ADVANTAGES AND BARRIERS TO ADOPTION OF GREEN BIM IN THE CONSTRUCTION INDUSTRY OF SINDH

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ABSTRACT

Objective: Green BIM, has gained the attention of researchers in last decade all over the world. Many construction industries are presently adopting Green BIM to improve construction practices and provide long-term advantages. Despite the long term benefits of this new technology, Green BIM technology in the construction industry still lacking in many countries, especially in Pakistan construction industry. Therefore, this research aims to enhance BIM enabled the sustainable design and explores its advantages and barriers in adopting the green BIM.

Research Method: This research was carried out quantitatively where data collection was carried out through a questionnaire survey to identify the advantages of green BIM and barriers in adopting of green BIM in construction industry of Sindh. A total 75 questionnaire forms were collected from clients, consultants, employees and contractors.

Findings: 58% factors were identified as advantages of green BIM and the 66% were identified as top barriers come in the adoption of green BIM.

Originality: This study will help professionals to understand the advantages of green BIM and also its barriers and their mitigation measures in the construction industry.

Keywords: Green BIM, Advantages, Barriers, Construction industry

1. INTRODUCTION

In 21st century new specifications and guidelines for building construction are constantly being added to the worldwide construction industry (Purchase et al. 2022). The European Parliament issued guidelines to its twenty-eight member states requiring the use of BIM for projects. It supports these nations in making their project management system efficient and successful (Charef et al. 2019). Pakistan construction industry is not well developed till this time, hence to overcome these problems new techniques are best for developing construction industry of Pakistan (Khaskheli et al. 2020). The western world environment has transformed because of the introduction of this technique known as green BIM. Thus, the capacity to evaluate sustainability factors such as minimize carbon in construction, minimizing energy use, improving environmental performance, efficient system waste management, and enhancing the indoor climate throughout the structure lifetime is defined as "green BIM." Additionally, its significant effects and contribution to the delivery of building projects sectors are plain to see. Construction sector is disintegrating, and operates in phenomena where knowledge management is always unclear and quickly changed in short time (Dave and Koskela, 2009).

1.1 CONSTRUCTION INDUSTRY OF PAKISTAN

220 million people are living in Pakistan, and there are about 60 million workers. Due to a population growth rate of 2.4% annually as of the 2017 census, there is an increasing need for homes. The Pakistan Economic Survey had estimated that the country's construction sector contributes 2.53% of the GDP. From total labor force in Pakistan, about 7.61% of labor force is working in the construction sector. The private sector's GFCF increased between FY2019 and FY2020 by 20.6%. Over 95% of the

whole GFCF came from the private sector. The China Pakistan Economic Corridor (CPEC), which involves building motorways, power plants, and dams, has strengthened the construction industry. In GDP, the contribution of Pakistan's construction industry is up to 380 billion PKR (BOI, 2022).

1.2 GREEN BUILDING DESIGN

The phrase "green building design" can go by a variety of titles in the built environment, including sustainable design, green architecture, green design," and environmental design, yet surprisingly; they all mean the same thing (McLennan, 2004). The researcher has come across a variety of distinct definitions for green construction or sustainable design. "Green design structure is the design approach that optimizes quality of the built environment concerning decreasing the adverse consequences to the surrounding environment (McLennan, 2004). In a different light, from an industrial standpoint, the U.S. agency EPA, describes the green structure as "the method of designing structures and using eco-friendly methods and the efficiency use of assets throughout a building's life cycle, from the initial site to design, construction, execution, maintenance, reconstruction, and demolition (Kubba, 2012).

2. LITERATURE REVIEW

Green construction was progressively spread over the world over the years (L, Chen et.al, 2022).Green building was a technique that provides eco-friendly, enhances occupant's health, utilizes and reuses viable material, minimizes CO_2 and other harmful gas emissions and stimulates more greenery (Meena et.al, 2022). Green buildings have several important advantages over traditional ones, including superior comfort, increased energy efficiency, reduced pollution and hazardous emissions, and environmental friendliness (Council, 2020). When it comes to operation and maintenance, green buildings have higher standards and needs than conventional structures (Hauashdh, et.al, 2022). In such a setting, various researches were suggested that building information modeling (BIM) was a useful technique to raise the standard of operation and maintenance for green buildings. As a multi-functional approach, BIM can assist management groups in achieving these goals during the structure's operational and maintenance phase (Panah et al. 2021). The use of BIM has tremendous potential in the management of maintenance tasks after construction period (Abideen et al. 2022). In the phase of operation and maintenance of sustainable structures, (Liao) also emphasized how BIM can successfully manage challenges and crises, maintain operational efficiency, and enhance service quality (Liao et al. 2012). In addition to this, the use of BIM was acknowledged to have advantages across the course of green building lifecycles, from the early conceptual design stage to the operation and maintenance stage (Ghaffarian hosein et al. 2017).

Through a methodical assessment of the literature, the objective of this study is to conduct a thorough evaluation of the BIM capacity in the period of operation and maintenance of green buildings. This systematic review was carried out in order to accomplish this goal using the PRISMA procedure. Finally, a thorough analysis of BIM's capabilities for facilities management of green buildings was created, and recommendations for more research were made (Cao et al. 2022). The efficient creation of sustainable and high-performance buildings is made possible by the detailed information provided to designers, allowing them to compare and choose the best sustainable solutions for their projects. Researchers contend that a sustainable practice to be examined and incorporated before construction even begins, if possible during the basic design stages. Additionally, during these stages, BIM can have a greater effect, enhancing its ability to have an impact on the sustainability of buildings (Carvalho et al. 2020). Green construction using BIM is presently given top emphasis in design. The main sustainability goals reached in the AEC sectors with BIM are reviewed and discussed in there articles. Throughout the entire project lifespan, building information modeling (BIM) data that is created during design enables quicker, more profitable, safer, and much less wasteful construction as well as more economical, more sustainable operation, repair, and ultimate decommissioning. It was determined from this research that BIM has the full potential to improve building design, lower costs, and further conserve energy (Min et al. 2022). For such a sustainable project, green BIM calls for taking into account procedures, technology, and an information management strategy that fosters inter-organizational cooperation. To achieve these green BIM standards, efficient information management is therefore likely to call for a lengthy discussion with stakeholders. Furthermore, it becomes clear that achieving social benefit is necessary in order to get the ecologically sustainable advantage from the combination of green practices and BIM technologies. It appears that in addition to the technological difficulties which mention software (Gourlis. 2017).

2.1 BUILDING INFORMATION MODELING (BIM)

A new method of construction design is known as building information modeling (BIM). It not only makes it easier to represent designs digitally, but it also provides all the information needed for any project before it is built (Memon et al. 2014; Hussain et al. 2022).BIM is the most popular tool used for designing and many more purposes related to engineering, construction, and architecture and facility management industries (Smith, P.2014). Even while BIM tools are used to design projects, document project all over data, and, improve communication system among all project teams, although construction professionals not at all completely grasp the principles underlying them (Patel et.al, 2023). There is a misperception that BIM is merely a software program, but the opportunities it opens up for project stakeholders go far beyond the definition of the word software (Krygiel and Nies 2008).

2.2 GREEN BIM CONCEPT

The combination of green building practices with BIM technology is known as green BIM (Cao et.al, 2022). BIM technology has the potential to influence green construction throughout the project lifecycle from an environmental, social, and economic perspective (Marzouk et.al, 2022). In addition to the aforementioned, the extensive data sources offered by the BIM tool when utilized by construction industry stakeholders, to evaluate sustainability features such as minimizing CO_2during all construction phase, evaluating energy consumption, evaluating the environmental performance, waste management, and enhancing indoor environment, all these parameters lead towards Green BIM (Shen and Pan. 2023).

2.3 RELATIVE IMPORTANCE INDEX (RII)

Relative Importance Index, or RII, is the average for a factor that determines its importance in respondents' perceptions. The factor with the highest weight has RII = 1, followed by the factor with the next-lowest weight with RII = 2, and so on. The sum of the Rensis Likert allocation divided by the total number of responses is the weighting (Formula for calculating the RII of each factor is given below (Almarashda et al. 2022),

$RII = \Sigma a_i n_i / (A5*N)$

RII: Relative Important Index

$a_i n_i$: Weighting given to each factor

A: Highest weightage

N: Total number of respondents

3. METHODOLOGY

This study was mainly a literature review and adopted to achieve the objectives of this research. A detailed literature review was carried out to identify the advantages of Green BIM and barriers to the adoption in Green BIM in the construction industries of Sindh. Published research papers as a qualitative analysis were reviewed for investigation of advantages and barriers factors. The study mainly focuses on advantages of green BIM and Barriers comes in the adoption of this new technology known as green BIM in construction industries of Sindh. On the basis of the literature review questionnaire survey form developed to contain the factors of mostly related and repeated advantages and Barriers of green BIM. A Likertsscale was used in this research for the identification of the level of occurrence and level of significance of each factor. It contains five-point scale for the level of occurrence (Not occurring, Sometimes occurring, moderately occurring, Mostly occurring, Always occurring) and level of significance (Not significant, slightly significant, moderately significant, Very significant, extremely significant) respectively. After getting responses, all the data were analyzed through SPSS software. Results are ranked based on relative important index RII.

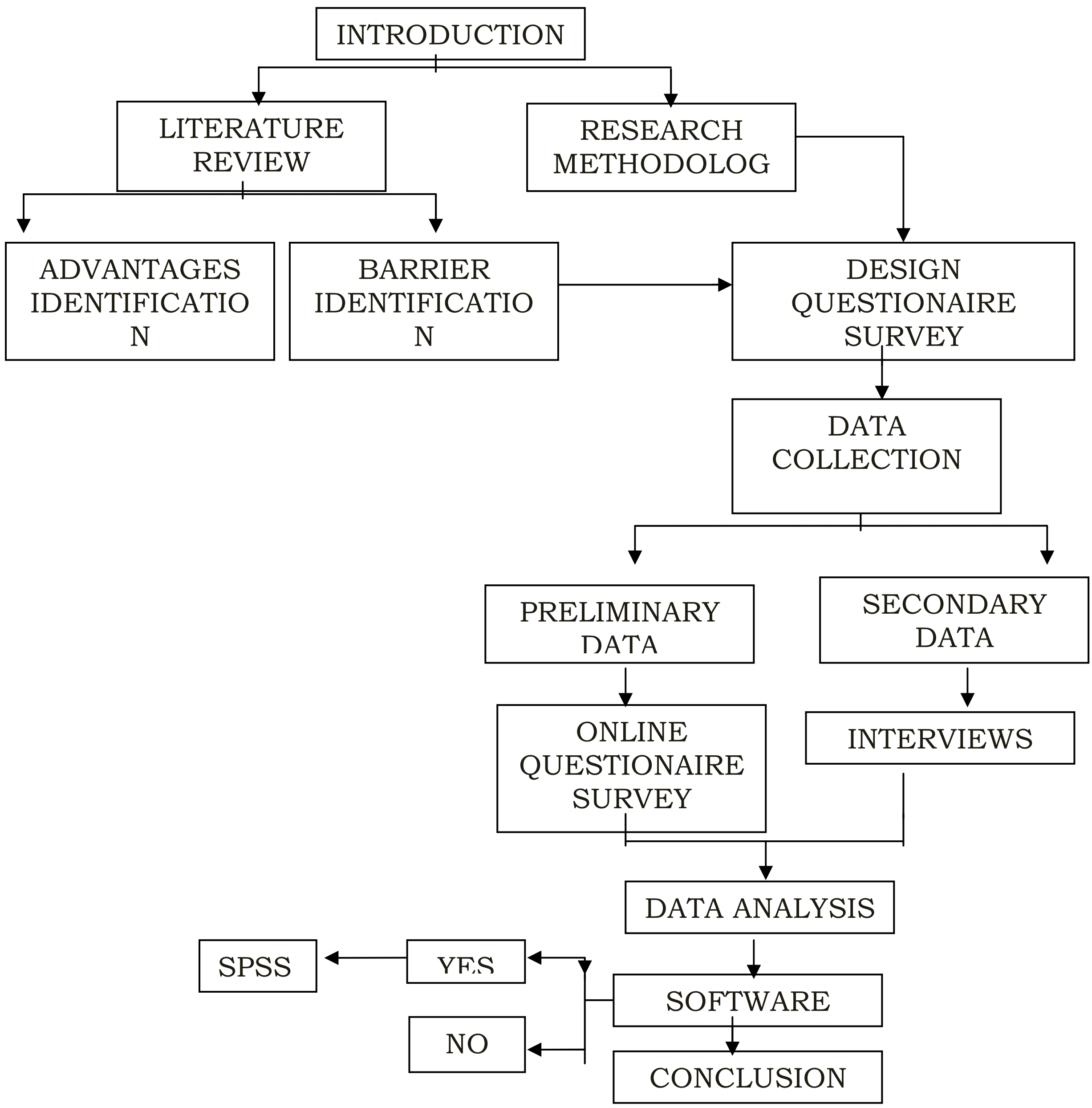

Figure 1. Flow Diagram of Research Methodology

4. RESULTS AND DISCUSSION

Results and comments from the questionnaires are presented in this chapter. Data from the questionnaires are evaluated, and the results are discussed, to achieve the objectives of the study. The researcher makes comments on the findings to clarify them in details.

4.1 DEMOGRAPHIC INFORMATION

Figure 1 shows the gender in construction industries of Sindh. From respondents 93.3% were male and other 6.7% are females. Figure 2 shows the type of current organization of respondents. In response we find 14.7% are from consultants firm, 10.7% are clients, 32% are contractors and 42.7% are from others organizations. Figure 3 shows the type of projects currently undertaken by your organization. In response 33.3% are residential projects, 28 are infrastructure projects, 21.3% are social amenities projects and 17.3% are non-residential projects. After that figure 4 was about the size of projects in which respondents are involved in terms of contract amount of projects in Million. In response 41.3% projects are less than 20 Million, 24% are from a range of 20 to 70 Million, 12% are in the range of 80 to 150 Million, 6.7% are in the range of 150 to 300 million and others are in the range above 300 million. In addition, figure 5 shows the highest level of education of respondents. The graph shows 61.3% of respondents are a bachelor in civil engineering, 21.3% are at master level, 16% have PHD level study and others have a diploma. Fig 6 shows the years of experience of respondents. In response, it shows 73.3% having 1 to 4 years of experience, 8% having 5 to 9 years, 16% having 10 to 14 years and others have greater than 14 years of experience. In last fig 7 shows the current position of respondents in their organization. It shows 42.7% are site engineers, 8% are resident Engineers, 9.3% are planner engineers, 12% are construction managers, 12% are project managers, 6.7% are directors, 4% are material engineers and others are general managers.

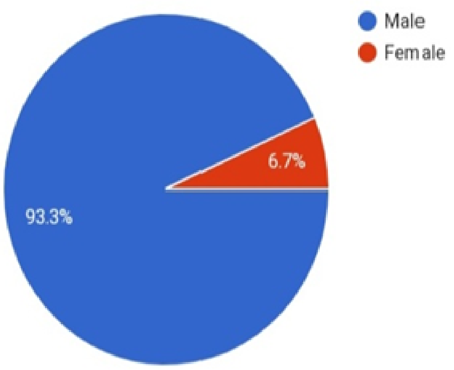

Figure 2: Gender of the Respondents

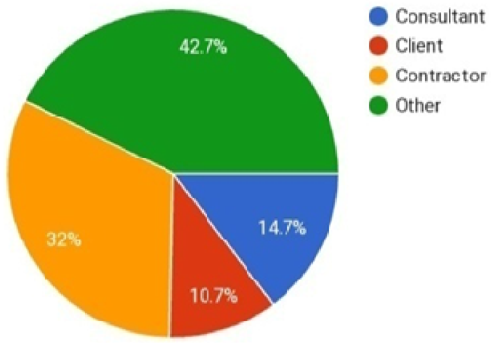

Figure 3: current Organization of respondents

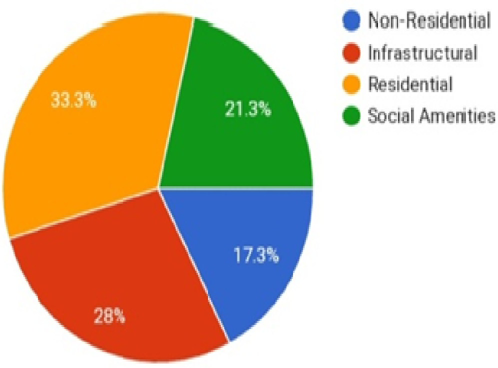

Figure 4. Under Taken Project by respondents organization

Figure 5. Size of Project of your organization.

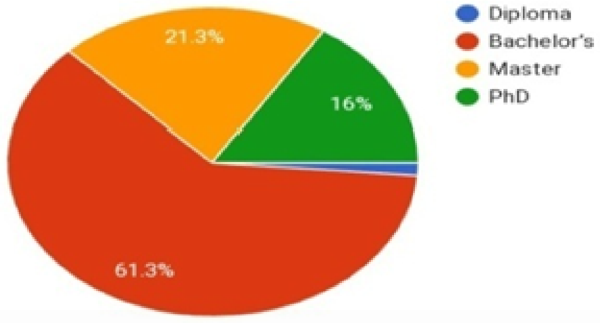

Figure 6. Education Level of respondents

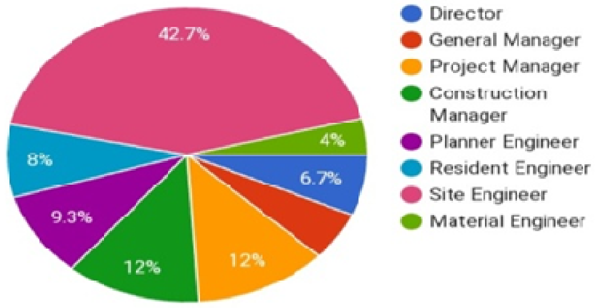

Figure 7. Current Position of respondents

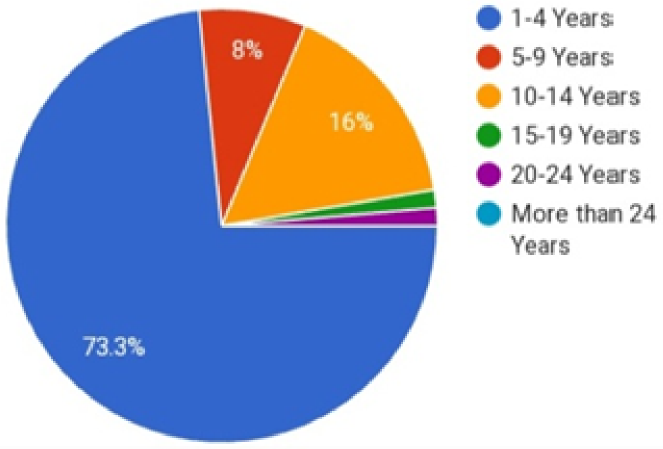

Figure 8. Experience of respondents

4.2 IDENTIFIED ADVANTAGES AND BARRIERS TO ADOPTION OF GREEN BIM

4.2.1 ADVANTAGES OF GREEN BIM BASED ON LEVEL OF OCCURRENCE

A total of 18 from 41 appropriated and significant advantages of green BIMare selected based on level of occurrence from outcomes of respondents. Results show the rank of each identified advantages based on a relative important index (RII). The value of RII is from 0 to 0.6. According to ranking the level of occurrence of each identified factor from top to bottom in table 4.2.1 are Material wastage management, Operation of infrastructure, Project cost, Site based conflicts, New construction methods, Performance analysis, Health risk, Resource planning, Fewer energy consumptions techniques, Resource allocation, safety risk, Maintenance of infrastructure, Recycle management, Energy analysis, Decision-making power, Project productivity, Project quality, and carbon Risk respectively.

Table 1. RII of each advantage based on level of Occurrence

Sr. No	ADVANTAGES	$\Sigma a_i n_i$	A5*N	RII	RANK
1.	Operation Of Infra Structure	224	375	0.597	01
2.	Material Wastage Management	210	375	0.597	01
3.	Project Cost	217	375	0.594	02
4.	Site Based Conflicts	215	375	0.578	03
5.	New Construction Method	216	375	0.576	04
6.	Performance Analysis	214	375	0.570	05
7.	Health Risk	213	375	0.568	06
8.	Resource Planning	211	375	0.562	07
9.	Less Energy Consumptions Techniques	223	375	0.560	08

10.	Resource Allocation	208	375	0.554	09
11.	Safety Risk	207	375	0.552	10
12.	Maintenance Of Infra Structure	207	375	0.552	10
13.	Recycle Management	224	375	0.552	10
14.	Energy Analysis	204	375	0.544	11
15.	Decision Making Power	200	375	0.533	12
16.	Project Productivity	198	375	0.528	13
17.	Project Quality	195	375	0.520	14
18.	Carbon Risk	207	375	0.520	14

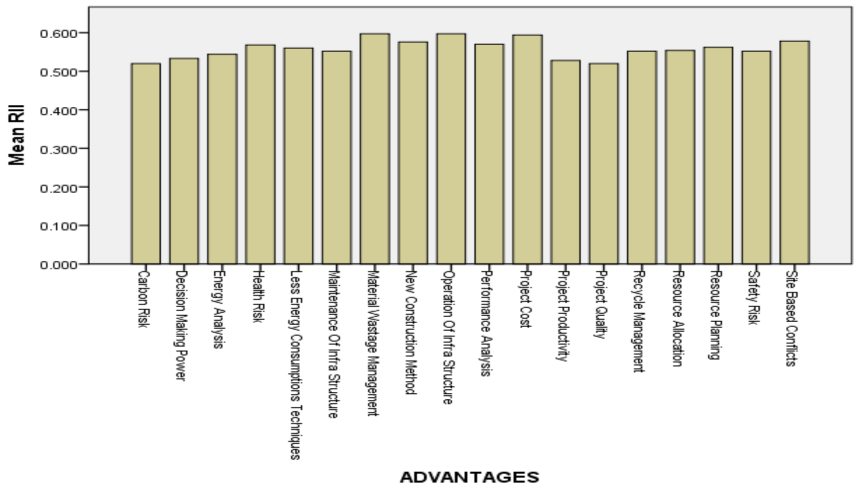

Figure. 9 Advantages of green BIM based on level of significance

4.2.2 BARRIERS TO ADOPTING OF GREEN BIM BASED ON LEVEL OF OCCURRENCE

8 majors Barriers out of 12 mostly came always in the adoption of green BIM in the construction industries of Sindh. Results show the rank of each identified Barrier based on the relative important index (RII). The value of RII is from 0 to 0.6. According to rank the level of occurrence of each identified factor from top to bottom in below table 4.2.2 are Existing Construction Culture, Financial Resource, Limited use of BIM, Vast and complex info required, ICT Infrastructure, Training Cost, Information Management Standard Practices and Apathy of client, team or customer respectively.

Table. 2 RII of each barrier based on level of Occurrence

Sr. No	ADVANTAGES	$\Sigma a_i n_i$	A5*N	RII	RANK
1.	Existing Construction Culture	225	375	0.600	01
2.	Financial Resource	222	375	0.592	02
3.	Limited use of BIM	217	375	0.578	03
4.	Vast and complex info required	217	375	0.578	03
5.	ICT Infrastructure	216	375	0.576	04
6.	Training Cost	204	375	0.544	05
7.	Information Management Standard Practices	201	375	0.536	06
8.	Apathy of client, team or customer	191	375	0.509	07

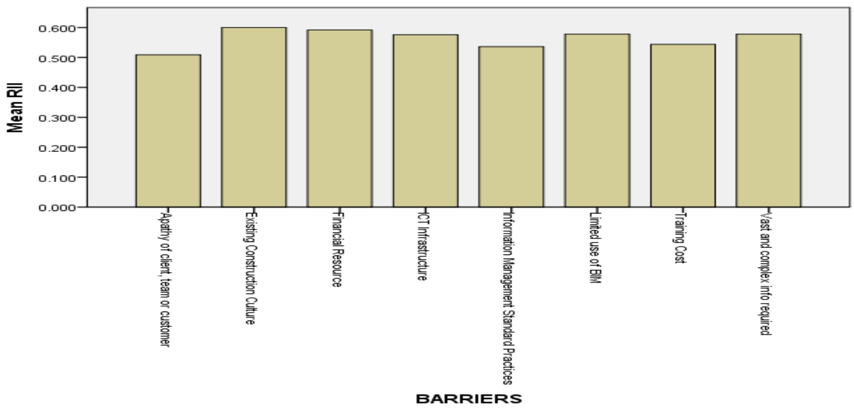

Figure 10. Barriers in Adopting of Green BIM Based on Level of Occurrence

4.2.3 ADVANTAGES OF GREEN BIM BASED ON LEVEL OF SIGNIFICANCE

Based on the level of significance in the results of the respondents, 18 out of the 41 appropriated and significant advantages of green BIM were chosen. Results show the relative importance index (RII) ranking of each of the advantages that were identified. RII's value ranges from 0 to 0.6. From top to bottom, the following table 4.2.3 ranks the level of each identified factor according to its level of significance are Energy Analysis, Performance Analysis, Less Energy Consumptions Techniques, Safety Risk, Resource Planning, Resource Allocation, Decision Making Power, Project Productivity, Health Risk. Operation Of Infra Structure, Maintenance Of Infra Structure, Project Cost, Project Quality, New Construction Method, Site Based Conflicts respectively.

Table 3. RII of each advantage based on level of Significance

Sr. No	ADVANTAGES	$\Sigma a_i n_i$	A5*N	RII	RANK
1.	Energy Analysis	220	375	0.586	01
2.	Performance Analysis	219	375	0.584	02
3.	Less Energy Consumptions Techniques	216	375	0.576	03
4.	Safety Risk	215	375	0.573	04
5.	Resource Planning	212	375	0.565	05
6.	Resource Allocation	210	375	0.560	06
7.	Recycle Management	210	375	0.560	06
8.	Project Productivity	209	375	0.557	07
9.	Decision Making Power	209	375	0.557	07
10.	Health Risk	205	375	0.546	08
11.	Operation Of Infra Structure	205	375	0.546	08
12.	Maintenance Of Infra Structure	208	375	0.546	08
13.	Project Quality	201	375	0.536	09
14.	Project Cost	210	375	0.536	09
15.	Carbon Risk	201	375	0.536	09
16.	New Construction Method	199	375	0.530	10
17.	Site Based Conflicts	197	375	0.525	11
18.	Material Wastage Management	197	375	0.525	11

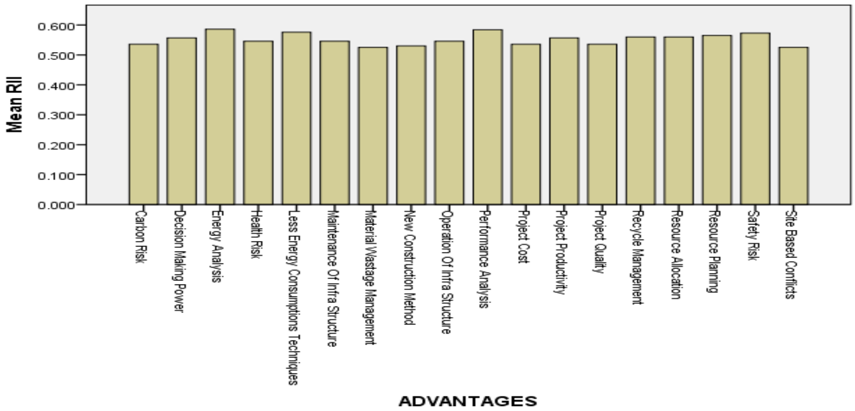

Figure 11. Advantages of Green BIM Based on Level of Significance

4.2.4 Barriers In Adopting Of Green BIM Based On Level Of Significance

Out of the 12 major barriers, 8 of them have consistently prevented Sindh's construction industries from implementing green BIM. Results show the relative importance index (RII) ranking of each identified barrier. RII's value ranges from 0 to 0.6. The table 4.2.3 below ranks each identified factor's level of significance from highest to lowest are Vast and complex info required, Financial Resource, Existing Construction Culture, Limited use of BIM, Information Management Standard Practices, Apathy of client, team or customer, ICT Infrastructure and Training Cost respectively.

Table 4. RII of each barrier based on level of Significance

Sr. No	BARRIERS	$\Sigma a_i n_i$	A5*N	RII	RANK
1.	Vast and complex info required	222	375	0.592	01
2.	Financial Resource	219	375	0.584	02
3.	Existing Construction Culture	210	375	0.560	03
4.	Limited use of BIM	208	375	0.554	04
5.	Information Management Standard Practices	205	375	0.546	05
6.	Apathy of client, team or customer	205	375	0.546	05
7.	ICT Infrastructure	200	375	0.533	06
8.	Training Cost	194	375	0.517	07

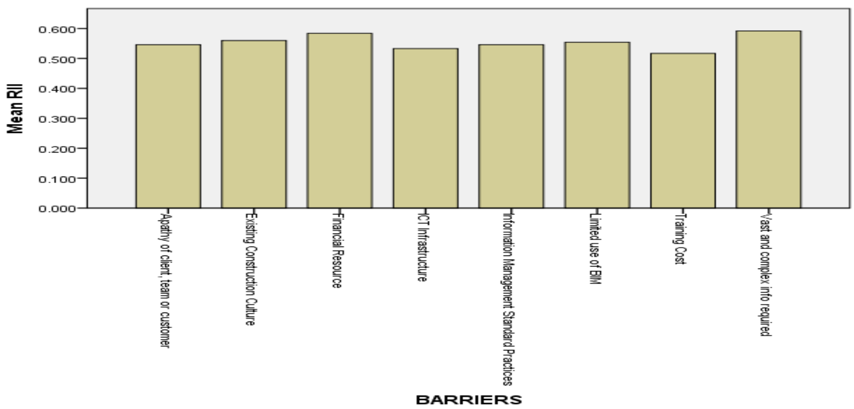

Figure 12. Barriers in Adopting of Green BIM Based on Level of Significance

5. CONCLUSION

The research aim was to identify the advantages of green BIM and barriers of adoption of green BIM in construction industries of Sindh. A detailed literature review, interviews, and questionnaires survey were carried out to achieve the objectives of the research. Results from participants show that 18 major out of 41 advantages (Project

Quality, Project Productivity, Resource Planning, Resource Allocation, Decision Making Power, Energy Analysis, Performance Analysis, New Construction Method, Safety Risk, Health Risk, Operation Of Infra Structure, Maintenance Of Infra Structure, Site Based Conflicts, Project Cost, Less Energy Consumptions Techniques, Material Wastage Management, Recycle Management, Carbon Risk) and 8 major out of 12 Barriers (Information Management Standard Practices, Training Cost, Financial Resource, Limited use of BIM, Vast and complex info required, Apathy of client, team or customer, ICT Infrastructure, Existing Construction Culture) of green BIM are the identified factors in construction industries of Sindh. The government, educational institutes, and construction companies of Sindh should have come forward to adopt of this new technology. Also, make feasible measures to the identified barriers. Authorities of both public and private construction companies play a key role to implement this new technology known as green BIM. Top management should support and encourage stakeholders to fully understand the idea of green BIM and change their previous culture to new cultural techniques.

REFERENCES

Abideen, D. K., Yunusa-Kaltungo, A., Manu, P., & Cheung, C. (2022). A Systematic Review of the Extent to Which BIM Is Integrated into Operation and Maintenance.Sustainability, 14(14), 8692.

Almarashda, H. A. H. A., Baba, I. B., Ramli, A. A., & Memon, A. H. (2022). User Expectation and Benefits of Implementing Artificial Intelligence in the UAE Energy Sector. Journal of Applied Engineering Sciences, 12(1), 1-10.

Azhar, S.; Carlton, W.A.; Olsen, D.; Ahmad, I. Building information modeling for sustainable design and LEED® rating analysis. Autom. Constr. 2011, 20, 217–224.

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.

Barlish, K., & Sullivan, K. (2012). How to measure the benefits of BIM—A case study approach. Automation in construction, 24, 149-159.

Cao, Y., Kamaruzzaman, S. N., & Aziz, N. M. (2022).Building Information Modeling (BIM) Capabilities in the Operation and Maintenance Phase of Green Buildings: A Systematic Review.Buildings, 12(6), 830.

Cao, Y., Kamaruzzaman, S. N., & Aziz, N. M. (2022). Green Building Construction: A Systematic Review of BIM Utilization. Buildings, 12(8), 1205

Carvalho, J. P., Bragança, L. And Mateus, R. (2021) 'Sustainable building design: Analysing the feasibility oF BIM platforms to support practical building sustainability assessment', Computers in Industry, 127. Doi: 10.1016/j.compind.2021.103400.

Chen, L., Chan, A. P., Darko, A., &Gao, X. (2022). Spatial-temporal investigation of green building promotion efficiency: The case of China. Journal of Cleaner Production, 362, 132299.

Council, L. C. (2020).Leeds. Leeds City Council, https://www. leeds. gov.uk/your-council/about-leeds, accessed, 6.

Dave, B., &Koskela, L. (2009). Collaborative knowledge management—A construction case study. Automation in construction, 18(7), 894-902.

El-Diraby, T.; Krijnen, T.; Papagelis, M. BIM-Based collaborative design and socio-technical analytics of green buildings. Autom. Constr. 2017, 82, 59–74.

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., &Raahemifar, K. (2017).Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges. Renewable and sustainable energy reviews, 75, 1046-1053.

Hauashdh, A., Jailani, J., &Rahman, I. A. (2022). Strategic approaches towards achieving sustainable and effective building maintenance practices in maintenance-managed buildings: A combination of expert interviews and a literature review. Journal of Building Engineering, 45, 103490.

https://www.google.com/search?q=BOI%2C+2022).&oq=BOI%2C+2022).&aqs=chrome..69i57.10951j0j7&sourceid=chrome&ie=UTF-8.

Hussain, M., Memon, A. H., & Bachayo, A. (2022).Building Information Modeling in Construction Industry of Pakistan: Merits, Demerits and Barriers. Journal of Applied Engineering Sciences, 12(1), 43-46.

Khaskheli, F. A., Ali, T. H., & Memon, A. H. (2020).Lean Construction Practices in Public Projects of Pakistan. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 5, 15-6

Krygiel, E., &Nies, B. (2008). Green BIM. Succesfil sustainable Design with Building information Modelling. Indianapolis: Richard Swadley, 10.

Kubba, S. (2012). Handbook of green building design and construction: LEED, BREEAM, and Green Globes. Butterworth-Heinemann.

Liao, C. Y., Tan, D. L., & Li, Y. X. (2012).Research on the Application of BIM in the Operation Stage of Green Building.In Applied Mechanics and Materials (Vol. 174, pp. 2111-2114). Trans Tech Publications Ltd.

Marzouk, M., Ayman, R., Alwan, Z., & Elshaboury, N. (2022).Green building system integration into project delivery utilising BIM. Environment, Development and Sustainability, 24(5), 6467-6480.

McLennan, J. F. (2004). The philosophy of sustainable design: The future of architecture. Ecotone publishing.

Meena, C. S., Kumar, A., Jain, S., Rehman, A. U., Mishra, S., Sharma, N. K., ...&Eldin, E. T. (2022). Innovation in Green Building Sector for Sustainable Future.Energies, 15(18), 6631.

Memon, A. H., Rahman, I. A., Memon, I., & Azman, N. I. A. (2014). BIM in Malaysian construction industry: status, advantages, barriers and strategies to enhance the implementation level. Research Journal of Applied Sciences, Engineering and Technology, 8(5), 606-614.

Min, J., Yan, G., Abed, A. M., Elattar, S., Khadimallah, M. A., Jan, A., & Ali, H. E. (2022).The effect of carbon dioxide emissions on the building energy efficiency.Fuel, 326, 124842.

Panah, R. S., &Kioumarsi, M. (2021). Application of building information modelling (BIM) in the health monitoring and maintenance process: A systematic review. Sensors, 21(3), 837.

Patel, A., Shelake, A., &Yadhav, A. (2023).Sustainable construction by using novel frameworks using BIM, LEED, and Lean methods. Materials Today: Proceedings.

Purchase, C. K., Al Zulayq, D. M., O'Brien, B. T., Kowalewski, M. J., Berenjian, A., Tarighaleslami, A. H., &Seifan, M. (2022). Circular economy of construction and demolition waste: A literature review on lessons, challenges, and benefits. Materials, 15(1), 76.

Shen, Y., & Pan, Y. (2023). BIM-supported automatic energy performance analysis for green building design using explainable machine learning and multi-objective optimization. Applied Energy, 333, 120575.

Smith, P. (2014). BIM implementation–global strategies.Procedia engineering, 85, 482-492.

Wu, W.; Issa, R. Integrated process mapping for BIM implementation in green building project delivery. In Proceedings of the 13th International Conference on Construction Applications of Virtual Reality, London, UK, 30–31 October 2013; pp. 30–39.

Wong, J.K.W.; Zhou, J. Enhancing environmental sustainability over building life cycles through green BIM: A review. Autom. Constr. 2015, 57, 156–165.

Woolley, T., & Kimmins, S. (2003). Green building handbook: Volume 2: A guide to building products and their impact on the environment. Routledge.

Wong, K. din and Fan, Q. (2013) 'Building information modelling (BIM) for sustainable building design', Facilities, 31(3), pp. 138–157. doi: 10.1108/02632771311299412.

Wu, W. and Issa, R. R. A. (2014) 'Key Issues in Workforce Planning and Adaptation Strategies for BIM Implementation in Construction Industry', (Hardin 2009), pp. 847–856. doi: 10.1061/9780784413517.087.