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Critical Barriers to Sustainable Construction Technology Adoption in Developing Countries – A Case Study in India

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Abstract
Sustainability of the construction is one of the important sector to improve the economy of developing countries. To improve sustainability, precast buildings are adopted in developing countries. Since the sustainability of the precast buildings is affected by various barriers it is essential to determine the barriers that affect their sustainability. Hence the novel Relative Factor Reliable Index framework is utilized to identify the most critical barrier while constructing precast buildings. Thus a survey is conducted with various participants by creating an online questionnaire using Likert scale with Polychromous Rasch Model. From survey data the existing methods does not find the appropriate barrier due lack representation of dependence between the barriers. So that the survey results are analyzed using Bayesian Belief structural equation modeling Network which utilizes Probabilistic Graphical Model (PGM) and directed polygonal graph to determine the interrelationship between the barriers by assigning weightage. To identify the barrier that affects the sustainability of construction, barriers are ranked with Relative Factor Reliable Index using Relative Importance Index and Z score normalization which statistically validate the barriers to Sustainable construction. From the ranked barriers, the barriers Professional fees for engineers and consultants, Lack of Public awareness about precast buildings, and Ineffective waste disposal are identified as the most critical barriers.
Keywords: *Sustainable construction, Probabilistic Graphical Model, Likert scale, Relative Importance Index, Z-score normalization.*

Nomenclature:

m_i	The maximum score for item i (here maximum score is 5)
X	An integer value between 0 to m_i
Y_i	Belief in an event
$P(Y_i\|A)$	The posterior probability of Y_i
$P(A\|Y_i)$	Conditional probability
$P(Y_i)$	The prior probability of an event Y_i
$P(A)$	The prior probability of event a
W	A weight of each factor
N	The total number of respondents
x	An index value
μ	A mean value
σ	The standard deviation

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1. Introduction

Quality is an important issue in the Indian construction industry for sustainability and customer satisfaction [1]. Sustainability of the construction is reduced due to frequent failures of construction and certain barriers to construction which results in increased project cost, a decrease in the efficiency of the project, and affects the overall performance of the construction industry [2-4]. The achievement of sustainability of construction is critical in construction projects, as poor-quality results in rework and dissatisfaction of client, contractor, designer, and consultant [5]. In developing countries like India, sustainability did not reach a sufficient level of acceptance and faces many obstacles due to the complex nature and lack management of the construction industry [6]. Thus implementation of effective management systems results in better control of suppliers and enables the contractors to meet the sustainability [7]. There are significant numbers of stakeholders in the management system making the assessment of delay and risk as a whole network a difficult task [8-9]. Risks are present in construction projects and have an important effect on the project's cost and schedule performance [10-11]. Thus precast construction has received increasing attention during the past decades with low risk and sustainability. Faster construction, higher quality, and relatively lower construction cost are among the main benefits of precast structures [12]. There have been some factors that had a negative impact on the development of precast construction. The construction industry has widely employed precast structures in many countries [13]. Fast construction and erection, reduced construction cost, better construction quality, ease in quality assessment, continuous production even under harsh environmental conditions, and enhanced safety are benefits that a precast construction scheme offers [14]. Moreover, energy efficiency of such systems is also of utmost importance in governing the construction process with economic sustainability [15]. Risks are becoming inevitable in construction projects, especially when complicated contracts govern construction processes. Risk factors in the construction are identified based on risk assessments or models/tools developed using available information [16]. Some of the methods used are relative importance index, descriptive statistics, and the factor analysis approach [17]. Basically, delay and risk assessment and management are used to meet project objectives related to cost, schedule, and quality. Hence a novel technique has to be adopted to determine the barriers to the sustainability of precast construction. The main contribution of this paper is as follows,

- Probabilistic Graphical Model uses a directed polygonal graph that identifies the interrelationship between the barriers by correlating with another barrier.
- Relative importance index analysis allows identifying the barrier which is highly critical to the adaption of precast construction in terms of cost, manpower, and other factors.
- Ranking based on the z-score value allows calculating the probability of a score occurring within a standard normal distribution, which gives the standard deviations from the mean of each weightage.

The content of the paper is organized as follows: Section 2 presents the literature survey; the novel solutions are presented in section 3; the implementation results and their comparison and conclusion are in sections 4 and section 5 respectively.

2. Literature Survey

Chan et al [18] adopted a quantitative research design using a structured empirical questionnaire survey. Also, a comparative analysis of the perceptions of the respondents' groupings was conducted. The major barriers to Building Information Modelling (BIM) adoption are related to the inherent resistance to change by construction stakeholders, inadequate organizational support and structure to execute BIM, and lack of BIM industry standards in Hong Kong. Meanwhile, the key benefits include better cost estimation and control, efficient construction planning and management, and improvement in design and project quality. Case study investigations should be explored to supplement the contents and findings of the current research study including the benefits, barriers, and drivers for BIM execution. Pham et al [19], in this study, managerial perceptions at various levels on main barriers to sustainable construction: firm-level and project level, were analyzed. A questionnaire was developed and distributed to respondents in Vietnam to collect data. First, barriers are ranked based on their mean. Kendall test affirmed that consistency of responses given by both directors and project managers significantly exists regarding the barriers. Moreover, Mann–Whitney U test proved there are no statistically significant differences among these two groups responding to the five main barriers. Through statistical analyses, the study identified the five most significant barriers, namely incompetence of project managers, limited sustainable materials and technologies, maintaining the current practice and resisting the change towards sustainability, lack of government incentives, and low implementation level of sustainable practices. Further studies should be compared to find out similarities and differences in the most significant barriers to SC in developing countries. Market et al [20] in this study seeks to move beyond the instruments debate and identify a broader range of factors inhibiting the transition to sustainability within the Australian building industry. It draws on focus group discussions held with 26 leading sustainability experts and practitioners from around the country. Whereas, earlier work on impediments to sustainability pre-identify potential causal factors, this study, with Sustainability Transition as the theoretical lens, allows for new and as yet unidentified impediments to emerge. Indeed, while findings confirm a range of technical shortcomings hindering sustainability transition, the deeper barrier is shown to be the prevalence of a dysfunctional sustainability ecosystem where siloed vested interest groups exploit Australia's ineffective transition regimes for their own gain. However, validating the findings in exposure to hard data required experts. Hussain et al [21] analyzed barriers to the GLS construction process (GLSCP) through a literature review and expert opinion. During brainstorming sessions, a group of experts validated the barriers and developed contextual relationships among them using a questionnaire. An 11-level hierarchal model was developed by implementing the interpretive structural modeling (ISM) methodology. The MICMAC technique was applied to delineate these barriers into the categories of 'driving', 'linkage', and 'dependent'. While the findings indicate that all barriers are critical and play a role in hindering the application of GLS in the construction process, the top five critical barriers to GLS are an unstable political environment, lack of government policy, lack of customer involvement and awareness of GLS, lack of funds, and lack of top leadership support for GLS adoption. The findings of this work should be practically analyzed and verified with modeling networks. Oraee et al [22] presented a conceptual model to capture the main barriers to collaboration in BIM-based construction networks. The study benefits researchers as well as project managers. For researchers, the conceptual model provides an intermediate theory, namely, a theoretical basis to direct further knowledge creation attempts on the topic. In addition, the conceptual model supports project managers on BIM-enabled projects. That is, it simplifies the knowledge now available for practical applications enabling it to be translated into guidelines and practical instructions on real-life projects. However, delving into the nature of each individual barrier or category of barriers should be identified. From the survey, for [18], case study investigations have to be explored to supplement the contents and findings of the current research study including the benefits, barriers, and drivers for BIM execution, for [19] similarities and differences in the most significant barriers to SC in developing countries has to be estimated, for [20] the findings in exposure to hard data and broader sample sizes of experts validation is a requisite for the work, for [21] practical analysis and verification of the work in terms of structural equation modeling (SEM) needs to be applied and

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for [22] delving into the nature of each individual barrier or category of barriers has to be identified. Hence to tackle the above-mentioned issues, a novel technique has to be implemented.

3. Critical Barriers To Sustainable Construction Technology Adoption In Developing Countries

Precast construction adaption in developing countries improve the sustainability of the construction. However, developing countries are not particularly serious about adopting and implementing sustainable construction practices, due to the different barriers that hinder them. Thus to identify the barrier affect the construction the survey has been conducted to collect the opinion from the public through designing online survey. The questionnaire survey generated using Relative Factor Reliable Index framework. Barriers are screened using five-point Likert scale and interval level values given to the options in the scale assigned using Polychromous Rasch model. The weightage provided by analyzing conditional dependences between random variable by Bayesian Belief structural equation modeling Network, which uses Probabilistic Graphical Model (PGM) that represents conditional dependence between the barriers through Directed Polygonal Graph (DPG). The directed edge of the graph indicates the dependent barrier of another barrier. After the collection of data from the participants each barrier is ranked according to score of barriers collected in survey. Ranking of barrier done with Relative Factor Reliable Index which calculates Relative importance factor and Z-score normalization. By calculated Z-score value the final barriers are statistically validated and ranked from high risk factor to low risk factor. Thereby the factors are ranked based on the barriers, determining the causes of construction delays and by determining their interrelationships, the key performance indicators are identified. The process flow of proposed model given in Figure 1.

Initially, a survey has been taken from various people from different fields related to construction using the Likert scale via online. The collected data is analyzed in the form of a PGM by a directed polygonal graph, which calculates the weightage of each barrier. Also, the equation modeling network identifies the interrelationship between the barriers. Then the ranking of the factors done by the Relative Factor Reliable Index incorporates with Z score normalization. The relative importance index is calculated based on the total number of responses received from the respondents. And the calculated index value is normalized in standard normal distribution using z-score normalization. Thereby the factors are ranked based on the barriers, determining the causes of construction delays.

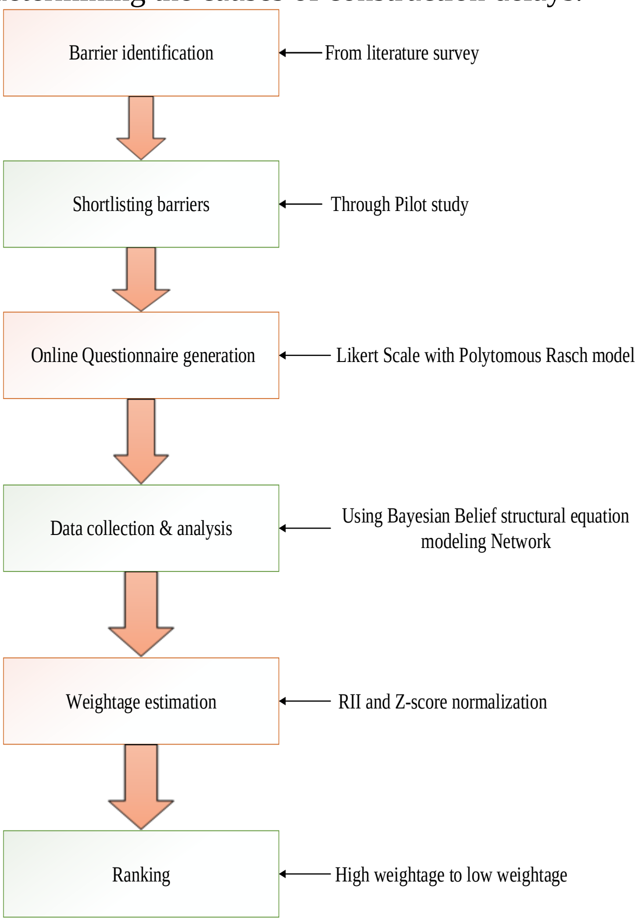

Figure 1 Process Flow of Proposed Ranking Method

3.1 Relative Factor Reliable Index Framework

To estimate the sustainability of precast structures in terms of economic, social, and environmental issues are to be considered. From the several

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barriers [23-25] most significant 92 barriers are selected by the professors and post-doctoral research associates by conducting pilot study to eliminate ambiguities barriers. Besides, the appropriateness of the technical terms and comprehensiveness of the list of barriers were checked. The questionnaire was finalized after receiving and implementing constructive comments from the pilot study participants. The finalized 92 barriers are categorized as economic factor (39 factors), social factor (20 factors), and environmental factor (33 factors). Some of the barriers listed below,

- Less durability of materials procured.
- Cost of repairing and defects.
- Improper Lead-times for the required tasks and activities.
- Changes in the environment lead to the discomfort of people and the biological system.
- Life cycle design incorporating environmental factors.
- Lack of Public awareness about precast buildings.
- Lack in improvement of infrastructure to the society and environment.
- Increased burden on infrastructure as a result of the use and depletion of natural resources.

3.1.1 Data collection

The data collected from the various hierarchical levels like Site Engineers, Developers, Contractors, and Project Managers via online through Likert scale which is low cost for implementation and high level of convergence. From the shortlisted set of barriers, the survey is generated in five point Likert scale by using the Polytomous Rasch model. The proposed Likert scale consist of five level of agreement to the participant so that the participant does not force into either-or opinion. Thus the proposed method received high responses from the participant, where the successive integer for each point of agreement assigned by Polytomous Rasch model. The integer values assigned in proposed model as follows: 5-very bad; 4-bad; 3-ok; 2- good; 1-very good.

The integer variable is assigned to a level of agreement by the following equation (1).

$$X = x \in \{0,1,\dots,m_i\} \quad (1)$$

In equation (1),

m_i Is the maximum score for item i (here maximum score is 5)

X Is an integer value between 0 to m_i.

Figure 2 Five-Point Likert Scale Design of Proposed Method

The proposed five-point Likert scale design is given in Figure 2. This online questionnaire survey is passed to participants via online through mail with a web link of the generated survey is included in the emails to provide an option for online response to the questionnaire. To enhance higher participation in the survey, potential respondents were invited to forward the questionnaire and web link to other experts whom they deemed appropriate, based on their industrial or academic experience, to provide the information as requested in the questionnaire. The survey has been allowed for some period of time for data collection. The participants choose any one out of these five options for every barrier given in the survey. If the participant voted as good, then the proposed model store the value of 3 for the particular barrier. Likewise, the values of each barrier from all the participants are collected. To analyze the conditional dependence between the barriers the Bayesian belief structural equation modeling network is utilized which is explained in the next section.

3.2 Bayesian Belief Structural Equation Modeling Network

In proposed model the data analyzed through Bayesian belief structural equation modeling network by considering the interrelationship

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between the barriers. Weightage of the barrier estimated in Bayesian network which each node of barriers correlated in DPG through joint probability distribution in which each edge is a conditional dependence and each node is a distinctive random barrier. For discrete node i, the probability of that node i takes on one of its possible values, for each combination of its parent node. For each barrier the conditional dependence table are generated in graphical model using joint probability distribution of node Y as follows in equation (2).

$$P(Y) = \prod_{i=1}^{n} P(Y_i | parent(Y_i)) \quad (2)$$

This probability distribution over random barriers determine dependence between the barriers. If one of the barrier node does not have any parent node, then its conditional probability coincides with the a priori probability of that node. The priori probability estimated by likelihood of an event occurring when there is a finite amount of outcomes and each is equally likely to occur. Thus the DPG determine the barriers are dependent if the outcome of one barrier would have an impact on the outcome of the other barrier. If the outcome of one barrier does not affect the outcome of the other barrier, then the barriers are independent. The outcomes in a priori probability are not influenced by the prior outcome. Conditional dependence between random variable in Bayesian network shown in Figure 3. The conditional probability of n barriers $(Y_1, Y_2, \dots, Y_n)$ is defined by following equation (3).

$$P(Y_1 \dots Y_n) = \prod_{i=1}^{n} P(Y_i | Y_1 \dots . Y_{i-1}) \quad (3)$$

The probability occurrence of conditionally dependent variable in the dependence table calculated by using Bayes theorem. Bayes theorem of probability is applied in the Bayesian belief network (BBN) as a mathematical model that updates the belief of the hypothesis E_i in consideration of event A. Therefore, Bayes' theorem calculates $P(Y_i|A)$ in terms of $P(A|Y_i)$, as expressed in Equation (4) [26].

$$P(Y_i|A) = \frac{P(A|Y_i).P(Y_i)}{P(A)} \quad (4)$$

In equation (4),
Y_i Is belief in an event?
$P(Y_i|A)$ Is the posterior probability of? Y_i
$P(A|Y_i)$ Is conditional probability
$P(Y_i)$ Is the prior probability of an event? Y_i
$P(A)$ Is the prior probability of event A?

Then the total weight of the barrier calculated from the conditional dependence probability by the following equation (5).

$$T_w = \sum_{i=1}^{N} y_i \, P(Y = Y_i) \quad (5)$$

In equation (5)
T_w Is total weight of each barrier?
N is the total number of respondents

Based on the dependence of the barriers factors are ranked by using a relative factor reliable index which utilizes the weightage of the factors as well as the relative importance index with Z-score normalization.

3.3 Relative Factor Reliable Index

Relative Importance Index is used to rank the barriers that consider the weightage of factors and the number of respondents. Then employing Z score normalization to find the rank by considering the correlation between factors. The Relative Importance Index is used to determine the relative importance of the quality factors involved. The points of the Likert scale used are equal to the value of W, with weighting given to each barrier by the respondent. The Relative Importance Index is calculated by using equation (6) [27].

$$Relative\ importance\ index\ (x) = \frac{T_w}{m_i \times N} \quad (6)$$

In equation (6),
m_i Is the maximum score

In addition, z-score normalization of the indexed value to rank the barriers according to correlation between factors, that statistically validate the final model of the barriers to Sustainable construction.

3.3.1 Z-Score Normalization

Z-score normalization is used to understand the probability of a score occurring within the normal distribution of the data. The z-score enables a data administrator to compare two different scores that are from different normal distributions of the data. Z-score relies on second order statistics and it also relies on the assumption that the location and scale parameters of the matching score distribution can be approximated by the mean and standard deviation in a satisfactory manner. Thus the normalized scores are not bounded. Moreover, Z-score is sensitive to outliers as the mean and standard deviation estimators are not robust to observations with extreme values. The Z-score is calculated as follows [28],

$$Z\ score = \frac{x-\mu}{\sigma} \qquad (7)$$

In equation (7)

x Is an index value

μ Is a mean value

σ Is the standard deviation Based on the z-score the factors were ranked accordingly to identify the possibility of an event occurring. The barrier which has the highest z-score value is considered as 1st rank, which is the most critical barrier that affects the sustainability of construction. The probability of factors and the ranking have been done by z-score normalization thereby the factors are ranked based on the barriers, determining the causes of construction delays and by determining their interrelationships the key performance indicators are identified. As a result, the approach efficiently identifies the barriers to developing nations adopting sustainable building technology and improves development by defining the key performance indicator.

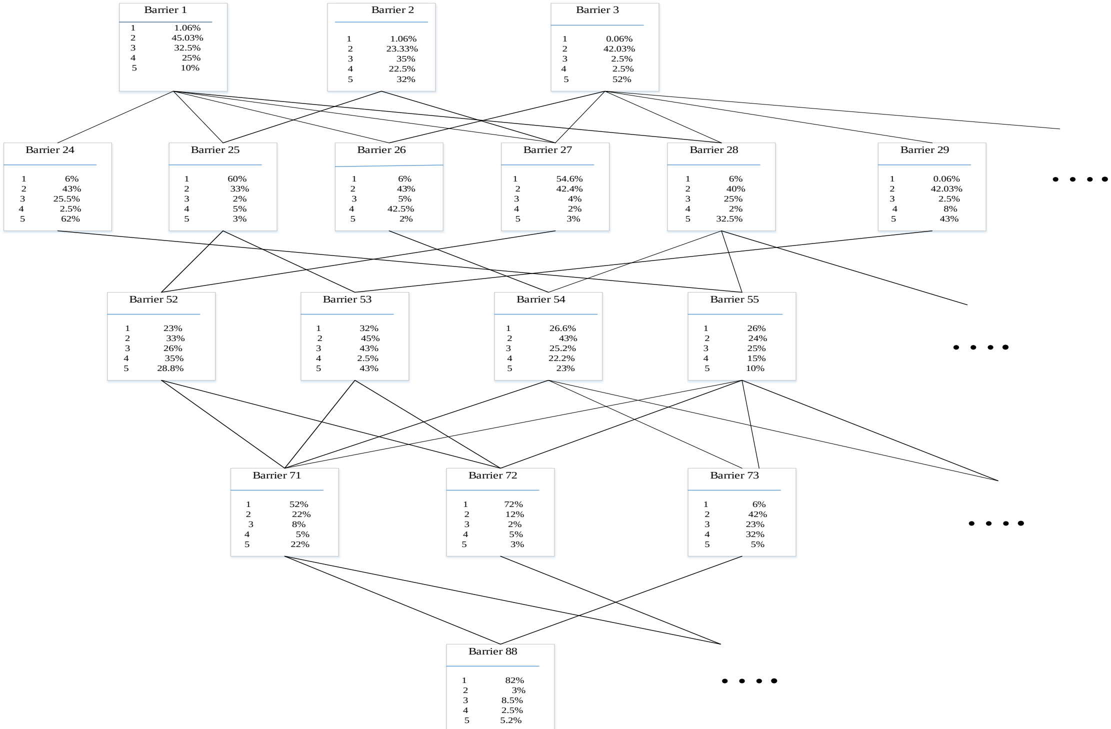

Figure 3 Conditional Dependence between Barriers

Overall, the proposed Critical barriers to sustainable construction technology adoption in developing countries identify the key performance indicators for sustainable construction adoption in developing countries with a relative factor reliable index framework with the Likert scale and Polychromous Rasch model to collect the survey data from different participants. Then the collected data is represented in the form of a probabilistic graphical model with a directed graph to find the probability of the factor. Finally, the relative importance index of all the factors is calculated by z-score normalization and ranked according to it. The results obtained from the proposed Critical barriers to sustainable construction technology adoption in developing countries were discussed in detail in the next section.

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4. Results and Discussion

This segment provides a detailed description of the implementation results as well as the performance of the proposed system with all factors z-score value and the weightages are tabled and the ranking done based on the z-score probability.

4.1 Experimental Setup

The following system specification was used to implement this study on the MATLAB working platform, and the simulation results are given below.

- **Platform:** MATLAB
- **OS:** Windows 10
- **Processor:** 64-bit Intel processor
- **RAM:** 8 GB RAM

4.2 Performance Metrics Of The Proposed System

4.2.1 Weightage

The total weightage of each barrier is calculated by adding the values obtained from the survey,

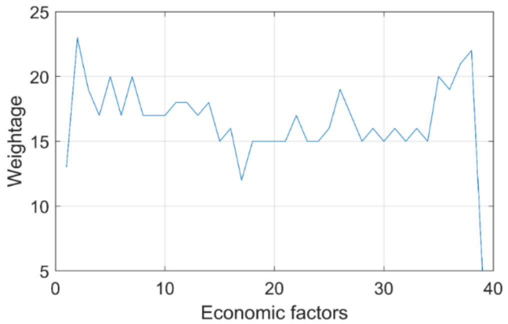

Figure 4 Weightage of Economic Factors

Figure 4 shows the total weights of each barrier calculated for economic factors. Where the barrier cost of installation of equipment and tools has the high weightage of 23 and Production of illegitimate prefabricated components causing extra payments has 2nd highest weightage of 22. The barrier rent in occupying extra space for the accommodation of precast components has lowest weightage which is 12. The factors are improper sizing of construction equipment and less inspection and maintenance of construction equipment having the same weight as 20. The proposed method estimates the appropriate weights by using a directed polygonal graph from the Likert scale data.

The weights of social factors are shown in Figure 5. Reliance on intensive labor rather than equipment barrier has the weight of 21. The maximum weightage of 24 was obtained for the barrier of increased burden on infrastructure as a result of the use and depletion of natural resources. The three factors have the same weight as 16 are a healthy environment at the workplace, coordination of all types of work on-site, and participation of all parties in project monitoring and decision-making. The social factors are represented in proposed method by probabilistic graphical model with directed graph.

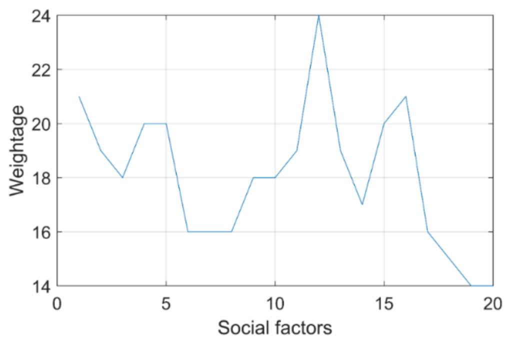

Figure 5 Weightage of Social Factors

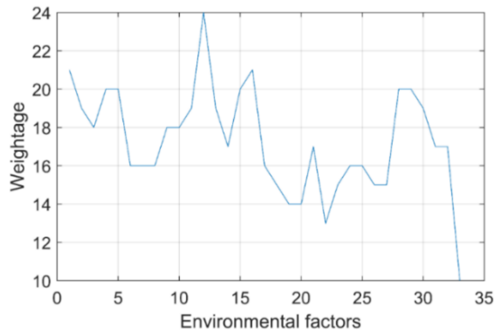

Figure 6 Weightage of Environmental Factors

From Figure 6, the environmental barrier for ineffective waste disposal has a weightage of 24. The factors not showing interest in ecology preservation, neglecting sustainable temporary facilities during the project, and neglecting sustainable material substitutions have the same weightage of 16. Very low weight is obtained for quality and dimensions of aggregate are improper in the production of prefabricated components. The proposed method estimates the appropriate weights of the factors by using the Polytomous Rasch model on Likert scale data.ure 5, the environmental barrier for ineffective waste disposal has a weightage of 24. The factors not showing interest in ecology preservation, neglecting sustainable temporary facilities during the project, and neglecting sustainable material substitutions have the same weightage of 16. Very low weight is obtained for quality and dimensions of aggregate are improper in the production of prefabricated components. The proposed method estimates the appropriate weights of the factors by using the Polychromous Rasch model on Likert scale data.

Figure 7 shows the mean square error (MSE) for 56 epoch's occurrence during ranking using RII and z-score normalization. The proposed method produces a low error because of the usage of a probabilistic directed polygonal graphical model. The training error is higher than the test error from 0 to 56 epochs and it maintains a constant mean square error during the whole process. The proposed survey data and weightage also the calculated z-score values of all the factors.

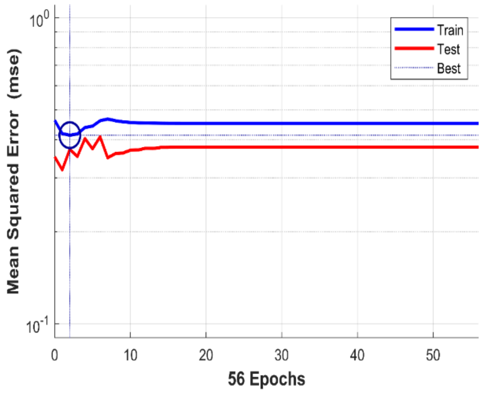

Figure 7 Mean Square Error of the Proposed Method

Table 1 Weightage and Z-Score Value For All Economic Factors

S. No	Factors	weightage	z-score	Rank
1	High cost of labor experienced in sustainable buildings	13	-1.196	10
2	Professional fees for engineers and consultants	23	2.112	1
3	Cost of using existing equipment	19	0.789	5
4	Cost of purchase and renting new equipment	17	0.127	7
5	Cost of installation of equipment and tools	20	1.120	4
6	Improper sizing of construction equipment	17	0.127	7
7	Lacking Use of full equipment capacity	20	1.120	4
8	Less Inspection and maintenance of construction equipment	17	0.127	7
9	High cost of securing and protecting the site	17	0.127	7
10	Less durability of materials procured	17	0.127	7
11	Cost of repairing and defects	18	0.458	6
12	Improper Lead-times for the required tasks and activities	18	0.458	6

13	Complex techniques in assembling	17	0.127	7
14	Complexity in design	18	0.458	6
15	Additional procurement costs	15	-0.534	9
16	High initial cost (cost on new machinery, fabricate molds, and factories)	16	-0.204	8
17	Extra labor cost on checking, counting, and sorting raw materials	12	-1.527	11
18	Rent in occupying extra space for the accommodation of precast components	15	-0.534	9
19	Additional transportation costs	15	-0.534	9
20	Additional use of tower cranes (vertical transportation)	15	-0.534	9
21	Improper storage according to work schedule	15	-0.534	9
22	High Life cycle cost	17	0.127	7
23	The cost incurred in Standardization of material selection	15	-0.534	9
24	Cost of waste disposal	15	-0.534	9
25	Unexpected equipment failure	16	-0.204	8
26	Storage Resources damage	19	0.789	5
27	Depreciation of fixed assets	17	0.127	7
28	Attrition rate of reinforcement	15	-0.534	9
29	Additional reinforcement due to connection points	16	-0.204	8
30	Lack of efficiency of production worker	15	-0.534	9
31	Training cost of production workers	16	-0.204	8
32	Transportation and shipment forms of Precast	15	-0.534	9
33	Not proper production to technical specifications.	16	-0.204	8
34	Curing condition to Precast	15	-0.534	9
35	Reuse rate of Precast mold	20	1.120	4
36	Scrap quantity of mold	19	0.789	5

37	Production of illegitimate prefabricated components causes the extension of term delivery	21	1.450	3
38	Production of illegitimate prefabricated components causing extra payments	22	1.781	2
39	Deformation failures at molds affect the manufacturing process negatively.	5	-3.843	13

From table 1, the high weightage factors are found to have better probability and the low probability has occurred when the factors have low voting from the participants. The barrier deformation failures at molds affect the manufacturing process negatively has a negative high z-core value which means the probability of the barrier is low because the weightage is also low for that particular factor. Social factor weightage and z-score are displayed in the table 2. It shows the weightage and z-score value for the factors that are taken for the survey under the social factor. Here the high weightage values the

High probability of the barrier than the low weighted factors. The values of environmental factors are given in table 3.

Table 2 Weightage and Z-Score Value For All Social Factors

S.No	Factors	Weightage	z-score	Rank
1	Reliance on intensive labor rather than equipment	19	0.792	2
2	Influence of the project on the job market	17	0.103	3
3	Lack of Labor availability	16	-0.241	4
4	Not providing qualified technical skilled laborers during the construction process affect the process negatively	16	-0.241	4
5	Promotion and development of capacity and skills for the labor force	19	0.792	2
6	A healthy environment in workplace	17	0.103	3
7	Coordination of all types of work on site	16	-0.241	4
8	Participation of all parties in project monitoring and decision-making	14	-0.930	5
9	Not following Project control guidelines	16	-0.241	4
10	Lack of Public awareness about precast buildings	22	1.825	1
11	Lack in improvement of infrastructure to the society and environment	16	-0.241	4
12	Increased burden on infrastructure as a result of the use and depletion of natural resources	19	0.792	2
13	Infrastructure capacity of building	17	0.103	3
14	Security consideration in worksite	19	0.792	2

15	Provision of services and facilities onsite	16	-0.241	4
16	Inefficient decision making	19	0.792	2
17	Not monitoring the installations periodically affects the construction process negatively.	19	0.792	2
18	Coordination of all types of work on site	13	-1.274	6
19	Manufacturers do not make production proper to technical drawings	16	-0.241	4
20	Manufacturers 'laborers do not have enough knowledge of reading and understanding technical drawings.	8	-2.996	7

Table 3 Weightage and Z-Score Value For All Environmental Factors

S.No	Factors	Weightage	z-score	Rank
1	Non-Integration of environmental factors with economic program	21	1.331	2
2	Lack of Communication of environmental management information	19	0.611	4
3	Improper Environmental management technology	18	0.251	5
4	Inclusion of environmental aspects in decisions during construction (*e.g.* buying greener materials)	20	0.971	3
5	Lacking Institutional interest in the environmental aspect	20	0.971	3
6	Not showing interest in Ecology preservation	16	-0.469	7
7	Neglecting sustainable temporary facilities during the project	16	-0.469	7
8	Neglecting sustainable material substitutions	16	-0.469	7
9	Lack of Recycling and reuse of products	18	0.251	5
10	Ineffective management of surplus materials	18	0.251	5
11	Improper monitoring of waste generation	19	0.611	4
12	Ineffective waste disposal	24	2.411	1
13	Depletion of dependency resources (water-energy-raw materials-land)	19	0.611	4
14	Pollution generation	17	-0.109	6
15	Natural habitat destruction	20	0.971	3
16	Changes in the environment lead to the discomfort of people and the biological system.	21	1.331	2
17	Life cycle design incorporating environmental factors	16	-0.469	7
18	Not following Environmental protection laws and regulation	15	-0.829	8

19	Quantity of particulate matter	14	-1.189	9
20	More use of sustainable fuels	14	-1.189	9
21	Improper vibration control	17	-0.109	6
22	Lacking the readiness to handle weather uncertainty	13	-1.549	10
23	Faulty design of joints and connections	15	-0.829	8
24	Faulty construction methodology	16	-0.469	7
25	Non-conformance with Tolerance limits for precast elements	16	-0.469	7
26	Lack of Frequency of quality checks during the manufacturing process.	15	-0.829	8
27	Damage to concrete elements	15	-0.829	8
28	Poor workmanship of structure joints	20	0.971	3
29	Improper type of sealant	20	0.971	3
30	Severe exposure conditions (like severe monsoons)	19	0.611	4
31	Inadequate level of concrete vibration during the production of prefabricated components	17	-0.109	6
32	Corroded steel and pre-stressing wire were used during the manufacturing process.	17	-0.109	6
33	The quality and dimensions of aggregate are not proper that are used in the production of prefabricated components.	10	-2.629	11

In table 3, the quality and dimensions of aggregate are not proper that are used in the production of prefabricated components received low weightage of 10 and the probability of occurrence also low so this barrier does not affect the sustainability of construction.

4.3 Comparison of Factors

Figure 8 shows the highest rank obtained factors Z-score comparison. The barrier in the environmental factor has the highest value of 2.411 which is most critical barrier that affect construction sustainability. The 2nd most critical barrier from environmental factor and last social factor has low value of 1.825. Similarities of barriers with earlier studies given in Table 4. Overall, the proposed ranking based on the barriers determine the causes of construction delays and their interrelationships. The ranking of the barriers is identifying the key performance indicator by the best probability of the barrier by relative importance index and z-score normalization. Thus, the proposed Critical barriers to sustainable construction technology adoption in developing countries identifies the maximum probability of the sustainable construction barriers.

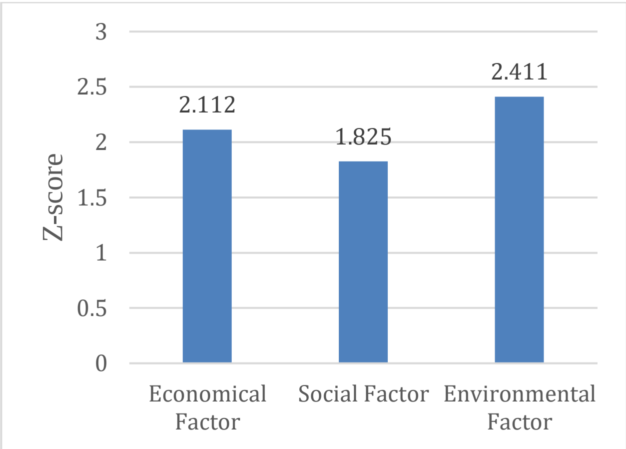

Figure 8 Highest Rank Comparison of Factors

Table 4 Similarities of Barriers Comparison

Rank	Palestine [29]	Malaysia	India
1	Lack of contractual agreement to Implement energy management During construction	Proper production equipment and technology	Ineffective waste disposal
2	Lack of energy management codes and regulation in construction	Set a quality criterion for component products	Professional fees for engineers and consultants
3	Lack of governmental rules and regulation regarding EMPs adoption	High cooperation between subcontractors and general contractor	Lack of Public awareness about precast buildings
4	Lack of awareness regarding energy Management adoption	Appointment of high experience and skills technical team	Non-Integration of environmental factors with economic program
5	Lack of technical skills and information about energy management technologies	Good and fair subcontract conditions	Cost of installation of equipment and tools

Conclusion

To analyze the sustainability of precast building factors, the survey has been taken from the various participants who related to the construction engineering through online using Likert scale with Polychromous Rasch model. Then ranking of the factors by Probabilistic Graphical Model to represent the conditional dependencies between the factors through directed polygonal graph. Also, the weightage of each factors were calculated by using relative importance index which rank the factors by combining the weightage and the number of respondents from the participants. Further correlation between the factors identified with z-score normalization have the better probability of the factors. The weightage value higher than 20 has always has high risk. Ineffective waste disposal from environmental factor identified as most critical barrier in sustainable construction development with Z-score value of 2.411.

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