BUILDING INFORMATION MODELING (BIM) USES AND APPLICATIONS IN PAKISTAN CONSTRUCTION INDUSTRY

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ABSTRACT: *Building Information Modeling (BIM) is one of the most promising and recent developments in the construction industry. In Pakistan, the studies on BIM in academia and construction industry are not very common. This work has tried to find out the potential for BIM for its use and applications in the construction industry. The objectives of this research were to assess the potential of BIM for its use and applications in designing, coordinating, managing and execution of construction projects, the main reasons to take interest in BIM and the major tasks for which it is considered to be adopted. The methodology of this research was based on a questionnaire survey to collect data. The collected data were analyzed by conducting different statistical procedures to make inferences.*

Results of this survey indicated that there was awareness about BIM technology and its processes among the construction industry stakeholders for better visualization and to increase the capacity of design reviews, constructability analysis, and model based estimation and construction sequencing. Results further indicate that the use of BIM minimizes risk of discrepancies between orthographic views including plan, section, and elevation and provides improvement in preparation of budgeting, cost estimating and scheduling capabilities. Finally, the results of this study provide useful information to clients, consultants, contractors and other stakeholders in the construction industry.

KEYWORDS: *Building Information Modeling (BIM), Questionnaire, Virtual Building Construction, Object-Oriented CAD Systems.*

1. INTRODUCTION

BIM is the development and use of a computer software model to simulate the construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and improve the process of delivering the facility (AGC 2009). Building information modeling is emerging as an innovative way to virtually design and manage projects. Predictability of building performance and operation is greatly improved by adopting BIM (Azhar 2011).

With BIM technology, one or more accurate virtual models of a building are constructed digitally. BIM supports design through phases, allowing better analysis and control than manual processes. When completed, these computer generated models contain precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realized (Eastman, Teicholz et al. 2011).

Building Information Modeling (BIM) is one of the most promising developments in the architecture, engineering, and construction (AEC) industries (Eastman, Teicholz et al. 2011). BIM is an emerging tool in the design industry that is used to design and document a project, but is also used as a vehicle to enhance communication among all the project stakeholders (Krygiel and Nies 2008). BIM is a revolutionary technology and process that has quickly transformed the way buildings are conceived, designed, constructed and operated (Hardin 2009).

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In the last 5 years, the concept of Building Information Modeling has gained considerable ground in Pakistan. Most of the medium to large architecture firms in the country have at least a basic understanding of BIM. BIM is understood as a design approach that involves data sharing between consultants involved in building projects. The integration of construction and procurement details, environmental data in BIM or its use in project management or facility management is understood to a lesser degree (Mankani 2009). Nonetheless, there is not much research conducted in the country for BIM potential and its use in the industry. The objective of this research is to assess the potential of BIM for its use and to investigate its applications in designing, coordinating, managing and execution of construction projects.

2. LITERATURE REVIEW

The ability to utilize BIM to virtually construct a building prior to construction of the actual building provides an effective means to check its constructability in the real world and to resolve any uncertainties during the process. This allows for more efficient, better designed structures that limit waste of resources, optimize energy usage, and promote passive design strategies (Bynum, Issa et al. 2012).

Building information modeling (BIM) is the latest generation of object-oriented CAD systems in which all of the intelligent building objects that combine to make up a building design can coexist in a single 'project database' or 'virtual building' that captures everything known about the building. A building information model (in theory) provides a single, logical, consistent source for all information associated with the building (Howell and Batcheler 2005).

BIM has shifted how designers and contractors look at the entire building process from preliminary design, through construction documentation, into actual construction, and even into postconstruction building management. With BIM, you create a parametric 3D model used to autogenerate traditional building abstractions such as plans, sections, elevations, details, and schedules. Drawings are not collections of manually coordinated lines, but interactive representations of the model. Working in a model-based framework guarantees that a change in one view will propagate to all other views of the model. As you shift elements in plan, those changes appear dynamically in elevation and section. If you remove a door from your model, the software simultaneously removes the door from all views and your door schedule is updated (Krygiel and Nies 2008).

The project's design performance can also be better developed with the help of a model. The improved ability to visualize the design proposals in the early project phases greatly aids in the assessment of the spaces and aesthetic finishes of the project. The intent of the designers is more easily and accurately communicated to the other project team members, and adjustments can be made until the design meets the desired goals (Kymmell 2008).

The creation of a virtual 3D project model often consists of multiple efforts by different team members. Either the consultants or the specialty subcontractors (if the model is to be used for fabrication purposes, thus functioning as the shop drawing) will generally model their area of responsibility in the project, so that these individual models may then be combined to show a more complete model of the project. All the parts of this composite model can be coordinated so that any existing conflicts (multiple objects occupying the same space) can be found and resolved. This process is referred to as *clash detection* (Kymmell 2008).

3. RESEARCH METHODOLOGY

After the preliminary study, a detailed literature review was carried out and a number of already developed questionnaire were examined. The specifics of the research survey were developed. Google documents were used to design the online questionnaire for the survey and to collect the data. The link of the questionnaire was sent to construction industry related members via email and by hand where it was required. The email addresses were acquired from the website of Pakistan Engineering Council (PEC), Pakistan Council of Architect and Town Planners (PCATP), and from Institute of Architects Pakistan (IAP) and through personal contacts.

Out of 175 questionnaires sent out, 157 were received. Twenty three (23) incomplete questionnaires were excluded and analysis was carried out on 134 questionnaires. The collected data were analyzed using MS Excel and SPSS. Cronbach's Coefficient Alpha was measured to check the reliability of the collected data and to examine the internal consistency of the items of the questionnaire when research variables were on Likert scale. The Shapiro-Wilk Normality Test was performed to check whether data is parametric or non-parametric i.e. whether it were normally distributed or otherwise. Kruskal-Wallis test was performed to check the differences or similarities in the perception of stakeholders about the research variables. A 5% level of significance was considered to represent statistically significant relationships in the collected data. The multiple choice research variables were analyzed through frequency analysis. The perception level of the respondents to this survey about the research variables was assessed by using the mean score (MS) computed by the following formula (Chan and Kumaraswamy 1996):

$$MS = \frac{\sum(f x s)}{N} \quad (1 \leq MS \geq 5) \qquad (3\text{-}1)$$

Where 's' is score given to each research variable by the respondents and ranges from 1 to 5 when 1 is "Strongly disagree" and 5 is "Strongly agree"; f is frequency of responses to each rating (l-5) for each research variable; and N is total number of responses (134). In addition to the mean score, the five-point scale was transformed to relative importance indices using the relative index ranking technique (Chan and Kumaraswamy 1997; Sambasivan and Soon 2007) to determine the rankings of the research variables and verify the evaluation by mean score.

$$\text{Relative Importance Index (RII)} = \sum w / (A*N) \qquad (0 \leq RII \geq 1) \qquad (3\text{-}2)$$

$$RII = \left(\frac{1n1+2n2+3n3+4n4+5n5}{(A*N)}\right)$$

Where

w = weighting assigned to each research variable by the respondents having range from 1 to 5

n1 = number of respondents for Strongly disagree

n2 = number of respondents for Disagree

n3 = number of respondents for Not sure

n4 = number of respondents for Agree

n5 = number of respondents for Strongly agree

A= highest weight is 5

N = sample size taken as 134

A random sample for this study was selected from a population of more than 30,000 construction industry establishments registered with Pakistan Engineering Council (PEC 2012). It was fairly a large population and the sample is representative of various construction experts.

4. FINDINGS AND DISCUSSION

This research survey was one of the first steps towards understanding and assessing the BIM use and its applications in the local context for coordinating, communicating and managing the construction projects. The data obtained from this study suggested that BIM is an effective tool and process for improving the delivery process of construction projects.

4.1 Respondent's Profile

The respondents to this survey as indicated in Table 1 were Architects / Designers, Engineers / MEP Consultants, Contractors / Specialty Contractors, Academicians and Developers / Facility Owners with the varied professional experience from I to 20 years or more and they were holding positions in their organizations as Managing Director, Project Director / Manager, Project Architect / Engineer / Planner, Contract Manager, Site Manager, Site Supervisor, Facility Manager, and Professor / Lecturer in Academia.

Figure 1 and 2 shows there was an increasing level of awareness about BIM technology and its processes. 88.1 % of the respondents were having either little or general knowledge and 11.2% were with working knowledge of BIM. Most of them (64.9%) have no working experience with BIM (because of varied adoption barriers) but quite a number of them (35.1%) were having varied experience with this technology. However, all of them were having the knowledge of this technology and its processes (the recorded level of knowledge about BIM was 44% for little, 44% for general and 11.2% for working).

Table 1: Respondent's grouping

CI Stakeholders	Frequency	Percent	Cumulative Percent
Architects / Designers	30	22.4	22.4
Engineers /MEP Consultants	48	35.8	58.2
General / Specialty Contractors	25	18.7	76.9
Academician	20	14.9	91.8
Developers / Facility owners	11	8.2	100.0
Total	**134**	**100.0**	

The intention of getting respondents' profile was to establish that the respondents were qualified to respond this survey with varied professional experience in construction industry and working knowledge or experience with BIM.

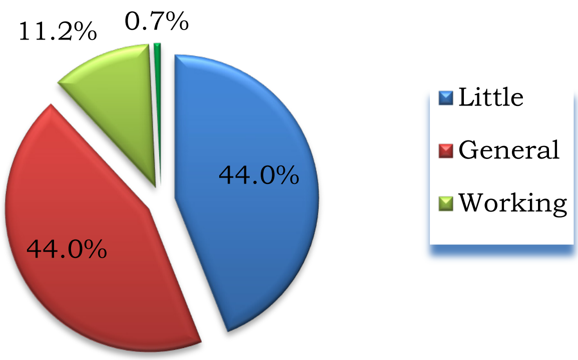

Fig. 1: Respondent's level of knowledge about BIM

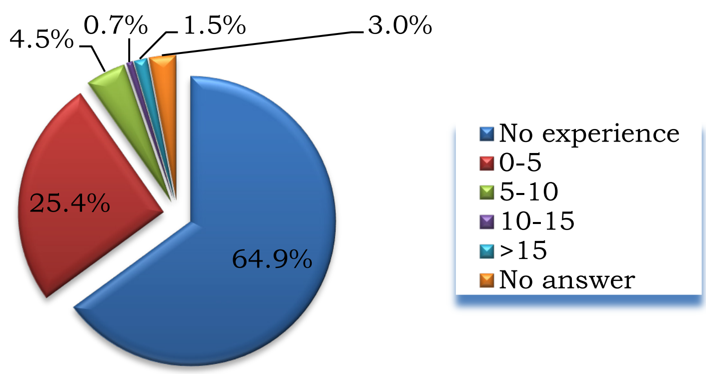

Fig. 2: Respondent's experience with BIM

4.2 Respondent's Organization Profile

The type of the Organizations participated in this survey were Architecture / Designers, Engineers / MEP Consultants, General / Specialty Contractors, Academic Institutions, and Developers / Facility Owners. The geographical location of the projects undertaken by the respondent's Organization was across the country (31% in Punjab, 15.1% in Khyber Pakhtunkhwa, 17% in Sind, 10.1% in Balochistan, 9.9% in Kashmir, and 8.5% in Gilgit Baltistan, whereas some were also working in abroad and having 8.5%). The average number of employees was from 25 to more than 500. The financial strength in terms of the projects undertaken was from 100 to more than 500 million and the type of the projects undertaken by these Organizations were residential, commercial, educational, healthcare, institutional, civil and cultural, industrial, hospitality, entertainment and sports, transportation, religious etc. The intent of getting organization profile was to make sure that the respondents were working in well-established organizations working in different parts of the country on different kind of projects.

4.3 Nature of the collected data

The validity of the collected data was measured and it was found the *p*-values for each research variable was less than 0.05 or 0.01. The correlation coefficient of each research variable was positive and significant at $\alpha = 0.01$ or $\alpha = 0.05$. Cronbach's Coefficient Alpha value was 0.817 and this value reflected a higher degree of internal consistency of the collected data. After conducting the normality test, the significance values were found 0.000 which were less than 0.05 indicating that the collected data was not normally distributed or the data was non-parametric in nature and non-parametric tests were required for further analysis.

4.4 Kruskal-Wallis test

Table 2 shows the outcomes of Kruskal-Wallis test conducted to compare the outcome of the research variables and no significant difference (as $p > 0.05$) was found among the construction industry stakeholders from each other indicating that all have similar general perception about the variables.

Table 2: Kruskal-Wallis Test for Potential for use of BIM

Research Variable	Chi-Square	df	Asymp. Sig.
BIM minimizes risk of discrepancies between plan, section, and elevation.	3.661	4	0.454
BIM facilitates the instant generation of new sections, elevations and 3D views.	4.973	4	0.29
BIM reduces time for drafting and increases for design.	1.292	4	0.863
BIM carries its ability to let AEC people (at different locations) work on the same building model at the same time.	3.735	4	0.443
BIM is connecting AEC people professionally in a new way by sharing the data in an integrated 3D environment for better decision making and project control.	6.997	4	0.136
BIM is efficient for site analysis, site utilization planning and to model the existing site conditions.	5.316	4	0.256
BIM reduces rework in building performance analysis (energy, thermal, acoustic, lighting and airflow).	4.331	4	0.363
BIM is also efficient in structural, mechanical and other Eng. Analyses.	2.883	4	0.578
BIM facilitates in reviewing building codes, bye laws, fire and life safety compliance in 3D environment.	3.572	4	0.467

a. Kruskal Wallis Test

b. Grouping Variable: Construction Industry Stakeholders

4.5 Frequency Analysis

Descriptive Statistics were used for frequency analysis of the research questions to draw the results. The following were the outcomes from this frequency analysis:

Autodesk Revit was being considered to be used in majority (54.4%) of the respondent's Organizations as a BIM application followed by Graphisoft ArchiCAD (7.4%) and the rest were considering or going to test the other applications. This indicated that Autodesk Revit was known to the majority of the respondents to be used as a BIM application. This may be due to the fact that most of the organizations were using Autodesk AutoCAD as 2D CAD application in their offices.

Figure 3 indicates the majority of the Organizations were Planning to adopt BIM in near future (46.3%) followed by the ones which were in the process 'For testing purpose' (29.1%). Also 22.4% were perusing its adoption 'Actively' whereas 2.2% 'Exclusively'. This shows the increasing awareness about BIM and the trend of its adoption in near future by most of the organizations.

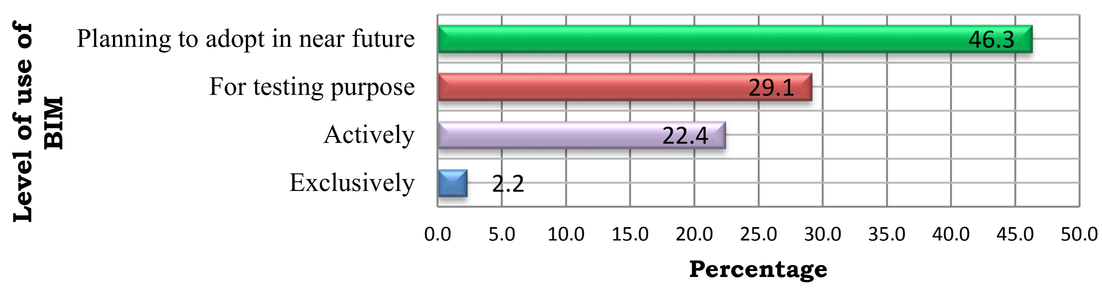

Fig. 3: The level of BIM to be used in the organizations

In response to two the multiple choice questions 'For better visualization and being an interactive tool', followed by 'To increase the capacity of design reviews', were the main reasons to take interest in the BIM applications as shown in Figure 4 whereas Figure 5 indicated 'Constructability analysis' followed by 'Model based estimation and construction sequencing' were the major anticipated tasks for which BIM is being considered to be adopted.

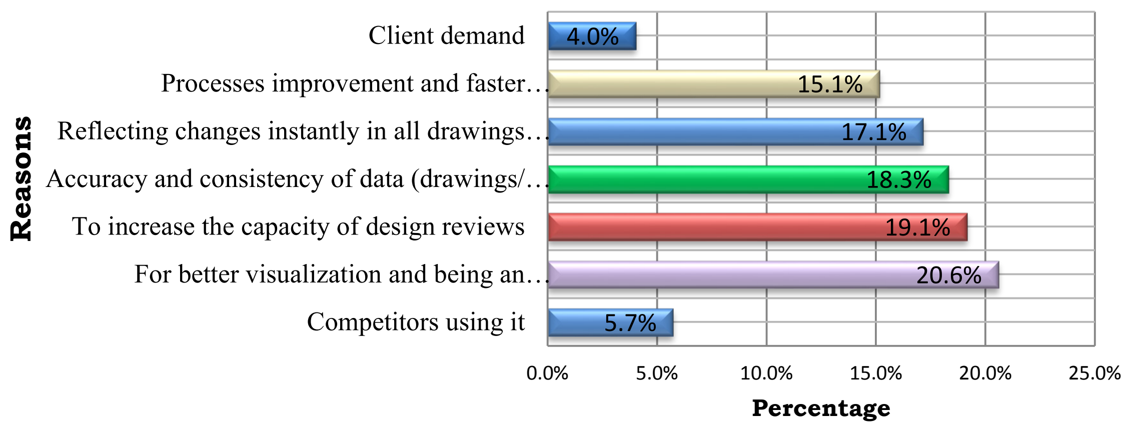

Fig. 4: The reasons for taking interest in BIM applications

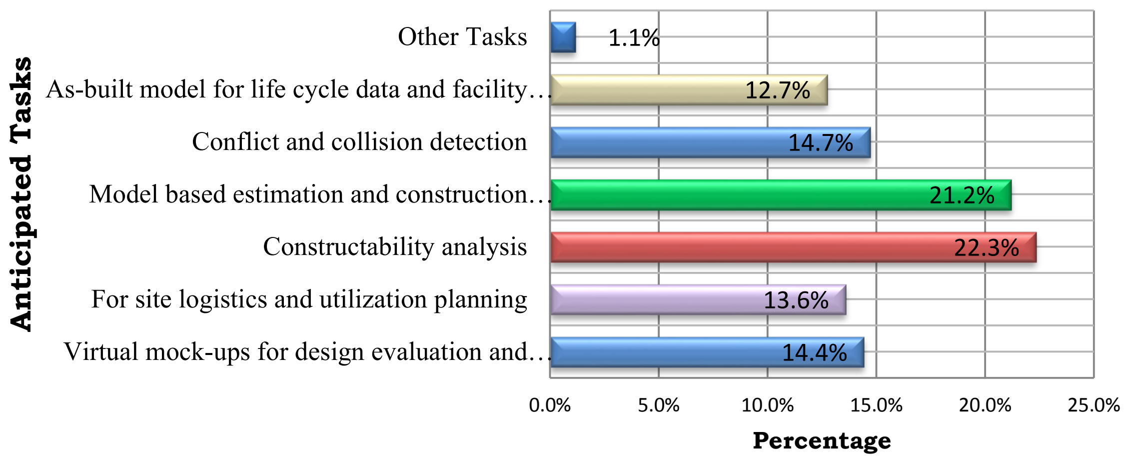

Fig. 5: The anticipated tasks for which BIM is to be adopted

With increasing interest in BIM use and its applications a set of research variables was developed in the questionnaire. The results of the responses to these variables have been shown in in Table 3. The Mean Score (MS) values of these variables indicated that the respondents to this survey were agreed that BIM minimizes risk of discrepancies between plan, section, and elevation, BIM facilitates the instant generation of new sections, elevations and 3D views, BIM reduces time for drafting and increases for design, BIM carries its ability to let AEC people (at different locations) work on the same building model at the same time, BIM is connecting AEC people professionally in a new way by sharing the data in an integrated 3D environment for better decision making and project control, BIM is efficient for site analysis, site utilization planning and to model the existing site conditions, BIM reduces rework in building performance analysis (energy, thermal, acoustic, lighting and airflow), BIM is also efficient in structural, mechanical and other Eng. Analyses, and BIM facilitates in reviewing building codes, bye laws, fire and life safety compliance in 3D environment.

Table 3: Frequency Analysis for use of BIM and its applications

		1	2	3	4	5
Research Variables	MS	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
BIM minimizes risk of discrepancies between plan, section, and elevation.	3.94	1	3	23	83	24
BIM facilitates the instant generation of new sections, elevations and 3D views.	3.93	0	3	24	86	21
BIM reduces time for drafting and increases for design.	3.75	0	7	41	65	21
BIM carries its ability to let AEC people (at different locations) work on the same building model at the same time.	3.74	0	5	41	72	16
BIM is connecting AEC people professionally in a new way by sharing the data in an integrated 3D environment for better decision making and project control.	3.81	0	4	37	73	20
BIM is efficient for site analysis, site utilization planning and to model the existing site conditions.	3.74	0	6	40	71	17

BIM reduces rework in building performance analysis (energy, thermal, acoustic, lighting and airflow).	3.75	0	5	39	74	16
BIM is also efficient in structural, mechanical and other Eng. Analyses.	3.83	1	0	38	77	18
BIM facilitates in reviewing building codes, bye laws, fire and life safety compliance in 3D environment.	3.69	1	3	49	65	16

4.6 Ranking of Research Variables

Table 4 shows that when the research variables were ranked through Mean Score (MS) and Relative Importance Index (RII) the following was the outcome:

1. Architects / Designers have ranked '*BIM minimizes risk of discrepancies between plan, section, and elevation*' at the top whereas
2. Engineers / MEP Consultants have ranked
   - '*BIM is efficient for site analysis, site utilization planning and to model the existing site conditions*' and
   - '*BIM is also efficient in structural, mechanical and other Eng. Analyses*' at the top.
3. General / Specialty Contractors have ranked '*BIM facilitates the instant generation of new sections, elevations and 3D views'* at the top.
4. Academicians have marked:
   - '*BIM reduces time for drafting and increases for design',*
   - '*BIM carries its ability to let AEC people (at different locations) work on the same building model at the same time',*
   - *'BIM reduces rework in building performance analysis (energy, thermal, acoustic, lighting and airflow)',* and
   - *'BIM is connecting AEC people professionally in a new way by sharing the data in an integrated 3D environment for better decision making and project control'*, at the highest rank whereas
5. Developers / Facility Owners have ranked '*BIM facilitates in reviewing building codes, bye laws, fire and life safety compliance in 3D environment*' at the top

Table 4: Comparison of ranks for BIM use and its applications

Research Variable	CI Stakeholders	Mean Score	RII	Overall Rank
	Architects / Designers	4.0667	0.8133	1

BIM minimizes risk of discrepancies between plan, section, and elevation.	Engineers / MEP Consultants	3.9167	0.7833	4
	General / Specialty Contractors	3.9200	0.7840	3
	Academician	3.9500	0.7900	2
	Developers / Facility owners	3.7273	0.7455	5
BIM facilitates the instant generation of new sections, elevations and 3D views.	Architects / Designers	4.0333	0.8067	2
	Engineers / MEP Consultants	3.9167	0.7833	3
	General / Specialty Contractors	4.0400	0.8080	1
	Academician	3.9000	0.7800	4
	Developers / Facility owners	3.5455	0.7091	5
BIM reduces time for drafting and increases for design.	Architects / Designers	3.6000	0.7200	5
	Engineers / MEP Consultants	3.7708	0.7542	3
	General / Specialty Contractors	3.8000	0.7600	2
	Academician	3.8500	0.7700	1
	Developers / Facility owners	3.7273	0.7455	4
BIM carries its ability to let AEC people (at different locations) work on the same building model at the same time.	Architects / Designers	3.7333	0.7467	3
	Engineers / MEP Consultants	3.8125	0.7625	2
	General / Specialty Contractors	3.5600	0.7120	5
	Academician	3.8500	0.7700	1
	Developers / Facility owners	3.6364	0.7273	4
BIM is connecting AEC people professionally in a new way by sharing the data in an integrated 3D environment for better decision making and project control.	Architects / Designers	3.8667	0.7733	2
	Engineers / MEP Consultants	3.8333	0.7667	3
	General / Specialty Contractors	3.6000	0.7200	4
	Academician	4.1000	0.8200	1
	Developers / Facility owners	3.5455	0.7091	5
BIM is efficient for site analysis, site utilization planning and to model the existing site conditions.	Architects / Designers	3.7000	0.7400	3
	Engineers / MEP Consultants	3.9167	0.7833	1
	General / Specialty Contractors	3.5200	0.7040	5
	Academician	3.6000	0.7200	4
	Developers / Facility owners	3.8182	0.7636	2
BIM reduces rework in building performance analysis (energy, thermal,	Architects / Designers	3.7000	0.7400	4
	Engineers / MEP Consultants	3.8333	0.7667	2
	General / Specialty Contractors	3.5600	0.7120	5

acoustic, lighting and airflow).	Academician	3.9000	0.7800	1
	Developers / Facility owners	3.7273	0.7455	3
BIM is also efficient in structural, mechanical and other Eng. Analyses.	Architects / Designers	3.8000	0.7600	3
	Engineers / MEP Consultants	3.9167	0.7833	1
	General / Specialty Contractors	3.8000	0.7600	3
	Academician	3.6500	0.7300	4
	Developers / Facility owners	3.9091	0.7818	2
BIM facilitates in reviewing building codes, bye laws, and fire and life safety compliance in 3D environment.	Architects / Designers	3.7333	0.7467	3
	Engineers / MEP Consultants	3.7500	0.7500	2
	General / Specialty Contractors	3.6400	0.7280	4
	Academician	3.4500	0.6900	5
	Developers / Facility owners	3.8182	0.7636	1

This ranking (as shown in Table 4) reflected how BIM was perceived by different construction industry stakeholders according to their interest in BIM use and its applications. Architects / Designers were more interested to use BIM to minimize risk of discrepancies between plan, section, and elevation whereas Engineers / MEP Consultants have indicated to apply BIM for site analysis, site utilization planning and to model the existing site conditions and to use BIM for Engineering Analyses. General / Specialty Contractors have the perception that BIM facilitates the instant generation of new sections, elevations and 3D views. This may be due to their interest in generating shop drawings for offsite prefabrication. Academicians were in a view to use BIM to reduce time for drafting and to increase for design and also to reduce rework in building performance analysis. Developers / Facility Owners have thought about BIM that it facilitates in reviewing building codes, bye laws, fire and life safety compliance.

In overall ranking as shown in Figure 6 for use of BIM in the Construction Industry 'BIM minimizes risk of discrepancies between plan, section, and elevation' is ranked at the top and followed by 'BIM facilitates the instant generation of new sections, elevations and 3D views' whereas 'BIM facilitates in reviewing building codes, bye laws, fire and life safety compliance in 3D environment', is ranked at the lowest and followed by 'BIM carries its ability to let AEC people (at different locations) work on the same building model at the same time' and 'BIM is efficient for site analysis, site utilization planning and to model the existing site conditions' both with the same ranking.

This overall ranking indicates that construction industry stakeholders have the perception for use of BIM that it minimizes risk of discrepancies between orthographic views like plan, section, and elevation. They also perceive BIM as a facilitator that instantly generates new sections, elevations and 3D views. They have least perception about BIM that it facilitates in reviewing building codes, bye laws, and fire and life safety compliance in 3D environment. This could be because of most of the industry people as indicated in Fig. 1 and 2 did not have sufficient working experience and knowledge with the BIM technology and its process.

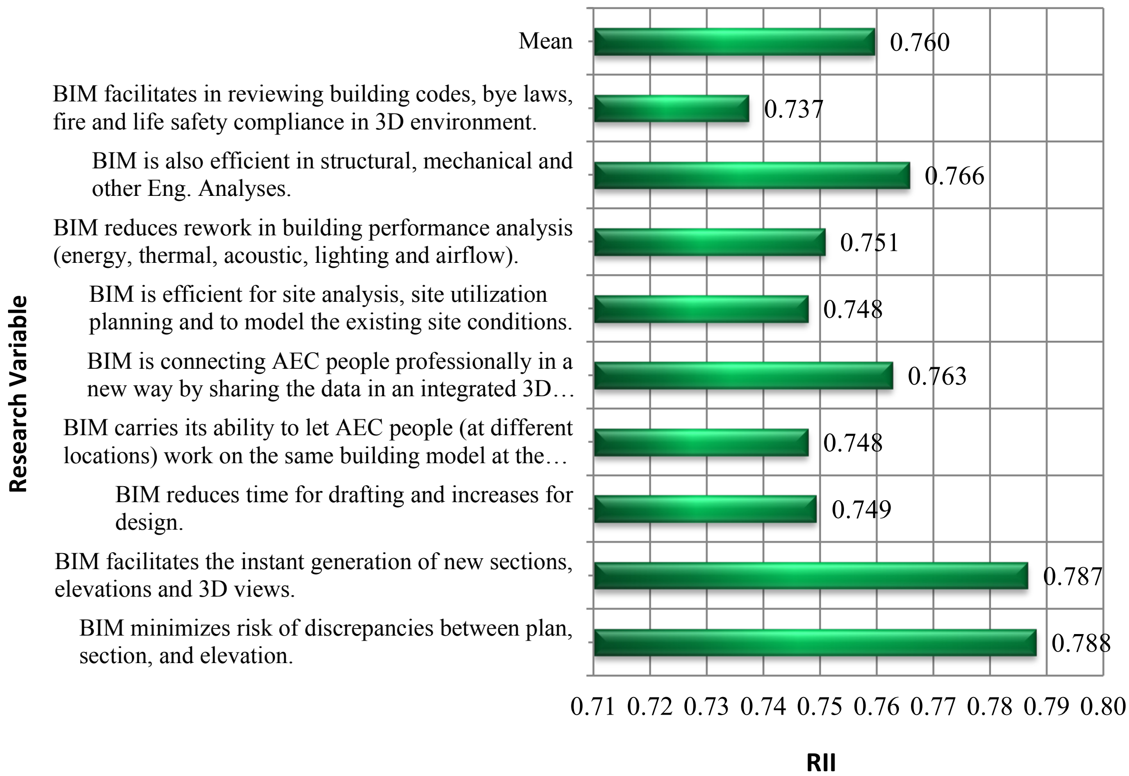

Fig. 6: Overall ranking for Potential for use of BIM

5. CONCLUSIONS

There was an increasing level of awareness about BIM technology and its processes as 88.1 % of the respondents were having either little or general knowledge and 11.2% were with working knowledge of BIM. Majority of the respondents (64.9%) of this survey have no working experience with BIM because of various adoption barriers but quite a number of them (35.1%) were having varied experience with this technology. According to the overall frequency analysis of the collected data 'For better visualization and being an interactive tool', followed by 'To increase the capacity of design reviews', were the main reasons to take interest in the BIM applications. 'Constructability analysis' followed by 'Model based estimation and construction sequencing' were the major anticipated tasks for which BIM is being considered to be adopted. Construction Industry stakeholders have perceived the use of BIM that it minimizes risk of discrepancies between orthographic views like plan, section, and elevation. They also believe BIM as a facilitator that instantly generates new sections, elevations and 3D views.

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