essentially the idea of a central database containing all the project information to produce technical documents suitable for project delivery was proposed. Zaneldin et al. (2001) went further in their research and proposed that the approach would be more successful if used in a collaborative setting. The key shift that happened around fifteen years ago was that researchers felt technology alone would not be sufficient for attaining success and that the interrelationships between people, organizations and processes must also be evolved with technology in order to produce a successful model. In recent years, this amalgamation of technology, people and processes that is allowed by BIM, has taken root in both research and practice (Sacks and Barrack 2010). While the idea of BIM as a technology has been around for over two decades, it is only recently that through the discussion of the people and process issues BIM has become popular in the industry and

amongst researchers. This shift has been less than a decade old and as recently as 2008 many researchers and practitioners are reporting the beginning of the "BIM Age" (Sacks and Barrack 2010); some marking the beginning of this as late as 2005 (Edgar, 2007). A flurry of activity in the industry and in academia in the US and UK surrounding BIM is evident (Lamb et al., 2009, Gu & London, 2010, Becerik-Gerber & Kensek, 2010, McGraw Hill, 2012, Taylor & Bernstein 2009). Succar (2009) proposed a "BIM framework" which aims to provide a research and delivery foundation so that industry practitioners can have a better understanding of underlying knowledge structures and are able to negotiate implementation requirements.

In recent years, the concept of BIM has been further developed to cover the entire project lifecycle (Eastman et al., 2010). Numerous studies documenting exemplar building projects providing anecdotal implementation details are also available (Kam et al., 2003, Khemlani, 2004, Khanzode et al., 2008, Kymell, 2008, Taylor & Bernstien, 2009). Industry-driven BIM surveys are also reported in the literature (McGraw Hill, 2012, BuildingSmart Australia, 2010). Taylor and Bernstien (2009) report the adoption paradigms for various organisations. Sacks and Barak (2008) studied the effects of BIM on 3D parametric modelling productivity through experiments in which parallel activities were completed in 2D and 3D. Industry perceptions pertaining to the use of BIM were reported by Suermann and Issa (2009). Becerik-Gerber and Kensek (2010) have used an industry-wide survey to demonstrate the perceived value of BIM in the US building industry; focussing. Further efforts have been made to expand the capability of BIM and to assess its advantages on construction projects (Zhang et al., 2013, Bryde et al., 2013, Won et al., 2013, Arayici et al., 2012, Porwal et al., 2013).

Strong support for BIM implementation is being provided by governments in UK, Singapore and Australia. While other parts of the world are also witnessing a strong growth in BIM adoption the status in India is not very positive. This study is directed towards identification of the status of BIM usage in India and also determining drivers and barriers to BIM implementation.

3. RESEARCH METHODOLOGY

The concept of BIM is relatively new in the Indian construction industry (Khemlani, 2012, Sawhney et al., 2011b, Sawhney & Maheswari, 2012). The industry has just moved past the "awareness phase" and moved into the early "adoption phase" (Sawhney et al., 2011b). There is limited literature available regarding the use of BIM in India and only a handful of success stories have been documented. Due to lack of available literature in the Indian context this research was divided into two stages. In the first stage, semi-structured interviews were conducted with industry professionals involved in BIM projects. This was done to get a deeper understanding of the issues surrounding the use of BIM in the context of the Indian construction industry. In the second stage, based on the findings of this qualitative research and the literature review done earlier, a web-based questionnaire survey was conducted that was designed to address a wide spectrum of professionals in the industry.

3.1. Stage 1: Semi-Structured Interviews

Semi-structured interviews are conducted with a fairly open framework which allow for focused, conversational two-way communication (Yin, 1984, Wengraf, 2001). Unlike the questionnaire framework, where detailed questions are formulated ahead of time, semi structured interviewing starts with more general questions or topics. Using this approach, information was collected by interviewing 16 industry professionals from 12 different organizations. Organizations that were reportedly using BIM at the time of the study were selected for this phase. Where avail-

able the semi-structured interviews were linked with the on-going BIM projects in the organizations so that the answers could be related to the recent experiences of the interviewees. The transcripts of the interviews were prepared and this qualitative data was analysed using NVivo (a qualitative research analysis tool). Figure 1 contains a flow chart which explains the steps involved in the analysis of the qualitative data using NVivo. The interview transcripts were prepared and were imported into NVivo. The source data was coded using various themes which emerged during the course of the analysis as shown in Figure 2. The themes which eventually developed during the analysis of the data were sorted into following three main heads:

- Drivers to the use of BIM
- Barriers to the use of BIM
- Factors related to the adoption of BIM

Once all the transcripts were analysed and the source data was coded at their respective nodes, these themes were further analysed to derive relationships, prepare charts and models based upon which the survey instrument was developed.

Figure 1. Flow chart of the steps involved in qualitative data analysis

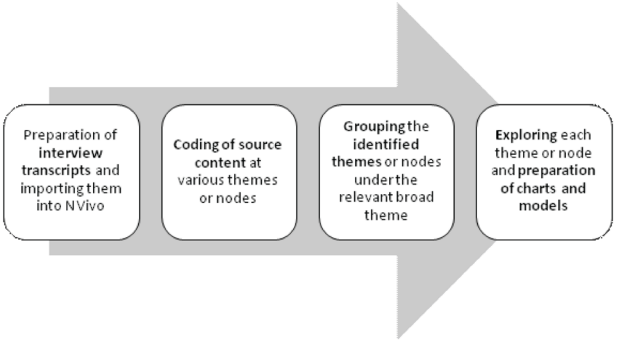
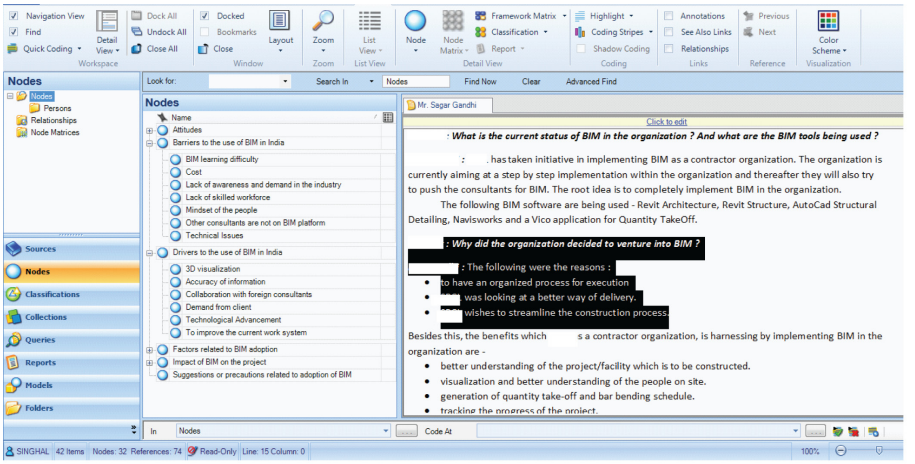


Figure 2. Qualitative analysis in NVivo



3.2. Stage 2: Questionnaire Survey

After analysing the qualitative data from the semi-structured interviews, a web-based questionnaire was developed. The survey was designed to accommodate a wide range of users and non-users across the country; and therefore had different sets of questions for the BIM users and for non-users. After a few common questions the respondents were routed to the appropriate parts of the survey on the basis of their usage of BIM. This particular method helped the non-users to skip past the questions which are not relevant to them. Table 1 shows the types of questions and target audience.

The target population for this survey were the industry professionals involved in the Architecture Engineering and Construction industry in India. A total of 107 responses were received out of which 16 were discarded as they were either incomplete or inappropriately answered. Out of the 91 correct responses 47 respondents were BIM users while 44 respondents were non-users. The data from the survey was analysed using Descriptive Statistics and Relative Importance Index (RII).

4. FINDINGS FROM SEMI-STRUCTURED INTERVIEWS

Useful insights into the current status of BIM usage was gained from the interviews. Being a recent phenomenon interviewees were able to relate very effectively between "BIM projects" and "Non BIM Projects" within their organizations. Figure 3 shows the distribution of the professionals interviewed by organization type. A total of 16 professionals were interviewed from 12 different organizations. The interviewees were from nearly every section of the industry i.e. architectural, structural, service consultants, BIM consultants, owner organization, contracting organization and also from government agency. Figure 4 shows the distribution of the interviewees as per their experience with BIM. The figure shows that 64% of the interviewees have over 3 years of experience with BIM. The interviewees which had over 10 years of experience in BIM were all from organizations providing BIM services on overseas projects.

The interviews with the industry professionals were either audio recorded or hand written notes were made during the interaction.

Table 1. Structure of the questionnaire

No.	Focus	Target Audience
1	Participant Profile	All the respondents
2	Participant's Company Profile	All the participants
3	Organization's Experience with BIM	Organizations working on BIM platform
4	BIM usage in the organization	Organizations working on BIM platform
5	Reasons for adopting BIM	Organizations working on BIM platform
6	Barriers to the use of BIM in India	Organizations working on BIM platform
7	Reasons for not adopting BIM	Organizations not using BIM
8	Impact of BIM on the Design and Construction Phase of the project	Already adopted BIM/ Aware but yet to adopt BIM
9	Impact of BIM on Time, Cost and Quality	Already adopted BIM/ Aware but yet to adopt BIM

Figure 3. Organization type and number of professionals interviewed

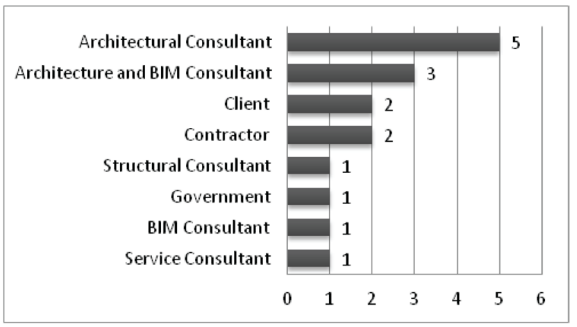
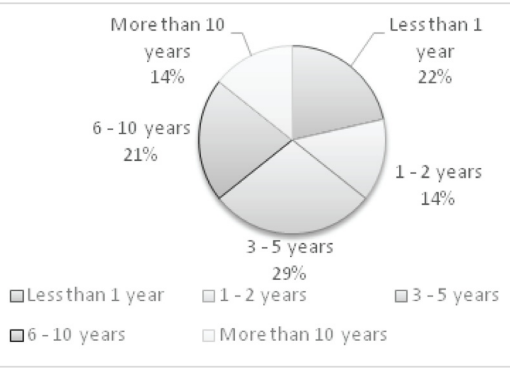


Figure 4. Years of BIM experience of interviewees



Later detailed transcript of the interview was made which was then imported into NVivo for search, query and visualization of themes and patterns. Findings from this qualitative analysis are reported in the next sub-sections as drivers, barriers and other factors relating to BIM implementation in India.

4.1. Drivers to the Use of BIM in India Identified Based on Semi-Structured Interviews

Based on the interviews a clear view of the drivers to BIM usage in India emerged. Figure 5 shows these drivers to the use of BIM in India. The reasons which received the maximum number of coding references (these are simply the number of times NVivo was able to find the phrase in the transcripts) are "technological advancement" and "to improve the current work system". Another reason which surfaced is that many Indian organizations are working with foreign consultants. Since these foreign consultants were using BIM, Indian companies were exposed to this concept thereby encouraging adoption.

4.2. Barriers to the Use of BIM in India Based on Semi-Structured Interviews

Early adopters who were interviewed in this study faced numerous challenges in the implementation process. These barriers became obvious during the interviews and emerged clearly in the NVivo analysis. Figure 6 shows the barriers being faced by the industry professionals in the implementation or adoption of BIM in India.

Figure 5. Reasons for adopting BIM as stated by the interviewees

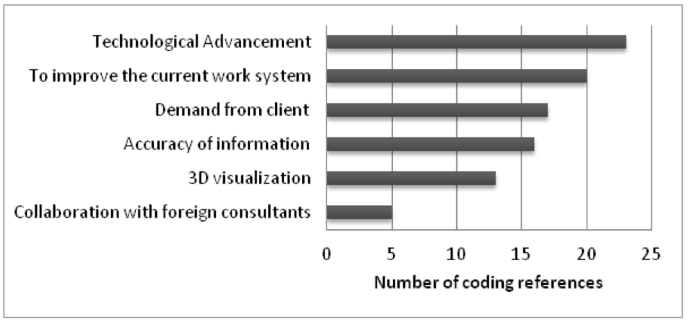
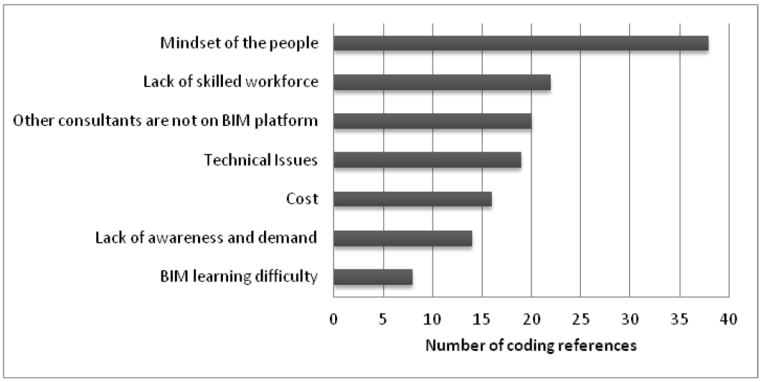


Figure 6. Barriers to the use of BIM in India as stated by the interviewees



The two reasons which received the maximum number of coding references are "mind-set of the people" and "lack of skilled workforce". During the interviews it became evident that structural engineering consultants and mechanical, electrical, and plumbing consultants in India currently do not use BIM platform. This disrupts the BIM workflow and therefore the adoption and implementation remains low.

Figure 7, an output of NVivo, shows the reasons behind the mind-set problem which has been considered as the most important barrier. Resistance to change, fear of technology and lack of patience are amongst the main reasons.

4.3. Factors Related to the Adoption of BIM in India Based on Semi-Structured Interviews

Besides the drivers and barriers a few other factors surfaced regarding the adoption of BIM in India. The three issues that were discussed the most include: (a) implementation process of BIM; (b) role of top management in implementation of BIM; and (c) problems due to the work processes and methodology in India. Figure 8 shows the distribution of various themes which were discussed during the interviews. The themes which were discussed the

Figure 7. Mind-set as a barriers to the use of BIM in India as stated by the interviewees

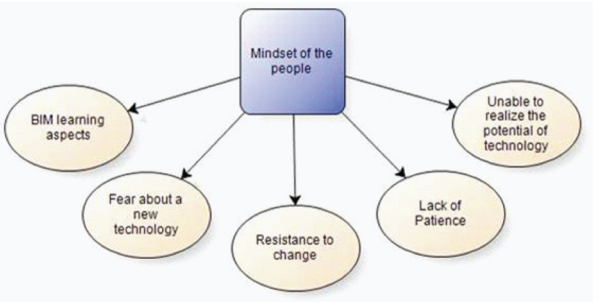
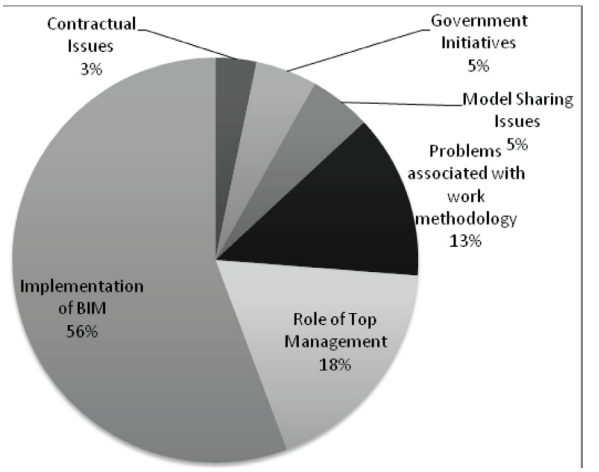


Figure 8. Factors related to the adoption of BIM in India



least were "model sharing issues", "contractual issues" and "government initiatives". A few of the interviewees were of the opinion that the government needs to take lead in implementing BIM as is being done by the governments of other countries. As per the role of top management in the implementation of BIM, most of the interviewees were of the opinion that the adoption of BIM is always from top to down. Nearly all the organizations which were studied had seen this reason as the most important driving force behind the implementation of BIM in their respective organization. Figure 9 explains the problems associated with implementation of BIM which various organizations seems to be facing currently.

The interviews also indicated that the current work processes in India are a deterring factor in the successful implementation of BIM in an organization. The industry in general does not adopt any standardized work flow methodology especially in the design phase. Ad hoc changes are common in the industry making the shift to a BIM based project workflow even more difficult. These work practices related issues are highlighted in Figure 10.

Figure 9. Issues pertaining to implementation of BIM

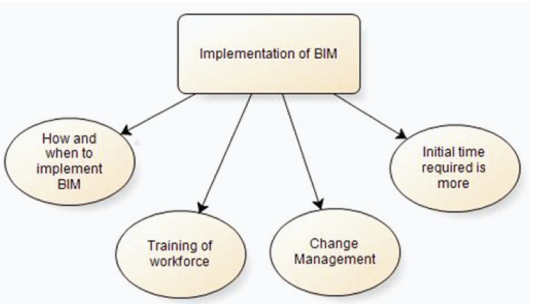
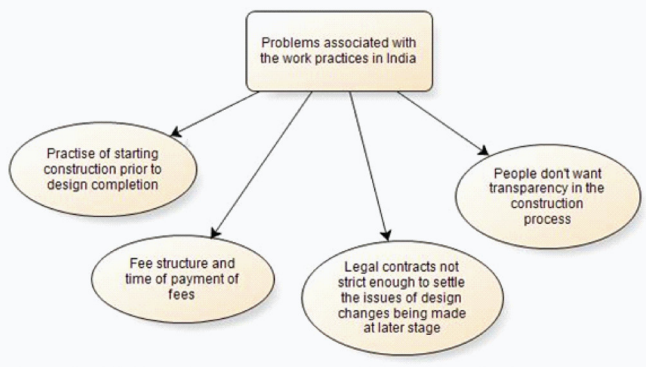


Figure 10. Problems associated with the work practices in India



5. FINDINGS FROM THE SURVEY

A total number of 107 responses were received out of which 91 responses were complete. Out of 91 completed responses, 51.6% of the respondents reported that they were using BIM in their organizations and 48.4% of the respondents reported that their organization is not using BIM. Figure 11 shows that 33% of the respondents have over 15 years of professional experience in the industry and 46.2% of the respondents have professional experience greater than 10 years.

Table 2 shows the distribution of the organizations types which are working on BIM platform and which are not.

Responses were received from nearly all the organization types in the industry except the sub-contractors. Architectural firms are far ahead in implementing BIM as compared to other organization types. Moreover only the architectural firms and BIM service providers seem to be the most aware of BIM; whereas the majority of the clients, project management consultants, structural consultants and contractor organization were reported to not to have been using BIM. Further BIM adoption in India is a recent phenomenon with 87% of the organizations reporting that they have started using BIM after 2005. More specifically, the Indian industry has seen an upward trend in the adoption of BIM in the last three to four years only.

Figure 11. Professional experience of the respondents

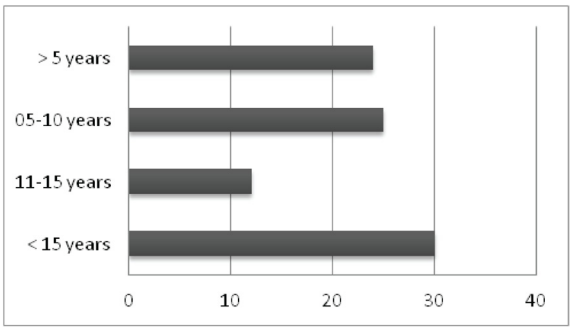


Table 2. Distribution of respondent's organization type

Answer Options	Response Percent	Response Count	BIM Users	Non-Users
Sub-Contractor	0.00%	0	0	0
Government Agency	5.50%	5	2	3
Sustainability Consultant	5.50%	5	3	2
Education / Training	8.80%	8	2	6
Construction Agency/Contractor	9.90%	9	4	5
Mechanical/Electrical/Plumbing/Services Engineering	9.90%	9	6	3
Civil/Structural Engineering	13.20%	12	6	6
Project Management Consultant	13.20%	12	3	9
Client/Owner/Developer	16.50%	15	5	10
BIM Service Provider	17.60%	16	16	0
Architecture/Design	41.80%	38	23	15
Other (please specify)		9	2	7

5.1. Drivers to the Use of BIM in India Identified Based on the Survey

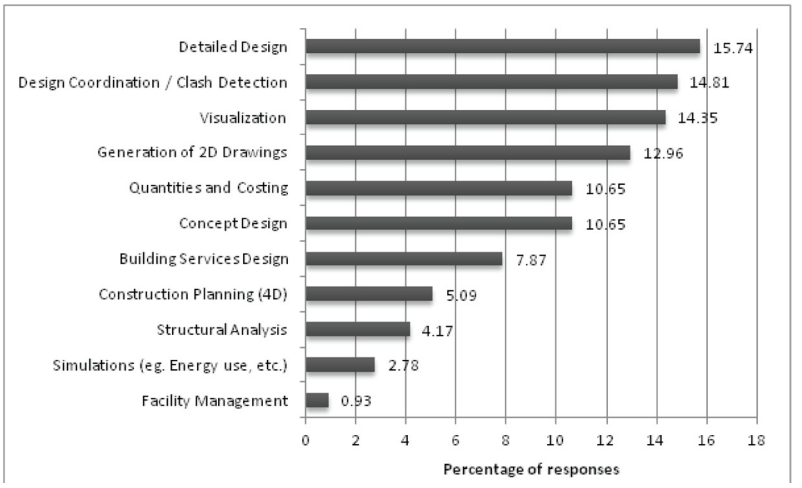
The analysis of the survey data revealed the key drivers to the adoption of BIM in India as shown in Table 3. The first driver that surfaced in the analysis related to the difficulties in the current work processes and systems adopted by various stakeholders. Respondents felt that the current work methodology was causing waste and impacting the project performance. BIM was therefore seen as a way to remove some of these inefficiencies in the project delivery process. The second driver suggested that top management realized the potential of BIM and was very much interested in implementing it. Thirdly, respondents felt that CAD technology having matured, BIM seemed like a natural technological development. Demand from client has been considered the next important reason for adopting BIM.

Figure 12 shows the applications for which BIM is being used the most in India. BIM is currently being used the most for detailed design (15.74%) and clash detection (14.81%). Since

Table 3. Reasons for adopting BIM

Response	Percent (Respondents)	Frequency	Valid Percent	Cumulative Percent
Demand from client	34.00%	16	15.38	15.38
Other consultants are using BIM	10.60%	5	4.81	20.19
Our competitors are using BIM	14.90%	7	6.73	26.92
Natural technological development	44.70%	21	20.19	47.11
Top management was interested in BIM	51.10%	24	23.08	70.19
To improve the current work system	66.00%	31	29.81	100.00
Total number of responses		**104**	**100**	
Number of respondents		**47**		

Figure 12. Applications for which BIM is being used by the organizations



the majority of the respondents were from architecture domain, detailed design thus has been rated the most used application; however clash detection is one aspect which is of interest to more than one organization type.

5.2. Barriers to the Use of BIM in India Identified Based on the Survey

The questions related to the barriers to the usage of BIM in India were asked twice in the survey. One for the BIM users and other for the non-users. For the BIM users the barriers were as identified from the findings of the semi-structured interviews. Whereas for the non-users the barriers listed in the survey were more detailed and specific. Figure 13 shows the barriers to the use of BIM in India as perceived by the BIM users. Mind-set problems which has been considered as the biggest barrier in the Indian context is really a universal barrier to technology adoption in construction. As per the literature review, factors such as resistance to change, fear of technology, lack of patience and disillusionment to new technology contribute to the mind-set problems of the industry professionals (Kiviniemi, 2013; Gu & London, 2010).

Figure 13. Barriers to the use of BIM in India as seen by the BIM users

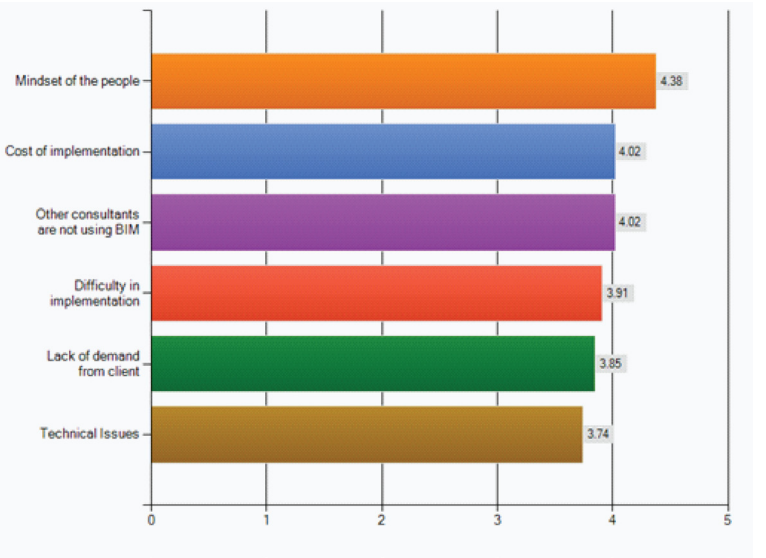


Figure 14 shows the barriers to the use of BIM as rated by the non-users. The data clearly shows that lack of awareness about BIM (18.45%) and lack of skilled workforce (14.56%) are cited as the most important barriers by the non-users. If the three barriers related to the cost associated with the implementation of BIM are combined, the total response percent amounts to 20.4% of the total responses which is the highest amongst all other listed factors. Factors like failure of BIM on previous projects (2.3%), unable to see the benefits (2.3%), negative feedback from others (2.3%) received the least number of responses. This suggest that these issues are of least importance and there is no doubt about the potential of the BIM technology.

5.3. Impact of BIM on the Project Performance Identified Based on the Survey

While there is dearth of documented BIM implementations in India, the survey tried to establish the perceptions of the respondents on the impact of BIM on project performance. Figure 15 suggests that factors such as better coordination of the documentation (RII 0.88), reduced errors and omissions in the construction documents (RII 0.86) and better design management (RII 0.856) are of higher relative importance whereas factors like less person-hours required to do the same quantum of work (RII 0.74) and faster plan approval permits / faster client approval cycles (RII 0.752) are the factors of least relative importance during the design phase of the project.

Figure 16 shows the impact of BIM on the construction phase of the project. The figure suggests that reducing rework (RII 0.878) and reduced conflicts during construction (RII 0.876) are of higher relative importance whereas factors like fewer claims / litigation (RII 0.73) and improved job site safety (RII 0.706) are the factors of least relative importance during this phase.

In continuation to the questions on impact of BIM on design and construction phase, the respondents were then asked questions related to the savings in time, savings in cost and improvement in the final quality. Figure 17 clearly indicates that the majority of the respondents (61%) were positive regarding time savings in the project due to the implementation of

Figure 14. Reasons for not implementing BIM as mentioned by non-users of BIM

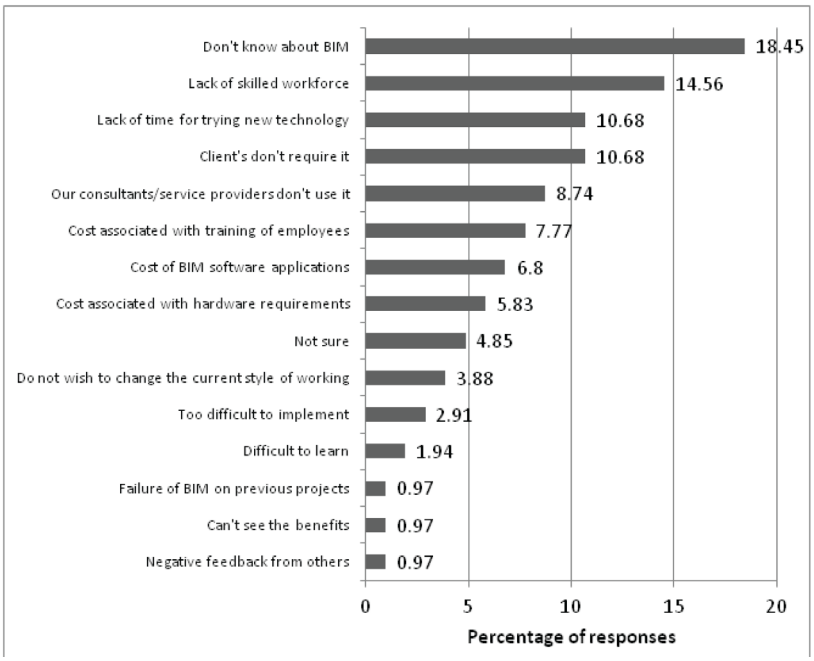


Figure 15. Impact of implementation of BIM on the design phase of the project

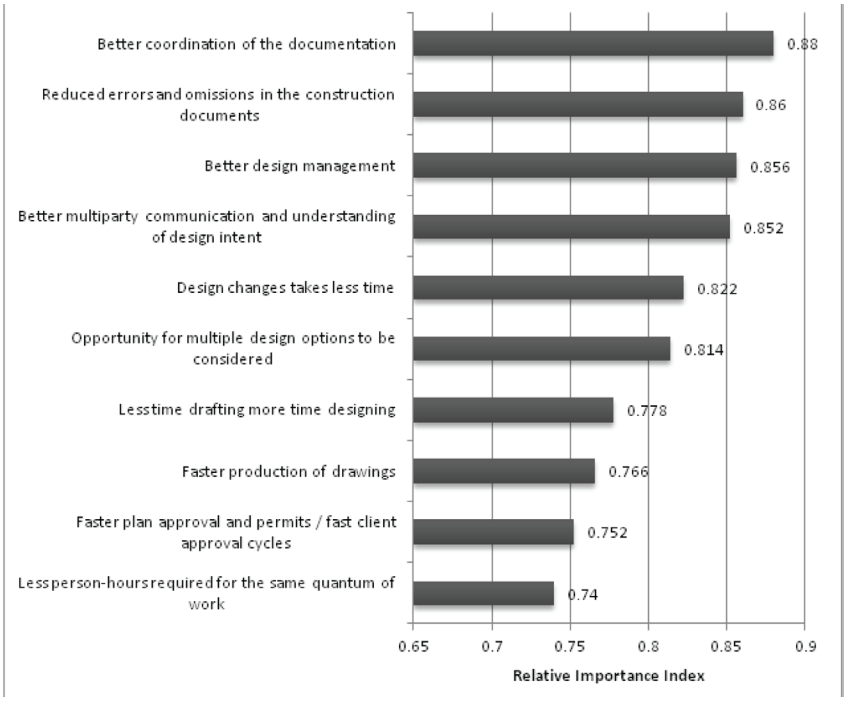


Figure 16. Impact of implementation of BIM on the construction phase of the project

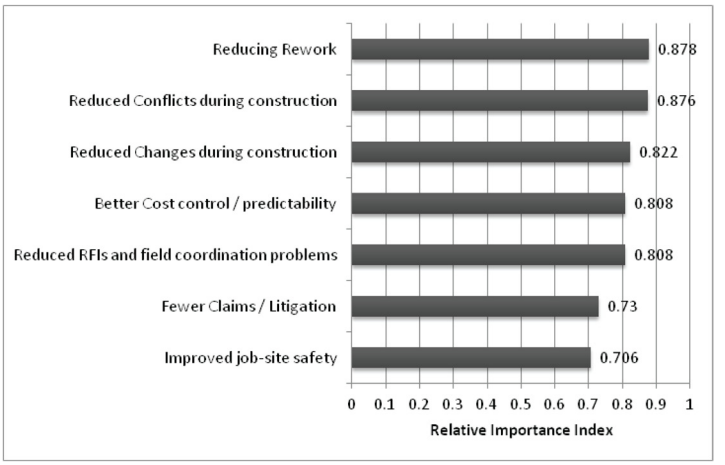
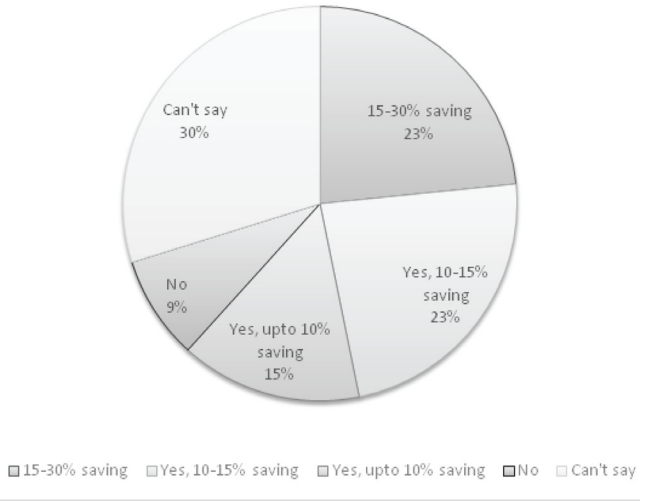


Figure 17. Impact of BIM implementation on the project duration



BIM and 46% of the respondents believed that there could be more than 10% savings in time. However 30% of the respondents were unable to decisively comment on the issue of BIM driven time savings on projects.

According to Figure 18, majority (51%) of the respondents are not in a position to comment on cost savings of the project. This indicates that BIM adoption and implementation is still in its nascent stage in India with 87% of the BIM users having started using BIM after 2005. However, 41% of the respondents are positive regarding savings in money in the project due to BIM implementation.

As shown in Figure 19, most of the respondents (85%) are positive regarding the improvement in quality of the final product due to the implementation of BIM. Whereas majority (62%) of the respondents are of the opinion that there is significant improvement in the quality of the final product.

Figure 18. Impact of BIM implementation on the overall cost of the project

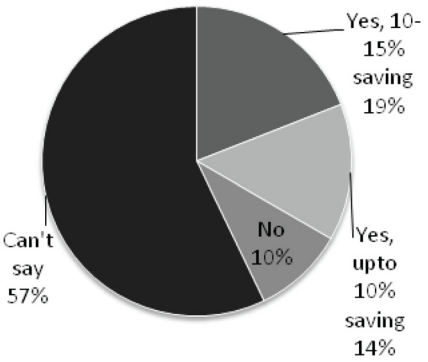
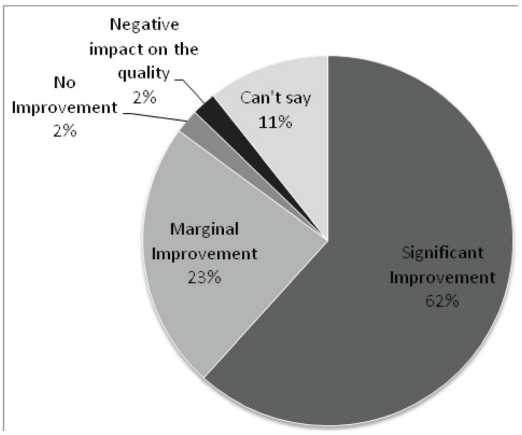


Figure 19. Impact of BIM implementation on the quality of the final product



6. CONCLUSION

This study found that full potential of BIM has not yet been explored on Indian projects. BIM utilization is still in its emerging stage and its adoption is facing significant headwinds. Limited number of projects are using BIM and the jury is still out on its adoption. The study determined that the depth of implementation along the project delivery network is also limited. This is evident from the fact that BIM adoption is comparatively more popular amongst the architects than any other discipline or specialization in India. Specialist consultants are not adopting BIM and in fact are blocking the collaborative BIM implementation process in India. The main reasons behind this limited adoption is lack of awareness amongst these specialists and lack of incentives to encourage adoption. For those who are aware and wish to adopt, there are significant hurdles stemming from lack of skilled workforce and perceived high cost of implementation (cost of hardware, cost of software and cost of training of workforce). Whereas for organizations using BIM, there are other challenges such as non-availability of specialist consultants who use BIM, lack of skilled workforce and mind-set of the plethora of stakeholders. Many instances of "lonely BIM" users exist on Indian projects. These factors limit BIM users in harnessing the full potential of BIM. Besides this the problems associated with

the work process and methodology in India limits the full use and holistic benefits of BIM. To meet the demands of clients or directions given by top-management many projects in India have adopted the "BIM Consultant" approach. A modelling team simply assists the design team in "converting" two-dimensional design information into BIM models. Obviously this approach fraught with fragmentation and other inefficiencies does not allow stakeholders to see the real value add of the BIM usage. Reports of failure of Indian projects using the "BIM Consultant" approach have caused significant problems in the BIM adoption journey. Based on hearsay many stakeholders are forming a negative view of BIM.

Despite all these factors the industry has seen an upward trend in the adoption of BIM in the past three to four years with 87% of the BIM users reporting to have started using BIM after 2005. The driving force behind the adoption of BIM is that these organizations are aware of the limitations of the 2D CAD based work methodology and wish to improve the current work system and also reap the benefits and advantages of the natural technological development in the construction industry. With the current status of BIM adoption and implementation of BIM in the industry, the majority of the professionals were not in a position to comment on the savings in money in the project due to BIM implementation. However majority of the respondents were intuitively positive regarding savings in time in the project. As per the improvement in the quality of the final product due to BIM implementation most of the respondents were positive regarding it while majority of the respondents reported to have significant improvement. From the study it is clear that there is a need to develop a BIM implementation plan keeping in mind work processes, methodologies and industry practices in India. A strong need to build the capacity of consultants and sub-contractors is apparent. A national BIM education and research agenda is required so as to ensure creation of a strong construction industry value chain driven by BIM.

REFERENCES

Ahsan, M. K., & Gunawan, I. (2010). Analysis of cost and schedule performance of international development projects. *International Journal of Project Management*, *28*, 68–78. doi:10.1016/j.ijproman.2009.03.005

Arayici, Y., Egbu, C., & Coates, P. (2012). Building information modelling (BIM) implementation and remote construction projects: Issues, challenges, and critiques. *Journal of Information Technology in Construction*, *17*, 75–92.

Becerik-Gerber, B., & Kensek, K. (2010). Building information modeling in architecture, engineering, and construction: Emerging research directions and trends. *Journal of Professional Issues in Engineering Education and Practice*, *136*(3), 139–147. doi:10.1061/(ASCE)EI.1943-5541.0000023

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International Journal of Project Management*, *31*(7), 971–980. doi:10.1016/j.ijproman.2012.12.001

BuildingSmart Australia. (2010). *BIM economic study: Industry survey.* Retrieved from http://buildingsmart.org.au/

Doloi, H., Sawhney, A., Iyer, K. C., & Rentala, S. (2011). Analysing factors affecting delays in Indian construction projects. *International Journal of Project Management, JPMA-D-11-00015R1*.

Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2011). *BIM handbook. Building* (2nd ed.). Hoboken, NJ: John Wiley and Sons, Inc.

Edgar, A. (2007). Message from the national BIM standard executive committee. *Journal of Building Information Modeling*. National Institute of Building Sciences.

Gu, N., & London, K. (2010). Understanding and facilitating BIM adoption in the AEC industry. *Automation in Construction*, *19*(8), 988–999. doi:10.1016/j.autcon.2010.09.002

Gupta, P., Gupta, R., & Netzer, T. (2009). *Building India accelerating infrastructure projects infrastructure practice*. McKinsey and Company Inc.

Iyer, K. C., & Jha, K. N. (2005). Factors affecting cost performance: Evidence from Indian projects. *International Journal of Project Management*. doi:10.1016/j.ijproman.2004.10.003

Kam, C., Fischer, M., Hänninen, R., Karjalainen, A., & Laitinen, J. (2003). The product model and Fourth Dimension project. *Journal of Information Technology in Construction (ITcon), 8*(Special Issue on IFC-Product models for the AEC Arena), 137-166.

Khanzode, A., Fischer, M., & Reed, D. (2008). Benefits and lessons learned of implementing building virtual design and construction (VDC) technologies for coordination of mechanical, electrical and plumbing (MEP) systems of a large healthcare project. [ITcon]. *Journal of Information Technology in Construction*, *13*, 324–342.

Khemlani, L. (2004). The Eureka tower: A case study of advanced BIM implementation. *AECBytes*. Retrieved August 22, 2012, from http://www.aecbytes.com/feature/2004/EurekaTower.html

Khemlani, L. (2012). A case study of BIM implementation in India. *AECbytes*. Retrieved August 22, 2012, from http://www.aecbytes.com/buildingthefuture/2012/InformArchitects-CaseStudy_pr.html

Kiviniemi, A. (2013). Public clients as the driver for open BIM adoption-how and why UK government wants to change the construction industry? In *Proceedings of the Conference Open BIM*.

Kymmell, W. (2008). *Building information modeling: Planning and managing construction projects with 4D CAD and simulations*. New York, NY: McGraw-Hill.

Lamb, E., Reed, D., & Khanzode, A. (2009). *Transcending the BIM hype: How to make sense and dollars from building information modeling*. AECbytes View point #48.

McGraw Hill. (2012). *SmartMarket report: The business value of building information modeling: Getting building information modeling to the bottom line*. New York, NY: McGraw Hill.

Mokhtar, B. A., Bedard, C., & Fazio, P. (1998). Information model for managing design changes in a collaborative environment. *Journal of Computing in Civil Engineering*, 82–98. doi:10.1061/(ASCE)0887-3801(1998)12:2(82)

Planning Commission. (2011). Faster, sustainable and more inclusive growth: An approach to the twelfth five year plan. Government of India, October, 2011

Porwal, A. & Hewage, K. N. (2013). Building information modeling (BIM) partnering framework for public construction projects. *Automation in Construction, 31*, 204-214. ISSN 0926-5805

Sacks, R., & Barak, R. (2010). Teaching building information modeling as an integral part of freshman year civil engineering education. *Journal of Professional Issues in Engineering Education and Practice*, *136*(1), 30–38. doi:10.1061/(ASCE)EI.1943-5541.0000003

Satyanarayana, K. N., & Iyer, K. C. (1996). Evaluation of delays in Indian construction contracts. *Journal of the Institution of Engineers (India)*, *77*, 14–22.

Sawhney, A., Iyer, K. C., Doloi, H., & Rentala, S. (2011a, December 9-10). Latent variables and their impact on time performance of Indian construction projects. In *Proceedings of 2011 Project Management Research & Academic Conference (PMIREC 2011)*, NICMAR, Pune, India.

Sawhney, A., Iyer, K. C., Kumar, S., & Singhal, P. (2011b, December 9-10). Building information modelling driven construction project management. In *Proceedings of 2011 Project Management Research and Academic Conference (PMIREC 2011)*, NICMAR, Pune, India.

Sawhney, A., & Maheswari, J. U. (2012). Design coordination using cloud-based smart building element models. *International Journal of Computer Information Systems and Industrial Management Applications, 5*(2013), 445-453. ISSN 2150-7988.

Singh, R. (2010). Delays and cost overruns in infrastructure projects: Extent, causes and remedies. *Economic and Political Weekly*, *xiv*, 43–54.

Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction*, *18*(3), 357–375. doi:10.1016/j.autcon.2008.10.003

Suermann, P., & Issa, R. (2009). Evaluating industry perceptions of building information modeling (BIM) impact on construction. [ITcon]. *Journal of Information Technology in Construction*, *14*, 574–594.

Taylor, J. E., & Bernstein, P. (2009). Paradigm trajectories of building information modelling practice in project networks. *Journal of Management Engineering*, *25*(2). doi:10.1061/(ASCE)0742-597X(2009)25:2(69)

Wengraf, T. (2001). Qualitative research interviewing: Biographic narrative and semi-structured methods. *Sage (Atlanta, Ga.)*.

Won, J., Lee, G., Dossick, C., & Messner, J. (2013). Where to focus for successful adoption of building information modeling within organization. *Journal of Construction Engineering and Management*. doi:10.1061/(ASCE)CO.1943-7862.0000731

Yin, R. K. (1984). *Case study research: Design and methods*. Beverly Hills, CA: Sage Publications.

Zaneldin, B. E., Hegazy, T., & Grierson, D. (2001). Improving design coordination for building projects. *Journal of Construction Engineering and Management*, 330–336. doi:10.1061/(ASCE)0733-9364(2001)127:4(330)

Zhang, S., Teizer, J., Jin-Kook, L., Eastman, C. M., & Venugopal, M. (2013). Building information modeling (BIM) and safety: Automatic safety checking of construction models and schedules. *Automation in Construction*, *29*, 183–195. doi:10.1016/j.autcon.2012.05.006

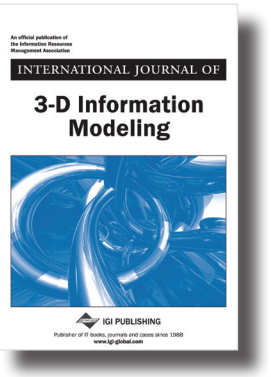
CALL FOR ARTICLES

International Journal of 3-D Information Modeling

An official publication of the Information Resources Management Association

MISSION:

The mission of the **International Journal of 3-D Information Modeling (IJ3DIM)** is to provide a comprehensive and collective body of knowledge in the domains of Building Information Modeling (BIM) and 3D Geographical/Geospatial Information Models & Systems (3D GIS). The journal stimulates the sharing of knowledge, research approaches and practical experience in domains related to BIM, 3D GIS and Urban Information Fusion and combines the worlds of BIM and GIS toward integrated management and re-use of "3D semantically rich information". IJ3DIM encourages developments in BIM, 3D GIS, City Modeling (including Indoor Modeling). IJ3DIM focuses on both advanced technologies and soft aspects, including human, process, organizational, industrial level problems, relating to BIM, 3D GIS and Urban Information Fusion. The journal also facilitates the sharing of scientific knowledge related to the development of indoor applications, such as indoor navigation, evacuation, facility management, intelligent buildings, and sustainable buildings.



ISSN 2156-1710
eISSN 2156-1702
Published quarterly

COVERAGE/MAJOR TOPICS:

- 3D augmented and virtual reality
- 3D data collection and reconstruction
- 3D GIS standards
- 3D interoperability
- 3D spatial analysis
- 3D spatial information infrastructures
- 3D static and dynamic network models
- 3D to nD spatial information modeling
- 3D/4D visualization and visual analytics
- BIM based 4/5/nD modeling and management
- BIM based collaborative working
- BIM based facilities/asset management
- BIM based visualization/simulation/augmented reality
- BIM in site automation
- BIM maturity/readiness/adoption
- BIM standards
- Building Information Modeling and Management (BIM)
- Disaster management
- Environmental Management
- Geo-coding and 3D location based services
- Integrated project delivery
- Location based scheduling
- Management of large 3D datasets
- Multi-source and multi-domain 3D data integration
- Ontology/schema/service level integration
- Serious games
- Spatial DBMS
- Training and education on BIM
- Urban planning, management and renewal
- Web semantics and knowledge engineering

All inquiries regarding IJ3DIM should be directed to the attention of:
Jason Underwood Editor-in-Chief IJ3DIM
ij3dim@igi-global.com
All manuscript submissions to IJ3DIM should be sent through the online submission system:
http://www.igi-global.com/authorseditors/titlesubmission/newproject.aspx

Ideas for Special Theme Issues may be submitted to the Editor-in-Chief.

Please recommend this publication to your librarian. For a convenient easy-to-use library recommendation form, please visit:
http://www.igi-global.com/IJ3DIM