Analysis of Critical Barriers in Bridge Construction using Best Worst Method

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***Abstract*—A Bridge is a structure that spans horizontally the road, body of water or a valley. Bridge Construction may vary depending on the intended functioning of the bridge and nature of the that geographical region. Keeping in view the bridge site and various constraints, type of bridge and method of construction are to be selected carefully for successful completion of bridge construction. Hilly region pose unique problem for bridge construction. However, It has been realized that critical barriers in bridge construction need to be identified and evaluated. The intended purpose of the presented research work is to check the critical barriers in bridge construction. The present assessment work is to compute relative weight age of the critical barriers in bridge construction using newly developed Multi Criteria Decision Making technique 'Best Worst Method'. Total six critical barriers in bridge construction have been identified. Further we have ranked the critical barriers in bridge construction using Best Worst Method. Input data are taken from a web based survey from thirty stakeholder individuals. The resultant will be instrumental for the strategy creators for designing influential plans and tactics to tackle with critical barriers in bridge construction.**

Keywords: Best Worst Method; Bridge; Construction; Critical barriers

I. INTRODUCTION

The first bridges had been created by nature itself as a log fallen across a stream or stones in the river. Early civilization used bamboo poles to cross small caverns to reach from one side to another. A common form of lashing deciduous branches together involved the use of harvested fibers woven together to create a connective rope capable of holding together the materials used in early bridges. With the technological advancement of civil engineering numerous types of bridges have come into scenario and these days it has emerged as symbol of progress for any nation.

Bridge is the structure built to span between supports, to provide passage over an obstacle without closing the way beneath. The obstacle to be crossed might be a river, a road, railway, a valley, body of water, or any other physical obstacle. The civil engineering problems to be overcome are inherent in every bridge: the supports must be strong enough to hold the structure up and the span between supports must be strong enough to carry the loads. Spans are generally made as short as possible; long spans are justified where good foundations are limited for example, over estuaries with deep water. Designs of Bridges will vary depending upon the function of the bridge and nature of the area where the bridge is to be constructed. In a restricted hilly area itself climatic conditions, geological features and hydrological parameters vary considerably.

All major bridges are built with the public's money. Therefore, bridge design that best serves the public interest as efficient, as economical, and as elegant. Keeping in view the bridge site and various constraints, type of bridge and method of construction are to be selected carefully for safe, economical and successful completion of bridge construction. Efficiency is a scientific principle that puts a value on reducing materials while increasing performance. Economy is a social principle that puts value on reducing the costs of construction and maintenance while retaining efficiency. Elegance is a symbolic or visual principle that puts value on the personal expression of the designer without compromising performance or economy.

A. Basic forms of Bridges based on load transfer mechanism

There are six basic bridge forms as shown in Fig. 1.

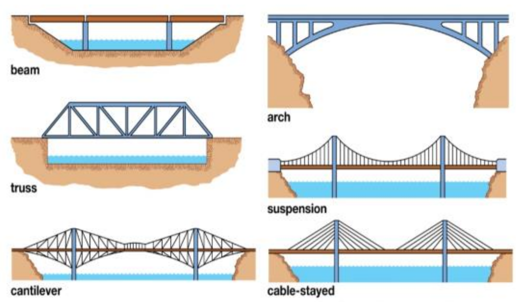

Fig. 1. Different Types of bridges

1. *Beam*: The most common bridge form, a beam carries vertical loads by bending. As the beam bridge bends, it undergoes horizontal compression on the top and tension at the bottom.
2. *Truss*: A single-span truss bridge is like a simply supported beam. There is either tension or compression in the vertical and diagonal members, depending on their orientation.

3. *Arch*: The arch bridge carries loads primarily by compression, which exerts on the foundation both vertical and horizontal forces. Arch foundations must therefore prevent both vertical settling and horizontal sliding.
4. *Suspension*: A suspension bridge carries vertical loads through curved cables in tension. These loads are transferred both to the towers, which carry them by vertical compression to the ground, and to the anchorages, which must resist the inward and sometimes vertical pull of the cables.
5. *Cantilever*: A beam is said to be cantilevered when it projects outward, supported only at one end. A cantilever bridge is generally made with three spans. The cantilevers carry their loads by tension in the upper chords and compression in the lower ones.
6. *Cable-stay*: Cable-stayed bridges carry the vertical main-span loads by nearly straight diagonal cables in tension. The towers transfer the cable forces to the foundations through vertical compression.

A. Types of Bridges based on construction material

The four primary materials used for bridges have been wood, stone, iron, and concrete. Of these, iron has had the greatest effect on modern bridges. Steel is used to make reinforced and prestressed concrete. Modern bridges are almost exclusively built with steel, reinforced concrete, and prestressed concrete.

1. *Wood and Stone*: Wood is relatively weak in both compression and tension, but it has almost always been widely available and inexpensive. Civil Engineers now incorporate laminated wooden beams and arches into some modern bridges.

   Stone is strong in compression but weak in tension. Its primary application has been in arches, piers, and abutments.
2. *Iron and Steel*: Cast iron is strong in compression but weak in tension. Wrought iron has much greater tensile strength. Steel is superior to any iron in both tension and compression. Steel can be made to varying strengths, some alloys being five times stronger than others. The civil engineer refers to these as high-strength steels.
3. *Concrete*: Concrete is an artificial stone made from a mixture of water, sand, gravel and cement. It is strong in compression and weak in tension. Concrete with steel bars embedded in it is called reinforced concrete. Reinforcement allows for less concrete to be used because the steel carries all the tension; also, the concrete protects the steel from corrosion and fire.

Paper is settled as the critical reviewing of past work has been done in Section 2. The barriers in bridge construction have been recognized and presented in Section 3. Method applied in the presented work has been explained in Section 4. Assessment of data and results are shown in Section 5. In the last section, Concluding statements are communicated with possibilities for future.

II. Review of relevant literature

Scottish engineer Thomas Telford was the first who had mentioned regarding aesthetics. The structure of a bridge is the area of the civil engineering and it's good looking is mainly obtained by the inclusion of architect ideas. The bridges using the best available utilization of materials are elegant. The civil engineers may apply unconventional aesthetic ideas without including cost or materials particularly.

There are numerous means for tackling with the requirement to explore new ways through the analysis of different barriers in the construction of bridge. Bridge construction is a common technical issue in the industry for research[1]. The pace of development in the construction industry is comparatively slower than manufacturing sector [2].

The bridges have a span of up to hundred years, but restoration of the bridges is needed. There might be several reasons like due to deep scouring as the structure had been designed for certain scour depth. There is also possibility of other factors related with the issue and therefore it requires the detailed investigations to spot the root causes of the issue and propose the restoration policies. [3] proposed bed protection works for the Balad bridge which is situated on the National Highway no.21A close to Baddi (Himachal Pradesh). [4] summarized the barriers to adopting simulation in the construction industry. Their search process resulted in 78 documents with 14 barriers recorded and then conducted a critical analysis of the barriers. They suggested four areas for improvement to overcome the identified barriers for a better realization of simulation benefits in the construction industry.

Bridge construction projects are inherently complex and iterative, and these place great demands on project management to apply innovative approaches for more comprehensive analysis of performance data under uncertain conditions. Although new technological-based methods such as simulation have proven to be powerful techniques to cope with cyclic and uncertain project behaviors, implementation of simulation-based modeling is below par in the construction domain especially in bridge construction. [5] had undertaken a questionnaire survey and a workshop to identify benefits and drawbacks for off-site manufacturing (OSM) in bridge construction. They showed that 'Quality' is a barrier in comparison with on-site construction. They suggested that the barriers like reduced quality and not aesthetically pleasing must be overcome to increase its market share. [6] observed that the widespread application of large-span mobile formwork construction technology has been favored by the bridge engineering community. They further concluded that the design and safety control of bridge construction may be improved.

TABLE 1. LATEST RESEARCH OF CRITICAL BARRIERS IN BRIDGE CONSTRUCTION

Sl. No.	Author	Objective & Outcome
1	Abdelmegid *et al.*, 2020	Paper conducted a critical analysis of the barriers for adopting simulation in the construction industry and further suggested four areas for improvement to overcome the identified barriers for a better realization of simulation benefits.
2	Kou *et al.*, 2016	Paper explored the literature on major landmarks of the pair wise comparison matrix (PCM). Paper concluded that some new approaches need to be devised for big data driven futuristic environment to use the PCM.

From literature review, it is clear that analysis of critical barriers in bridge construction is a complex task to be addressed. Therefore, it becomes essential to identify critical barriers in bridge construction. Next section deals with identification of critical barriers in bridge construction.

III. IDENTIFICATION OF CRITICAL BARRIERS IN BRIDGE CONSTRUCTION

Various research papers published were reviewed and then six critical barriers in Bridge Construction have been sorted from literature and expert's inputs. To conceptualize the task of identifying most critical barrier in Bridge Construction, some of key factors have been identified from the contributed research. The key factors include *'Back filling material'*, *'Coffer dam building'*, *'Public safety measures issue'*, *'Flowing water diversion'*, *'Hydrological features'*, *'Thermal expansion'*. These Critical factors have been shortlisted from review (Table 2) and validated from experts' views.

TABLE 2. THE CRITICAL BARRIERS IN BRIDGE CONSTRUCTION

Critical barriers in Bridge	Abbreviation
'Back Filling Material'	BM
'Coffer Dam Building'	CB
'Public Safety Measures Issue'	PS
'Flowing Water Diversion'	WD
'Hydrological Features'	HF
'Thermal Expansion'	TE

1 *'Back filling material'*

It is related with the material used to refill a hole, usually what was previously dug out of the hole. Dirt and gravel are examples of backfill.

2 *'Coffer dam building'*

It is an enclosure built within a body of water to allow the enclosed area. This pumping creates a dry working environment so that the work can be carried out safely.

3 *'Public safety measures issue'*

When we construct a road, we use heavy machines. Then it is our duty to make public safety.

4 *'Flowing water diversion'*

A water diversion is the removal or transfer of water from one watershed to another.

5 *'Hydrological features'*

These are the unit of water information required to convey identity of real-world water-objects through the data processing chain from observation to water information.

6 *'Thermal expansion'*

It relates the increase in linear dimensions of a solid or in volume of a fluid because of rise in temperature.

IV. METHODOLOGY: BEST WORST METHOD

In In the present work a newly developed MCDM method by Rezaei, best worst method, has been utilized [7]. It's method is based on two evaluation vectors, The Best criterion against the Other criteria, the Other criteria against the Worst criterion. The weights of the criteria are determined by solving a linear [8] or a nonlinear model. The ability of BWM to obtain more consistent results due to its structured pairwise comparison system makes it much employable [9].

Compared to the popular pairwise comparison based MCDM method AHP, it allows to determine several reliable results according to previous analyses[4]. The Best-Worst Method utilises ratios of the relative importance of criteria in pairs on the basis of the analysis performed by decision-makers[10]. The BWM incorporates determining a solution of a nonlinear model to derive the weights from the comparisons. A linear model had been developed in a follow-up to approximate the initial nonlinear model [11].

There are three effective methods to get the quantum of importance of the attributes within the Best-Worst scaling. These may be the object case, the profile case, the multi-profile case. In object case, the respondent is said to pick the best and worst alternatives out of a series of objects, without showing any characteristic. In the profile case, the respondent is said to select the best and worst from a list of attributes, the selection is made between the different characteristics. Third case is related to the classic discrete alternative experiments, while the alternatives are made between a group of alternatives consisting of different characteristics with different levels[12]. The steps of the BWM have been shown in Figure 2.

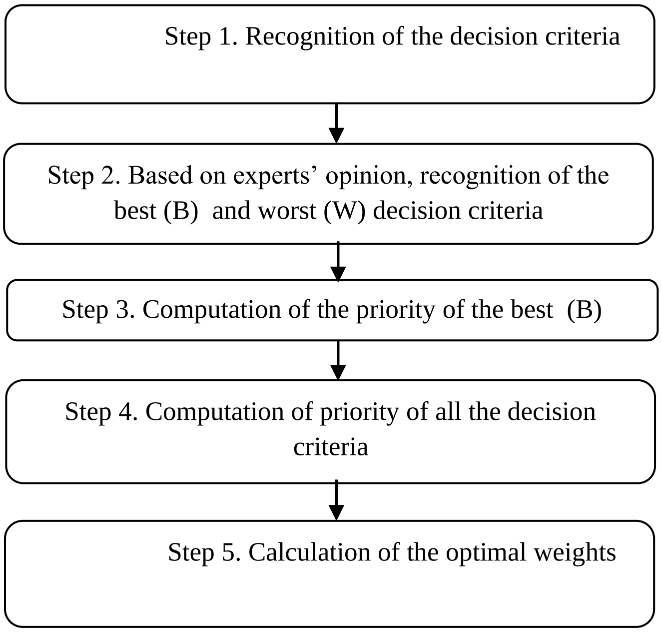

Fig. 2. Steps in Best Worst Method

V. DATA ANALYSIS & RESULTS

For validation of our proposed model, a web based survey with twenty seven civil engineers, who had been associated in bridge construction, was performed in the month of March 2021. In the survey, the respondents have marked the importance of all barriers on the scale of 1-5 as 1 for the least importance and 5 for the most importance, as shown in Table 3.

TABLE 3. DATA COLLECTED BY WEB BASED SURVEY

How much Important which barrier is in Bridge Construction

Timestamp	Back filling material	Coffer Dam Building'	Safety Measures'	Flowing Water Diversion'	Hydrological Features	Thermal Expansion
3/3/2021 19:13:34	1	4	3	5	5	2
3/3/2021 19:15:24	3	5	4	3	3	4
3/3/2021 19:27:13	1	2	3	1	2	1
3/3/2021 19:28:09	2	1	1	1	1	2
3/3/2021 19:41:54	5	2	5	3	3	5
3/3/2021 19:43:00	4	3	5	5	4	4
3/3/2021 19:48:22	3	3	3	2	3	2
3/3/2021 19:49:58	2	3	3	2	5	1
3/3/2021 20:02:41	5	3	4	4	3	4
3/3/2021 20:31:44	5	5	5	5	3	5
3/3/2021 20:52:54	4	5	5	4	4	4
3/3/2021 21:04:39	3	3	5	4	2	5
3/4/2021 0:19:53	4	3	3	3	4	3
3/4/2021 11:58:17	3	3	5	4	5	4
3/4/2021 12:20:49	3	2	4	2	4	3
3/4/2021 12:45:01	1	4	5	3	2	3
3/4/2021 13:12:33	4	4	5	1	3	2
3/4/2021 13:35:45	2	1	5	3	3	2
3/4/2021 18:31:34	4	4	4	4	5	4
3/4/2021 19:02:43	1	3	3	5	2	1
3/5/2021 2:45:46	2	3	5	4	2	1
3/5/2021 9:23:57	3	3	3	3	4	4
3/5/2021 19:51:01	3	3	4	4	4	3
3/6/2021 1:45:12	3	5	5	4	5	5
3/6/2021 11:40:37	4	4	5	4	5	4
3/7/2021 7:32:31	1	3	3	3	2	4
3/9/2021 22:51:37	3	3	5	2	4	3
SUM	79	87	110	86	88	85

Following is the formation of the priority of the best criteria over the others on a 9-point scale as shown in Table 4.

Table 4. Priority of the best criterion (B) over all the other criteria

THE BEST	BM	CB	PS	WD	HF	TE
PS	9	3	1	5	2	7

Following is the formation of the priority of all the decision criteria over the worst criterion (W) on a 9-point scale as shown in Table 5.

TABLE 5. PRIORITY OF ALL THE DECISION CRITERIA OVER THE WORST CRITERION (W)

THE WORST	BM
BM	1
CB	4
PS	9
WD	3
HF	6
TE	2

With the help of online 'Best Worst Method' solver for 6 barriers in MS excel sheet form has been generated and shown in Figure 3. The weight-age of all critical barriers has been considered up to three digits of decimal.

Criteria Number = 6	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6
Names of Criteria	BM	CB	PS	WD	HF	TE

Select the Best	PS
Select the Worst	BM

Best to Others	BM	CB	PS	WD	HF	TE
PS	9	3	1	5	2	7

Others to the Worst	BM
BM	1
CB	4
PS	9
WD	3
HF	6
TE	2

Ksi*	0.036

	BM	CB	PS	WD	HF	TE
Weights	0.042	0.152	0.42	0.091	0.228	0.065

Fig. 3. Results of BWM Solver

Final values of the optimal weights and Consistency ratio (Ksi) (denoted as ξ) have been calculated as shown in Figure 3 and tabulated in Table 6. Consistency ratio value is 0.036 and we know that the lower Consistency ratio value signifies the more consistent and more reliable results. Table 6 depicts the priorities calculated using the Best Worst Method and the ranking of the various critical barriers in Bridge Construction. It has been found that *'Public Safety Measures Issue'* is the most important critical barriers in Bridge Construction, followed by *'Hydrological Features'* and *'Coffer Dam Building'*.

TABLE 6. RELATIVE WEIGHTS OF CRITICAL BARRIERS IN BRIDGE CONSTRUCTION

Consistency Ratio ξ	**0.036**
'Back Filling Material'	0.042
'Coffer Dam Building'	0.152
'Public Safety Measures Issue'	0.420
'Flowing Water Diversion'	0.091
'Hydrological Features'	0.228
'Thermal Expansion'	0.065

VI. CONCLUSIONS AND SCOPE FOR FUTURE WORK

This paper has projected a multi-criteria decision making (MCDM) methodology for analysis of critical barrier of bridge construction using Best Worst Method, considering six barriers ('Back filling material', 'Coffer dam building', 'Public safety measures issue', 'Flowing water diversion', 'Hydrological features', 'Thermal expansion'). Six critical barrier of bridge construction have been compared and ranked. It is clearly evidential from the findings of the work that 'Public Safety Measures Issue' is the most important critical barriers in Bridge Construction, followed by 'Hydrological Features' and 'Coffer Dam Building'.

Some other multi-criteria decision making techniques like TOPSIS, ANP, DEAMATEL methodology with some appropriate statistical tool like Structural equation modeling technique may be utilized for similar problems and their results may be further compared.

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