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Barriers to Building Information Modeling (BIM) Implementation in Pakistan during The Post-Flood Era: An Interpretive Structural Modelling (ISM) Approach

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ABSTRACT

Pakistan experienced one of the most severe floods recently in 2022. The post-flood eras have faced huge destruction in economic loss and infrastructure disaster. Effective infrastructure is essential in the development of a region. Pakistan is a developing country having less availability of resources and a lack of proper planning to cater to natural hazards and faces huge destruction in flood-hit areas. The reasons behind these destructions are unending, some of which have been identified through past literature. Building information modelling is thus a foundation of digital transformation in the infrastructure or architecture, engineering, and the Architecture, engineering, and construction industry. Incorporating BIM in the renovation and rebuilding of infrastructure is a prominent solution to prevent the post-flood era from devastation. This study aims to determine the barriers to the implementation of BIM. After reviewing the literature, several barriers have been identified, and 13 of them have been used in this study as strong hurdles in the implementation of BIM in the post-flood areas of Pakistan. The ISM technique (interpretive structure modelling) has been used to draw results regarding the identified barriers. The results indicated these barriers of different levels corresponding to their importance. This study is a great addition to the growing body of literature regarding flood adverse effects and a practical guideline to the AEC industry where architecture, constructors, and other experts in this field can take great assistance towards lessening and overcoming the barriers identified to implementing BIM.

Keywords: Building information modelling; post-flood era; Interpretive structure modelling; Architecture, engineering, and construction sector; Infrastructure development

SARI PATI

Pakistan mengalami salah satu banjir terparah pada tahun 2022. Era pasca-banjir negara itu menghadapi kerusakan besar dalam hal kerugian ekonomi dan bencana infrastruktur. Infrastruktur yang efektif sangat penting dalam pengembangan suatu wilayah. Pakistan adalah negara berkembang yang memiliki keterbatasan sumber daya dan kurangnya perencanaan yang memadai untuk menghadapi bencana alam, dan mengalami kerusakan besar di daerah yang terkena banjir. Alasan di balik kerusakan tersebut sangat beragam, beberapa di antaranya telah diidentifikasi melalui literatur sebelumnya. Oleh karena itu, pemodelan informasi bangunan merupakan dasar dari transformasi digital dalam industri infrastruktur atau arsitektur, teknik, dan konstruksi. Menggabungkan BIM dalam renovasi dan pembangunan kembali infrastruktur adalah solusi utama untuk mencegah kerusakan pada era pasca-banjir. Studi ini bertujuan untuk menentukan hambatan-hambatan dalam implementasi BIM. Setelah meninjau literatur, beberapa hambatan telah diidentifikasi, dan 13 di antaranya digunakan dalam studi ini sebagai hambatan kuat dalam implementasi BIM di daerah pasca-banjir di Pakistan. Teknik ISM (interpretive structure modelling) digunakan untuk menggambarkan hasil terkait hambatan-hambatan yang diidentifikasi. Hasil penelitian menunjukkan hambatan-hambatan ini dalam berbagai tingkat kepentingan mereka. Studi ini merupakan tambahan yang sangat berharga dalam literatur mengenai dampak buruk banjir *dan panduan praktis bagi industri Arsitektur, Teknik Sipil, dan Konstruksi (AEC) di mana arsitek, kontraktor, dan para ahli lainnya dalam bidang ini dapat mengambil bantuan besar dalam mengatasi hambatan-hambatan yang diidentifikasi dalam implementasi BIM.*

Kata Kunci: : Pemodelan informasi bangunan; era pasca-banjir; Interpretive structure modelling; Sektor Arsitektur, Teknik Sipil, dan Konstruksi; Pengembangan infrastruktur

INTRODUCTION

Global warming has been the point of focus for the past few decades as the world has experienced various natural disasters such as floods, cyclones, earthquakes, and others in this regard. One such example of a natural disaster was the devastating floods experienced by Pakistan in 2022. About 1,569 people died in these floods, and the total losses of the country were recorded to be US$40 billion. According to USAID, about 32,800 square miles of Pakistan were flooded. These floods not only impacted the lives of people but it has also caused serious damage to the country's infrastructure, destroying around 801,633 houses, more than 22,000 schools, 374 bridges and 7,901 mi of roads (Pradhan, Najmi, & Fatmi, 2022). The most affected areas were found to be Baluchistan and Sindh. A cost of about $30 billion was stated by the government officials of Pakistan for reconstruction purposes as well as for economic damages. This has diverted the attention towards the construction sector of Pakistan, and it was observed that Pakistan lacks an effective structural framework (Analytica, 2022). In order to overcome this issue, efficient Building Information Modeling (BIM) is required. However, various barriers are observed in the construction sectors of Pakistan, which prevent the successful completion of a construction project. Such barriers included cost constraints, lack of quality products for manufacturing, inefficient planning, time constraints, and others (Babar & Ali, 2022). These barriers have prevented the implementation of an effective BIM in Pakistan during the post-flood era.

The infrastructure of a country is crucial in improving its economic growth. Effective techniques are needed to be focused on developing the infrastructure to prevent the impacts of natural disasters like floods, earthquakes, and others (Alfirman, Fauziah, Arifin, & Susanto, 2022; Mahmood & Rani, 2022). However, developing and under-developed countries lack effective technologies like BIM in this regard and are more likely to suffer from the hazardous impacts of natural disasters. In recent times, Pakistan has been fighting the floods of 2022, and the country requires an effective BIM technique for reconstructing its damaged infrastructure. Therefore, various barriers are observed that impact the implementation of BIM in Pakistan during the post-disaster recovery. The present study is found to be effective in assessing these barriers.

The main aim of the present study is to implement an effective BIM approach to improve post-disaster recovery in Pakistan. The proposed objectives for the present study are presented below:

- To assess various barriers impacting Building Information Modeling (BIM) implementation in Pakistan during the post-flood era.
- To determine interrelationships among the identified barriers impacting Building

Information Modeling (BIM) implementation in Pakistan during the post-flood era.

- To provide recommendations for Building Information Modeling (BIM) implementation in Pakistan during the post-flood era.

In the past, almost no such study focused on the BIM barriers in the context of Pakistan, especially during the post-flood era. Another gap observed in previous studies was that they least focused on BIM barriers and emphasised BIM benefits. Thus, the present study is found to be effective in filling these gaps. The current research is beneficial in improving the literature review reading the BIM barriers and providing empirical results for future studies. This has also helped in improving the implementation of BIM in Pakistan and has encouraged the government, along with the policymakers, to develop as well as implement a legal framework in the context of BIM implementation. The management of construction sectors in Pakistan has also taken initiatives for the implementation of BIM during the post-flood recovery.

Literature Review

This section focuses on presenting a literature review regarding BIM and its implementation in various countries. This section is also important as it presents various BIM barriers which usually influence BIM implementation.

1.1 Building Information Modeling (BIM)

As per international standards, BIM is defined as the «shared digital representation of physical and functional characteristics of any built object which forms a reliable basis for decisions» (Sardroud, Mehdizadehtavasani, Khorramabadi, & Ranjbardar, 2018). BIM originated from the models of the products that were applied in the shipbuilding, petrochemical, or automotive industry widely. The real buildings are represented by BIM virtually over complete LC as persistent and enriched digital models of buildings. This technique includes parametric objects which represent the components of the building (Hong, Hammad, Sepasgozar, & Akbarnezhad, 2018). The objects are considered to have non-geometric or geometric attributes with topologic, semantic, or functional information. For instance, the functional attributes include installation costs or durations, while the topologic attributes might include information related to the locations of the objects, perpendicularity or adjacency, and semantic attributes might include aggregation, intersection information, connectivity or containment.

In 1982, Autodesk took the initiative to present ”2D computer-aided design.» This was found to be effective in saving time, precise drafting, and providing better documentation. The AutoCAD technology is found to be user-friendly, which has encouraged many construction professionals, engineers as well as architects to opt for this technology. The BIM concept was initially presented in 1970 by Robert and Chuck Eastman. This concept was used for item models, virtual structure, and shrewd articles in earlier times (Huang, Niniç, & Zhang, 2021). Later on, BIM took over the CAD 2D and was used for designing, planning, operating, and construction projects. Construction, engineering, and design experts encourage BIM for productive and effective structure along with board development. BIM is a complete process and is not only a product. Eventually, in the 21st century, «Revit Software» was formulated. In 2004, «Autodesk Revit» was introduced, promoting new and effective changes. Progressive variations were acquired in this technology for effective building design. This technique has helped in improving the construction process (Cortés-Pérez, Cortés-Pérez, & Prieto-Muriel, 2020).

1.2 BIM Implementation

The persistent implementation and development of BIM have gained the attention of various researchers worldwide, and they are continuously determining various problems associated with the implementation of BIM in the construction industry (Santos, Costa, Silvestre, & Pyl, 2019). The implementation of BIM was found to be 26% worldwide in 2007 and eventually reached 57% in 2016. These figures were later doubled within ten years. Studies have shown that the developed countries developed policies related to BIM implementation, which has increased its application in these countries (Oraee et al., 2019). While in developing countries, for instance, Malaysia, the implementation of BIM is comparatively low as no national policies are developed or implemented for promoting BIM.

Studies have shown that in Pakistan, ill procedures are practised by the construction industry, as a result of which Pakistan's infrastructure is not found to be effective in comparison to other countries around the world. As a result of this, the infrastructure of Pakistan is influenced by natural disasters such as heavy floods. The implementation of BIM was only found to be 11% of Pakistan (Farooq et al., 2020). However, various barriers are observed in the implementation of BIM in Pakistan. Such barriers included poor quality, higher costs, lack of new technologies, no support from the government, and many others (Olanrewaju, Kineber, Chileshe, & Edwards, 2022). The present study is found to be effective in presenting these barriers to improving BIM implementation in Pakistan during post-flood recovery in 2022.

1.3 BIM Barriers

Short-term interventions are usually considered for dealing with infrastructural damages. However, long-term interventions such as BIM should be encouraged in this context. In this context, BIM barriers are found to impact BIM implementation. Previous studies have presented various BIM barriers (Hatem, Abd, & Abbas, 2018). A few of these are discussed as follows for the present study:

1.3.1 Initial High cost of BIM

The cost of BIM is considered to be quite higher for developing and under-developed countries like Pakistan, and they are unable to opt for this technique for effective outcomes. BIM promotes the quality and efficacy of construction projects, which require many new and effective technologies promoting the burden on the economy. Studies have shown that developed countries like the US and the UK utilise BIM by 79% and 74% effectively, while it is implemented in 90% of the projects in Germany (Lesniak, Górka, & Skrzypczak, 2021). This shows the reason for the better infrastructure of these developed countries. Contrary to this, poorer countries like Pakistan are unable to tolerate the burden of the high cost of BIM on its economy. As a result of this, the infrastructure of Pakistan is not found to be at a high level.

1.3.2 Less Awareness of BIM

The BIM approach is not largely implemented in developing countries such as Malaysia, Pakistan, and others, which prevents the spreading of awareness regarding BIM in such countries. As a result of this, the engineers, as well as the architecture experts, are not well familiar with the usage of the BIM technique, and it is merely used for model designs and other such purposes instead of being applied for manufacturing effective buildings (Tan, Chen, Xue, & Lu, 2019). This is one of the most important barriers which impacts the BIM implementation in various developing and other poorer countries, influencing their infrastructure development.

1.3.3 Less Trained Employees Regarding Novel Technologies

Studies have shown that human capital is essential for improving the overall performance of a company (Evans & Farrell, 2020). Similarly, in BIM implementation, certain techniques and skills, as well as capabilities, are needed to be developed among the employees. The lack of such skills among the employees also results in a barrier to the implementation of BIM. However, studies have shown that various training sessions are held to promote skills among employees regarding novel technologies in this regard in various developed countries (Biswal, 2021; Olawumi, Chan, Wong, & Chan, 2018). Employees are crucial in implementing this technique because they conduct various operations during the application of this model, so they are needed to be trained accordingly.

1.3.4 Resistance to Cater Change

It has been observed that many construction sectors around the world still follow various traditional approaches, and they are less likely to adopt any new and advanced changes such as BIM. Such resistance in the construction industry in developing countries has prevented the persistent application of BIM in various projects related to construction, and BIM has been limited to model structure (Durdyev, Mbachu, Thurnell, Zhao, & Hosseini, 2021). Such prevention of BIM application is clearly due to the resistance of old top managers who do not promote technologies and other advanced approaches. As a result of this, resistance to change has also emerged as one of the barriers influencing the implementation of the BIM technique.

1.3.5 Traditional Method of Contracting

Another observed BIM barrier was the traditional method of contracting. Studies have stated that the construction industry is not open to new technologies and often follows conventional approaches to completing a construction project (Marefat, Toosi, & Hasankhanlo, 2018). Other factors, such as the cost-effectiveness of traditional approaches, also give them an upper hand in comparison to BIM. The present study has also assessed the traditional method of contracting as one of the barriers which influence the implementation of BIM.

1.3.6 Lack of Expertise Concerning BIM

As BIM is an advanced and high-quality technique, very few experts are available who can implement this technique. This shows the lack of expertise concerning BIM. Studies have also stated that the persistent advancements and improvements in BIM have complicated the technique for construction purposes (Saka & Chan, 2021). As a result of this, few professionals are present in this regard which lowers the accessibility of the construction industry to this technique. Thus, the lack of.

1.3.7 Complicated BIM Software

Although BIM has been an effective approach for construction projects, it possesses various technicalities that are often difficult to understand by the employees. This shows the complicated aspect of BIM software. Therefore, various construction sectors in developed countries arrange training sessions for their employees to promote an effective as well as productive workforce for implementing BIM software (Al-Yami & Sanni-Anibire, 2019). The complex nature of BIM software often becomes a big challenge for various construction companies, and they are hesitant to use this technique. For the present study, complicated BIM software has also been stated as one of the BIM barriers which impact the implementation of BIM.

1.3.8 No Support from Top Management and Policymakers

In any industry, the contribution of various organisations is necessary for attaining the desired goals. Studies have stated that top management plays an essential role in motivating employees, and they also influence their overall performance (Hajj, Jawad, & Montes, 2021). In this regard, the involvement of policymakers is also crucial as they establish and promote effective policies and procedures for improving the overall performance of a firm. In the case of BIM, the support from both policymakers and top management is also considered to be vital to encourage various strategies related to BIM to ensure the effective completion of construction projects, and the lack of such support often prevents BIM implementation resulting in various negative influences.

1.3.9 Costly Learning and Training

The BIM technique is not cost-effective due to various new and advanced technologies which are used during this technique. This also made the learning as well as training of BIM costly because highly skilled professionals are required for this purpose. Additionally, the approaches of BIM are also very costly (Babatunde, Udeaja, & Adekunle, 2020). So, the construction sectors in developing as well as underdeveloped countries have to pay a large sum of money to carry out such sessions. This prevents many construction sectors from utilising this technique due to its high costs. This is found to be the biggest barrier to the implementation of BIM.

1.3.10 Difficulty in Learning BIM

As explained above, BIM is a complicated software that prevents its adoption by various construction sectors which lack the required resources and skilled staff in this regard. However, the increased application of BIM has encouraged various construction sectors to utilise professionals to train employees regarding various techniques of BIM (Hasan & Rasheed, 2019). Usually, the employees face various difficulties in learning BIM as most of the workforce in the construction sector are not highly qualified. Thus, such difficulties negatively influence the overall performance of the employees in learning BIM, and it is also one of the essential barriers observed in BIM implementation.

1.3.11 Less time to experience Novel Technologies

Novel technologies are referred to as «those technologies that make unprecedented combinations of existing technological components.» BIM is being adopted worldwide by various construction sectors to reduce costs as well as time (Farooq et al., 2020). This technique is also found to improve quality. However, the lack of time to experience various novel technologies in the context of BIM is usually referred to as a barrier to the implementation of BIM in the construction industry. Studies have shown that the continuous increase in BIM applications has also improved the application of novel technologies in the construction industry (Aitbayeva & Hossain, 2020). Thus, less knowledge of novel technologies might disrupt the overall performance of the BIM technique.

1.3.12 Government Policies Inconsistency

Government policies are also considered to have an impact on the construction industry of a country. Studies are of the view that the support of the government is necessary for promoting BIM for effective outcomes. However, the inconsistency in government policies has emerged as a barrier to the implementation of BIM (Belay, Goedert, Woldesenbet, & Rokooei, 2021). Political tensions, as well as corruption, are considered to be essential factors that impact the policies of the government in this regard. Therefore, persistent and effective policies are needed to be established as well as developed concerning BIM to promote this model for better infrastructure development.

1.3.13 New Technologies Uncertainties

BIM is considered to involve new technologies which are not easily applicable. Even though these technologies are considered to be quite effective and helpful in improving structural designs, but still various uncertainties are observed in these new and advanced technologies. Studies have stated that the continuous advancements in BIM over the years it has also included various new technologies to improve the overall procedure of constructing a building and other structures. As a result of this, new technology uncertainties have also emerged as a BIM barrier that impacts the implementation of BIM.

1.3.14 Economic Issues

Various economic issues are also found to impact the implementation of BIM. Studies have shown that BIM is not a cheap technique as it involves advanced technologies and professionals (Fitriani, Budiarto, Ajayi, & Idris, 2019; Purwoto et al., 2020). A larger sum of money is required for conducting the BIM technique as its various phases are quite complicated and involve high technology and quality products. This led to economic pressure on the construction sector, as a result of which many such sectors are hesitant to adopt this technology for different construction projects.

METHODOLOGY

For the present study, the «Interpretive Structure Modelling (ISM) approach» was used to determine the steps acknowledged using literature for barriers impacting Building Information Modeling (BIM) implementation. The ISM approach is an interpretive technique as it includes the decisions as well as the judgments of the professionals (Muduli, Govindan, Barve, Kannan, & Geng, 2013). The research methodology for the present research is presented in table 1, which shows all the phases of this method along with their outcomes. In phase I, a systematic literature review approach was used to determine various BIM barriers which might influence the implementation of BIM. Various global barriers were also discussed to reach common solutions. In the second phase, a questionnaire-based survey was conducted with the construction, engineers, and architecture (CEA) professionals to filter the most important BIM barriers. For this purpose, the purposive sampling technique was used for selecting the sample of respondents to collect the required data.

In the final phase, a structural model was formulated based on the ISM approach by assessing the interrelationships among the identified BIM barriers to improve BIM implementation. For this purpose, semi-structured interviews were conducted with the professionals via telephone by the researcher. A sample of 10 architects, 6 constructors, and 4 engineers was selected for conducting the interviews. The opinions of these experts were essential for determining the interdependencies as well as relationships between the identified BIM barriers. Later on, the ISM model, as well as the digraph, was developed based on experts' opinions.

Interpretive Structural Modeling

This study has incorporated the ISM technique to draw results regarding barriers to BIM. Interpretive structural modelling is a procedure to develop the interrelationships among various elements of interest in a particular domain through the information gained from experts regarding the context of the elements. It has been performed in three steps explained below: Identify the Final set of barriers to BIM.

Table 1. Research Methodology

Methods	Research Flow	Outcomes
Phase I: Literature Review	Step 1: Attain an initial set of barriers	14 barriers were collected.
Phase II: Questionnaire-based Survey	Step 2: Assess the barriers' final set	13 barriers were selected
	Step 3: Correlation identification among identified barriers	Develop SSIM
Phase III: ISM	Step 4: Structure Development	ISM Model and Diagraph

After reviewing the literature and identifying barriers in the way of building information modelling, a self-administered questionnaire was used by the researcher targeting the professionals who belong to the field of construction, the engineers, and the architecture of Pakistan. The purpose of this survey was to record the response of these experts regarding the barriers to BIM. More than 15 barriers were previously identified and later screened; the reason for this is that utilising the method of interpretive structural modelling becomes complex when there are more than 12 factors incorporated in the procedural technique (Attri, Dev, & Sharma, 2013). The experts acting as the respondents of this survey were then asked to select the importance of each barrier to IBM for identification of barriers to building information modelling during the post-flood era in Pakistan by considering a scale of 1 to 5, fluctuating from least significant, less significant, moderately significant, significant and very significant. There was a total of 100 questionnaires that were dispersed to the participants, out of which 42 questionnaires were obtained and indicated to have valid responses. Of these 42 responses, 25 were construction engineers, and the rest were expert architects. All the experts aimed for data collection had a work experience of more than 6 years. Based on these responses, 13 barriers to BIM with the greatest scores were determined as related to this research. Figure 1 shows the response rate of each barrier, and the selected barriers to BIM are shown in Table 2.

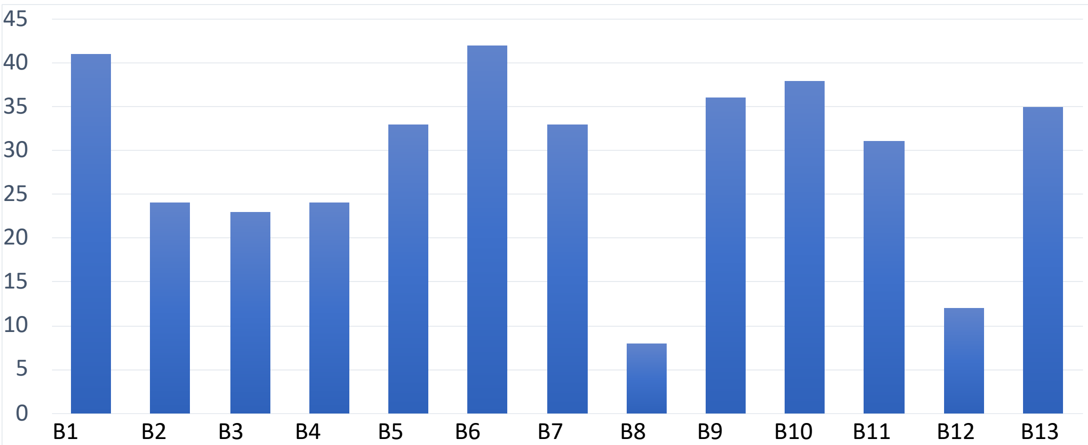

Figure 1. Score of the 13 Barriers to BIM

Table 2. Selected Barriers to BIM for this research

Step no.	Step Detail
B01	The initial prohibitive cost of BIM
B02	Less awareness of BIM
B03	Less-trained employees regarding novel technologies
B04	Resistance to cater to change
B05	The traditional method of contracting
B06	Lack of expertise concerning BIM
B07	Complicated BIM software
B08	No support from top management and policymakers
B09	Costly learning and training
B10	Difficulty in learning BIM
B11	Less time to experience novel technologies
B12	Government policies inconsistency
B13	New technologies uncertainties

Identify the correlation between Barriers to BIM

The ISM procedure can be useful to determine how the selected barriers to BIM are correlated in a complicated way. The other tools or systematic procedures, such as Analytical Network Process (ANP), can also be used to ensure the provision of the same functional operations, but the researchers are of the view that ANP cannot exhibit all sorts of dependencies being a complicated procedure to observe and draw results of the interactions in the huge cluster of influenced factors (Wu, 2008) while ISM is beneficial in contrary to ANP in such a way that it enables for the recognition regarding the path/direction of rank and the direct or indirect interdependencies among those factors that have been taken into account for studying. (Attri et al., 2013; Thakkar, Deshmukh, Gupta, & Shankar, 2005). In this research, ISM has been used to formulate a structural map regarding interactions of different steps that can be proved to greatly help to enhance the improvement of the post-flood era of Pakistan by identifying and trying to overcome the barriers regarding BIM implementation. Five crucial steps must be taken as compulsory for this procedure after identifying and finalising the 13 key barriers to BIM. These steps are:

1. Development of a contextual linkage between the variables and establishment of the structural self-interaction matrix (SSIM)
2. Formulation of the reachability matrix
3. Dividing the reachability matrix into different stages
4. Elimination of transitivity and the establishment of reachability matrix into tapering form.
5. Auxiliary of the variable nodes with connectivity statements and the depiction of the ISM model

Establishing Correlation Structure

When 13 barriers to BIM were finalised through questionnaires, the telephonic interviews of semi-structured nature were held with the involvement of 20 experts which there were 10 architects, 6 constructors, and 4 engineers who had worked in renowned Pakistani companies were involved. Previously, the researcher utilised LinkedIn to contact 35 experts, and out of these, 20 agreed to contribute to the study. The interviews were thus recorded and later transcribed. The respondents chosen to participate in this research had experience of more than 10 years to ensure that their opinion adds value to our research, and they all have strong experience in their respective fields along with adequate knowledge. The contextual interrelationships among barriers to BIM were interpreted through these interviews, and the results drawn were adopted to use for the SSIM. The interrelationship among barriers x and y has been represented as follows:

P mentions that ”item x sources item y, but it does not happen vice versa.”

Q mentions that ”item y sources item x, but it does not happen vice versa.”

R mentions that ”item x and y are consistent, i.e., two-way influence happens.”

S mentions that ”item x and y are not connected.”

Reachability Matrix

The reachability matrix is explained as a representation of a binary relation on the graph nodes. Table 4 shows the rules of substitution that have been considered for the translation and conversion of the SSIM into the matrix of binary reachability (Tan et al., 2019). According to these prescribed rules, the research has formulated an initial reachability matrix that is shown in table 5. This depicts the linear connection among the barriers that have been inculcated in this study. To examine the indirect or transition relationships among the barriers and the interdependencies, the researcher has established a finalised matrix of reachability which has been presented in table 6. The rules of transition have been investigated by the transmission of power repetition analysis, and the symbols 1* illustrate transitivity.

Table 3. SSIM

Barriers	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	B13
B13	S	S	S	R	P	P	Q	S	S	S	Q	S	–
B12	S	S	S	S	P	P	Q	S	S	S	P	–	
B11	S	Q	S	S	S	Q	S	Q	Q	P	–		
B10	S	S	S	S	S	S	Q	Q	Q	–			
B09	S	S	S	S	S	Q	S	S	–				
B08	P	S	S	S	P	S	P	–					
B07	Q	P	R	R	R	P	–						
B06	S	P	R	Q	P	–							
B05	S	S	R	S	–								
B04	Q	P	R	–									
B03	Q	S	–										
B02	S	–											
B01	–												

Table 3 exhibits the consequences of the feedback that was gained from the experts, such as engineers and architects, after the interviews in the form of SSIM, which illustrates that B03, B04, B06, and B13 are highly interlinked

Table 4. Rule of substitution

SSIM	Reachability Matrix	
(x, y)	(x, y)	(y, x)
P	1	0
Q	0	1
R	1	1
S	0	0

Table 5. Initial Reachability Matrix

Barriers	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	B13
B01	1	1	1	0	0	1	0	0	0	0	0	0	0
B02	0	1	0	0	0	0	0	0	0	0	1	0	0
B03	0	1	1	1	0	1	0	0	0	0	0	0	0
B04	0	0	1	1	1	1	0	0	0	0	0	0	1
B05	0	1	1	0	1	1	0	0	0	0	0	0	0
B06	0	1	1	0	1	1	0	1	1	0	1	0	0
B07	1	0	0	0	1	0	1	0	0	1	0	1	1
B08	0	0	0	0	0	0	0	1	1	1	1	0	0
B09	0	0	0	0	0	0	0	1	1	1	1	0	0
B10	0	0	0	0	0	0	0	0	0	1	1	0	0
B11	0	0	0	0	0	0	0	0	0	0	1	0	0
B12	0	0	0	0	1	1	0	0	0	0	0	1	1
B13	0	0	0	1	1	1	0	0	0	0	0	0	1

Table 6. Final Reachability Matrix

Barriers	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	B13	Driving power
B01	1	1	1	1*	1*	1	0	1*	1*	1*	1*	0	1*	10
B02	0	1	0	0	0	0	0	0	0	0	1	0	0	2
B03	0	1	1	1	1*	1	0	1*	1*	1*	1*	0	1*	9
B04	0	1*	1	1	1	1	0	1*	1*	1*	1*	0	1	9
B05	0	1	1	1*	1	1	0	1*	1*	1*	1*	0	1*	9
B06	0	1	1	0	1	1	0	1	1	1*	1	0	1*	8
B07	1	1*	1*	1*	1	1*	1	1*	1*	1	1*	1	1	12
B08	0	0	0	0	0	0	0	1	1	1	1	0	0	4
B09	0	0	0	0	0	0	0	1	1	1	1	0	0	4
B10	0	0	0	0	0	0	0	0	0	1	1	0	0	2
B11	0	0	0	0	0	0	0	0	0	0	1	0	0	1
B12	0	1*	1*	1*	1	1	0	1*	1*	1*	1*	1	1	10
B13	0	1*	1*	1	1	1	0	1*	1*	1*	1*	0	1	9
Dependence power	2	9	8	7	8	8	1	10	10	10	12	2	8	

**1 characterises the transitive relationship in the above table 6*

Level Partitions

The researcher has also utilised the matrix of final reachability for the determination of the sets concerning reachability and antecedent of each barrier to BIM to establish the p used the final reachability matrix for the identification of reachability and antecedent sets of each item to formulate the partitions provided in table 7. The Barriers which have similar reachability sets and intersections as well have been inculcated at a similar level in the finalised model.

Table 7. Level partitions results

Barriers	Reachability Set	Antecedent Set	Intersection	Level
B01	B01; B02; B03; B04; B05; B06; B09; B10; B11; B13	B01; B07	B01	V
B02	B02; B11	B01; B02; B03; B04; B05; B06; B07; B12; B13	B02	III
B03	B02; B03; B04; B05; B06; B09; B10; B11; B13	B01; B03; B04; B05; B06; B07; B12; B13	B03; B04; B05; B06; B13	IV
B04	B02; B03; B04; B05; B06; B09; B10; B11; B13	B01; B03; B04; B05; B07; B12; B13	B03; B04; B05; B13	IV
B05	B02; B03; B04; B05; B06; B09; B10; B11; B08	B01; B03; B04; B05; B06; B07; B12; B13	B03; B04; B05; B06; B13	IV
B06	B02; B03; B05; B06; B09; B10; B11; B13	B01; B03; B04; B05; B06; B07; B12; B13	B03; B05; B06; B13	IV
B07	B01; B02; B03; B08; B05; B06; B07; B09; B10; B11; B12; B13	B07	B07	IV
B08	B08; B10; B11	B01; B03; B04; B05; B06; B07; B10; B12; B13	B10	III
B09	B09; B10; B11	B01; B03; B04; B05; B06; B07; B10; B12; B13	B10	III
B10	B10; B11	B01; B03; B04; B05; B06; B07; B09; B10; B12; B13	B10	II
B11	B11	B01; B08; B03; B04; B05; B06; B07; B09; B10; B11; B12; B13;	B11	I
B12	B02; B03; B04; B05; B06; B09; B10; B11; B12; B13	B07; B08	B12	V
B13	B02; B03; B04; B05; B06; B08; B10; B11; B13	B01; B03; B04; B05; B06; B07; B12; B13	B03; B04; B05; B06; B13	IV

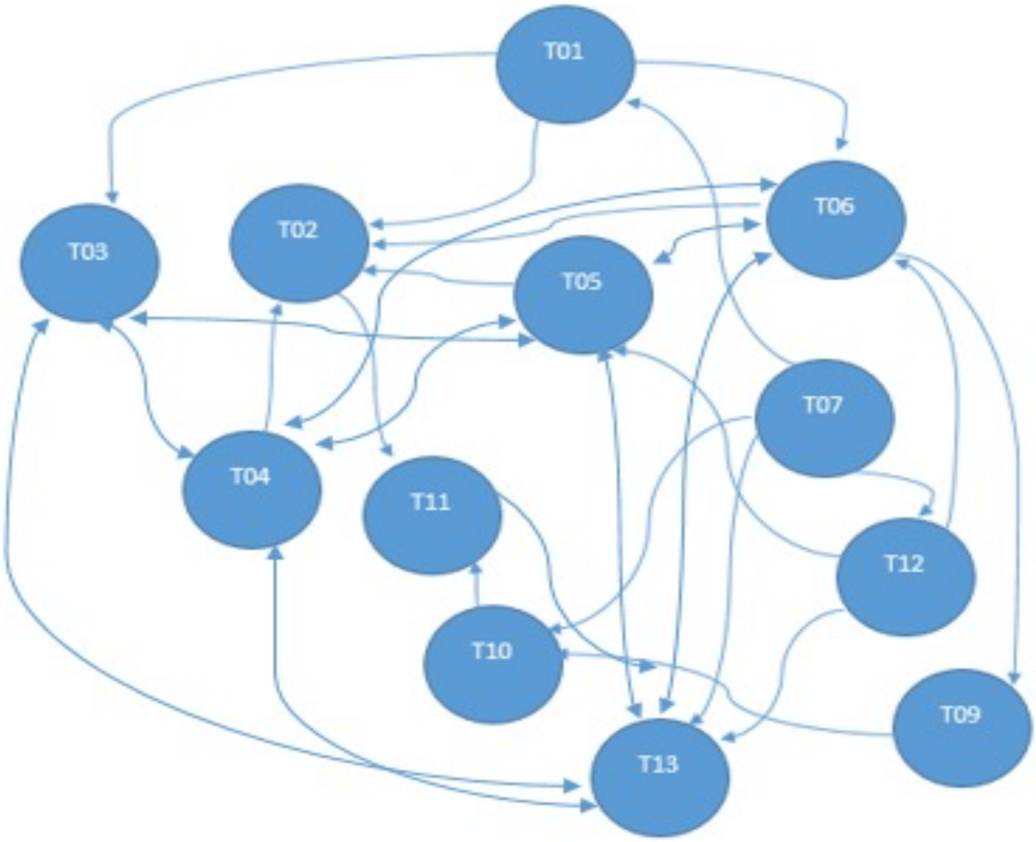

Figure 2. Diagraph Showing Interrelations between Selected Factors

Formation of ISM Diagraph and Model

Figure 2 shows the digraph, which was formulated by utilising the results from the level of partition in table 7. The 13 barriers to BIM have been illustrated along with their connection while exhibiting the effects on each other. The arrow directing from an item x to item y depicts that x has an effect on y or that x can affect establishing an occasion for y, while the two-way arrows show that the factors affect each other equally, which has been explained by transition occupations in table 7.

Finally, in figure 2, given above, the digraph has been malformed to the finalised ISM model. Six levels in the model have been illustrated using figure 2 and table 7 and depict that complicated BIM software is the most prominent barrier that has to be faced in the implementation of BIM in the post-flood era of Pakistan. After the complicated BIM software, the inconsistency of government policies and the initial excessive cost of BIM is assessed, which has been placed at level 5. At the fourth level, multiple steps exist which are related to each other. At level 3, the resistance to cater to change after incorporation of BIM in the post-flood era has been observed, i.e. B04 and the costly training and learning of BIM, which is the barrier B09 is presented to be the outcome of the items belonging to the 5th level which leads to difficulty in the learning of BIM, i.e. B10. At level 1, less time to experience novel technologies and no support from top management and policymakers, i.e. B11 and B08, are present.

RESULT AND DISCUSSION

This study has incorporated a hierarchal framework that can be utilised as a roadmap and a guideline for building information modelling

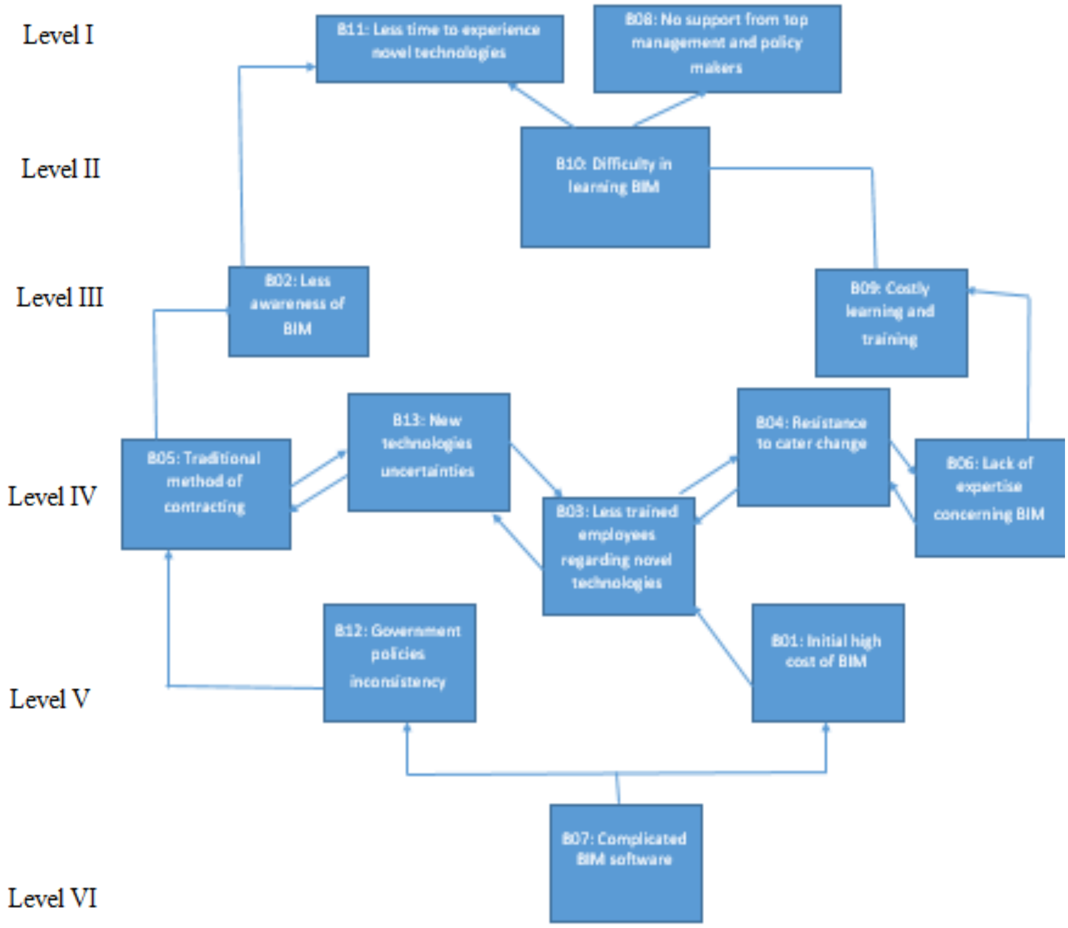

Figure 3. ISM Model of Steps for implementation of BIM in a post-flood era

by overcoming the barriers identified through the literature. The results explain that there are certain barriers to BIM that have resulted in more significance at various levels. The less time to experience novel technologies and no support from upper authorities have proved to be major barriers to implementing BIM (Al-Mohammad et al., 2022). Pakistan's economic losses are severe that have to be borne by people in this devastating flood of 2022, and the post-flood era has to be renovated and redesigned in such a way that can decrease the chances of future hazards if such calamity appears again (I. Khan, Lei, Shah, Khan, & Muhammad, 2021). The study thus has incorporated expert opinions of engineers and architects etc., to assess and rank the level of barriers. Level 3 indicates that less awareness of BIM has caused severe issues in the implementation of BIM. As novel and advanced technologies need proper implementation planning and resource availability to overcome the weak points, such as from the construction point of view, the engineers should install resilient material in the manufacturing of buildings (A. A. Khan, Rana, Nawaz, & Waheed, 2021). Difficulty in the learning of BIM has also been indicated as a level 2 of the ISM model. The innovative and novel technology used and the advanced processes of BIM have made it a costly procedure which is also a hurdle in its implementation (Ahmad & Afzal, 2022). The post-flood era of Pakistan must be viewed closely so that these barriers may no longer hinder the resilience or defensiveness of the buildings. Some engineers knew it as a complicated software to learn and use; in the post-flood times, people of Pakistan were observed to be panicking and afraid, and the employees or engineers thus did not have time to learn this BIM technology to gain a smooth implementation (Adekunle, Aigbavboa, & Ejohwomu, 2022). That is the reason for this barrier in hindering BIM implementation. The proper elevation, positioning, and installation of flood vents safeguard homes and buildings by preventing and securing the water pressure buildup that can destroy the basic foundations and walls. The major requirement in post-flood areas from a construction point of view is that flood openings are needed for low enclosures of the resident's places being constructed in the zones of higher-risk floods, but the installation can also be done in existing homes (Shah et al., 2022).

The less expertise available for the installation of building information modelling has also added to the difficulty in its implementation, specifically in the post-flood regions (Azhar, 2022). And whenever it has tried to implement these novel technologies in such under-developed regions, the government shows no concern or very little devotion where much cost and resources are required (Ahmed & Zaman, 2021) as explained that BIM is complicated or complex to operate, which is why its practical installation and implementation in many regions are still under question (Jasiński, 2021). The results thus explain a long way to go toward overcoming these barriers to BIM.

CONCLUSION

Theoretical and practical contributions

The study is a great addition to existing literature, as BIM is a novel technique, and in under-developed or developing regions, the installation of BIM is much more difficult; thus, it has to face many hurdles. This study is important in enlightening those hurdles so that in the future, the deficiencies or these hurdles can be overcome. The theoretical addition in the post-flood region's development is also prominent in this study. As 2022 has caused severe floods in Pakistan, where the community has to exhibit many dangers and issues, this study is important in providing knowledge regarding the smooth implementation of BIM. The practical contributions of this study are also significant because in the field of construction and engineers can take huge assistance from this study by knowing the barriers to implementing BIM and then formulating strategies and policies to overcome those barriers. Training programs to learn the BIM software must be encouraged to overcome the barrier of «difficulty in learning» of building information modelling. The government and authoritarian bodies must also be encouraged to formulate those strategies that can conveniently install BIM in post-flood areas. Funds and proper resource allocation need to be done for this purpose.

Limitations and future research indications

Every study has its shortcomings, and so is the case with this research. The study has targeted only Pakistan for assessing the post-flood scenarios and BIM implementation hurdles. In the future, some other developing countries or under-developed countries having limited resources and experiencing natural disaster as floods can be taken into consideration. Another methodology instead of ISM can be applied to assess the fluctuation in results, such as a qualitative tool to interview experts, i.e. engineers and construction professional architects, to understand the variation in results regarding BIM implementation barriers. Future research can be done to overcome these deficiencies.

REFERENCES

Adekunle, S. A., Aigbavboa, C. O., & Ejohwomu, O. A. (2022). Understanding the BIM actor role: a study of employer and employee preference and availability in the construction industry. *Engineering, Construction and Architectural Management*(ahead-of-print).

Ahmad, D., & Afzal, M. (2022). Flood hazards and agricultural production risks management practices in flood-prone areas of Punjab, Pakistan. *Environmental Science and Pollution Research, 29*(14), 20768-20783.

Ahmed, W., & Zaman, D. (2021). FINANCIAL RISK ASSESSMENT AND QUICK RECOVERY STRATEGY DURING MAJOR DISASTERS IN PAKISTAN (A STUDY OF QUALITATIVE AND QUANTITATIVE ANALYSIS). *Journal of Business Strategies, 15*(2), 1-20.

Aitbayeva, D., & Hossain, M. A. (2020). Building information model (BIM) implementation in perspective of Kazakhstan: opportunities and barriers. *J. Eng. Res. Rep, 14*, 13-24.

Al-Mohammad, M. S., Haron, A. T., Esa, M., Aloko, M. N., Alhammadi, Y., Anandh, K., & Rahman, R. A. (2022). Factors affecting BIM implementation: Evidence from countries with different income levels. *Construction Innovation*(ahead-of-print).

Al-Yami, A., & Sanni-Anibire, M. O. (2019). BIM in the Saudi Arabian construction industry: State of the art, benefit and barriers. *International Journal of Building Pathology and Adaptation*.

Alfirman, D. M., Fauziah, A. N., Arifin, A. Z., & Susanto, D. (2022). How to Manage Residual Impacts of Infrastructure Projects in Developing Countries. *Journal of Infrastructure Policy and Management, 5*(1), 15-21.

Analytica, O. (2022). Floods give a new focus to Pakistan's foreign policy. *Emerald Expert Briefings*(oxan-db).

Attri, R., Dev, N., & Sharma, V. (2013). Interpretive structural modelling (ISM) approach: an overview. *Research Journal of Management Sciences, 2319*, 1171.

Azhar, A. (2022). Disaster Management Reforms in Pakistan. In *Public Sector Reforms in Pakistan* (pp. 329-348): Springer.

Babar, A. H. K., & Ali, Y. (2022). Framework construction for augmentation of resilience in critical infrastructure: Developing countries a case in point. *Technology in Society, 68*, 101809.

Babatunde, S. O., Udeaja, C., & Adekunle, A. O. (2020). Barriers to BIM implementation and ways forward to improve its adoption in the Nigerian AEC firms. *International Journal of Building Pathology and Adaptation, 39*(1), 48-71.

Belay, S., Goedert, J., Woldesenbet, A., & Rokooei, S. (2021). Enhancing BIM implementation in the Ethiopian public construction sector: an empirical study. *Cogent Engineering, 8*(1), 1886476.

Biswal, P. S. (2021). Improving Governance in Major Infrastructure Projects. *Journal of Infrastructure Policy and Management, 4*(1), 27-38.

Cortés-Pérez, J. P., Cortés-Pérez, A., & Prieto-Muriel, P. (2020). BIM-integrated management of occupational hazards in building construction and maintenance. *Automation in Construction, 113*, 103115.

Durdyev, S., Mbachu, J., Thurnell, D., Zhao, L., & Hosseini, M. R. (2021). BIM adoption in the Cambodian construction industry: key drivers and barriers. *ISPRS International Journal of Geo-Information, 10*(4), 215.

Evans, M., & Farrell, P. (2020). Barriers to integrating building information modelling (BIM) and lean construction practices on construction mega-projects: a Delphi study. *Benchmarking: An International Journal*.

Farooq, U., Rehman, S. K. U., Javed, M. F., Jameel, M., Aslam, F., & Alyousef, R. (2020). Investigating BIM implementation barriers and issues in Pakistan using ISM approach. *Applied Sciences, 10*(20), 7250.

Fitriani, H., Budiarto, A., Ajayi, S., & Idris, Y. (2019). Implementing BIM in architecture, engineering and construction companies: Perceived benefits and barriers among local contractors in Palembang, Indonesia (Similarity). *International Journal of Construction Supply Chain Management, 9*(1), 20-34.

Hajj, C. E., Jawad, D., & Montes, G. M. (2021). Analysis of a construction innovative solution from the perspective of an information system theory. *Journal of Construction Engineering and Management, 147*(9), 03121003.

Hasan, A. N., & Rasheed, S. M. (2019). The benefits of and challenges to implement 5D BIM in construction industry. *Civil Engineering Journal, 5*(2), 412.

Hatem, W. A., Abd, A. M., & Abbas, N. N. (2018). Barriers of adoption building information modeling (BIM) in construction projects of Iraq. *Engineering Journal, 22*(2), 59-81.

Hong, Y., Hammad, A. W., Sepasgozar, S., & Akbarnezhad, A. (2018). BIM adoption model for small and medium construction organisations in Australia. *Engineering, Construction and Architectural Management*.

Huang, M., Nini, J., & Zhang, Q. (2021). BIM, machine learning and computer vision techniques in underground construction: Current status and future perspectives. *Tunnelling and Underground Space Technology, 108*, 103677.

Jasiski, A. (2021). Impact of BIM implementation on architectural practice. *Architectural Engineering and Design Management, 17*(5-6), 447-457.

Khan, A. A., Rana, I. A., Nawaz, A., & Waheed, A. (2021). Gender-based emergency preparedness and awareness: empirical evidences from high-school students of Gilgit, Pakistan. *Environmental Hazards, 20*(4), 416-431.

Khan, I., Lei, H., Shah, A. A., Khan, I., & Muhammad, I. (2021). Climate change impact assessment, flood management, and mitigation strategies in Pakistan for sustainable future. *Environmental Science and Pollution Research, 28*(23), 29720-29731.

Leśniak, A., Górka, M., & Skrzypczak, I. (2021). Barriers to BIM implementation in architecture, construction, and engineering projects—The polish study. *Energies, 14*(8), 2090.

Mahmood, S., & Rani, R. (2022). People-centric geo-spatial exposure and damage assessment of 2014 flood in lower Chenab Basin, upper Indus Plain in Pakistan. *Natural Hazards, 111*(3), 3053-3069.

Marefat, A., Toosi, H., & Hasankhanlo, R. M. (2018). A BIM approach for construction safety: applications, barriers and solutions. *Engineering, Construction and Architectural Management*.

Muduli, K., Govindan, K., Barve, A., Kannan, D., & Geng, Y. (2013). Role of behavioural factors in green supply chain management implementation in Indian mining industries. *Resources, conservation and recycling, 76*, 50-60.

Olanrewaju, O. I., Kineber, A. F., Chileshe, N., & Edwards, D. J. (2022). Modelling the relationship between Building Information Modelling (BIM) implementation barriers, usage and awareness on building project lifecycle. *Building and Environment, 207*, 108556.

Olawumi, T. O., Chan, D. W., Wong, J. K., & Chan, A. P. (2018). Barriers to the integration of BIM and sustainability practices in construction projects: A Delphi survey of international experts. *Journal of Building Engineering, 20*, 60-71.

Oraee, M., Hosseini, M. R., Edwards, D. J., Li, H., Papadonikolaki, E., & Cao, D. (2019). Collaboration barriers in BIM-based construction networks: A conceptual model. *International Journal of Project Management, 37*(6), 839-854.

Pradhan, N. A., Najmi, R., & Fatmi, Z. (2022). District health systems capacity to maintain healthcare service delivery in Pakistan during floods: A qualitative study. *International Journal of Disaster Risk Reduction*, 103092.

Purwoto, H., Budhiarto, R., Widhyharto, D. S., Agriawan, J. I., Kurniawan, D. A., Soemardjito, J., . . . Novitasari, D. (2020). Development of Ex-Ante Analysis Method on Socio-Economic Impact of Infrastructure Project. *Journal of Infrastructure Policy and Management, 3*(1), 35-50.

Saka, A. B., & Chan, D. W. (2021). BIM divide: an international comparative analysis of perceived barriers to implementation of BIM in the construction industry. *Journal of Engineering, Design and Technology*.

Santos, R., Costa, A. A., Silvestre, J. D., & Pyl, L. (2019). Informetric analysis and review of literature on the role of BIM in sustainable construction. *Automation in Construction, 103*, 221-234.

Sardroud, J. M., Mehdizadehtavasani, M., Khorramabadi, A., & Ranjbardar, A. (2018). *Barriers analysis to effective implementation of BIM in the construction industry.* Paper presented at the ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction.

Shah, A. A., Ajiang, C., Gong, Z., Khan, N. A., Ali, M., Ahmad, M., . . . Shahid, A. (2022). Reconnoitering school children vulnerability and its determinants: Evidence from flood disaster-hit rural communities of Pakistan. *International Journal of Disaster Risk Reduction, 70*, 102735.

Tan, T., Chen, K., Xue, F., & Lu, W. (2019). Barriers to Building Information Modeling (BIM) implementation in China's prefabricated construction: An interpretive structural modeling (ISM) approach. *Journal of Cleaner Production, 219*, 949-959.

Thakkar, J., Deshmukh, S., Gupta, A., & Shankar, R. (2005). *Selection of third-party logistics (3PL): a hybrid approach using interpretive structural modeling (ISM) and analytic network process (ANP).* Paper presented at the Supply Chain Forum: An International Journal.

Wu, W.-W. (2008). Choosing knowledge management strategies by using a combined ANP and DEMATEL approach. *Expert Systems with Applications, 35*(3), 828-835.