Causes and Effects of Design Change of Construction Projects

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ABSTRACT

Purpose: *Design is the mother of all construction as it is not only technical but also strategic process for competitiveness. In last decade, enormous bridge projects have been designed in Nepal but not all of them have been implemented. The causes of bridge design changes, and their effects on projects in terms of cost and time schedule is found to be complex and are influenced by numerous interrelated factors. This research focuses on the causes, effects and impacts of design change/reviews in bridge projects designed and constructed under Bridge Branch, Department of Roads (DoR).*

Design/Methodology/Approach: *Five case studies were taken along with schedule questionnaire to contrast the causes, effects and impacts identified from questionnaire survey. The data obtained from the questionnaire were analyzed using the Relative Importance Index (RII) for finding the importance of each causes, effects, and impacts.*

Findings/Result: *The design change was found to be done mostly in the foundation of the bridges. Sometime the redesign was done for change in scope and location of the bridge due mostly due to social and political interference and interest rather than value engineering. The Consultant was the main origin agent for design changes of bridge projects as they were the most responsible for the detail survey, soil investigation and design and estimate of the bridge whereas the client found to be second origin agent for design change due to lack of required data, change of plans or scope. The major causes for the bridge design change were Non-complaint design with site requirement, Errors in design, Differing site conditions, unforeseen problems and Inadequate working details. The top three common effects of design changes are time overrun, cost overrun and requirement of additional specialist/equipment/personnel.*

Originality/Value: *It is basic research. This study helps in motivating and creating awareness among the design professionals working in design review which will create the influence to overcome issue of design change strategically.*

Paper Type: *Ex-Post Facto Research*

Keywords: Status, Design Change, Effects, Cause, Impacts, Department of Roads (DoR)

1. INTRODUCTION :

In Nepal, the consulting services started early in mid-1950's (Mishra, 2020) [1]. Later, the consulting industry received new opportunities and challenges from early-seventies when government sector started using private professionals/firms to provide services in small engineering projects like small water supply, micro-hydropower etc. Most of the engineering designs in civil engineering field of roads, bridges. water supply, irrigation etc. are being done by the engineering consulting firm. In DoR also the detail survey, design and estimate of roads and bridges are being done by outsourcing these consulting firms.

The key input to design is required in early stages of planning and design of a project. The bridge design work starts from desk study to detail survey, soil investigation, design and many other engineering works which equally have the chances of errors. These sources of errors can create conditions for design changes of bridges. Any design cannot be perfect in itself; rather it differs with the designer requirement, field conditions, etc.

In last decade, enormous bridge projects have been designed in Nepal. But not all of them have been implemented as per the design. Many bridge construction projects are still not completed due to poor designs. Design changes have been done at different steps of the project like after finalization of design, before and after contracting, during construction and so on. These changes have many impacts on the project causing, delay in project implementation, complications in contract, increased or decreased cost, technical difficulties during construction, etc.

2. PROBLEM STATEMENT :

The research will be significant for the consultant/firms involved in bridge design works. It will also be beneficial to the clients, contractors involved in the bridge project to complete the bridge projects efficiently within stipulated time and cost. Several studies conducted at different parts of the globe illustrates that time extension is not an exception but norms of the industry in all sector of construction projects some of the scholar could be referred as Ndihokubwayo, (2009) [2], Odeyinka et al, (1997) [3], Theodore. T, (2009) [4], Mohammed et al, (2010) [5], Haseeb, et al, (2011) [6], Assaf et al, (1995) [7], Apolot, et al, (2010) [8], Mishra and Magar, (2017) [9] and Grimier and Mishra, (2019) [10] and many more. In this respect one cause might be design review, so we want to draw the attention through the research in that direction.

Similarly, the shortcomings, related to design and survey, found from the study will help the concerned agencies, consulting firms/personnel's to minimize the errors occurred during the detail survey, design and minimize the changes in up-coming projects. Thus, this study will help the DoR, Bridge Branch as well as other bridge project implementing agencies in decision making process, documentation and effectiveness of design and implementation of the projects.

Therefore, it is required to find out and analyze the issues related to design of bridge projects which may ultimately guide for enhancement of the performance of the bridge projects.

3. OBJECTIVES :

The general objective of the study is to analyze the issues related to the design changes of the bridge projects done under Bridge Branch of Department of Road.

The specific objectives are:

(1) To assess the current state of design change practiced in bridge projects of DoR,

(2) To study the causes rendering the design change in bridge projects,

(3) To find out the effects of design change on bridge projects.

4. LITERATURE REVIEW :

4.1 Process of Bridge Design and Changes (Redesign) in DoR

The design works are done by consulting firms or the Consultant, also known as the design professionals is the party, organizations, or firm that designs the project (Ndihokubwayo, (2009) [2], Odeyinka et al, (1997) [3] Theodore. T. (2009) [4], Mohammed et al, (2010) [5], Haseeb, et al, (2011) [6], and Assaf et al, (1995) [7],). The Consultant should perform their services and carry out their obligations with all due diligence, efficiency.

The Bridge Branch, DoR has been outsourcing and utilizing the consultancy services from the engineering, consulting firms for the detail survey, design and estimate of the bridges to be constructed under construction contracts to be built by contractors. The objective of the services is to design a safe, reliable and cost-effective bridge using the appropriate technologies. The services include detail soil investigation, hydrological studies, bridge design, river training works, detail quantity and cost estimate (DoR, 2012: Dor, 2012) [11 & 12]. The bridge design and estimate provided by consultants are then finalized by Client with cross check followed at different phases of design. The approved bridge design is forwarded to the Division Road Offices (DRO) who will be implementing and construction the approved designs after going through contract agreement with Contractors. The bridge designs are changed more during implementing stage after contractors starts construction work. It may be either during or after foundation construction or even during superstructure construction. Some pre-identified bridge projects are implemented through "Design and Build (D&B) projects under Bridge Branch. The projects under D&B are designed and build by Contractors although they hire consultants for design.

The performance of the Consultants/firms has always been seen doubtfully. The errors in designs, drawings, difficulties in construction, alteration in designs have been found in many projects including

bridge projects as well. The issues have also been seen with the human resources involved in the designs and surveys compared to those agreed in the contract.
In Bridge branch, DoR, there are two party involvements in design process: (i) the Client-DoR and (ii) the Consultants-Designing Firms. The DoR as client utilizes the consulting services following the Public Procurement Act-2007 A.D (PPA) (Mishra and Singh, 2019) [13].
The trend of low bidding system is also seen in consulting works and it has resulted in the negligence during soil investigation and survey works. The low amount bid by consultants binds them to limit the soil investigation and poor survey works which don't meet the requirement of clients. This has resulted in varying site conditions with the original designs, varying foundation requirement compared to the design.

4.2 Causes and Effect of design changes

Change in design by consultant, errors and omissions in design, inadequate scope of work, lack of coordination, inadequate working details, lack of experience and so on are majour causes of design change (Sunday, 2010 [14]: Alnuami et al, 2010) [15]. Al-Jishi and Al-Marzoug (2008 [16]) ranked the top five causes of change orders viz; Change of plans by owner, Substitution of materials and procedures, Errors and omissions in design, Owner's financial problems and change in design by consultant based on the response of contractors and consultants.
Al-Jishi and Al-Marzoug (2008) [16] also examined the effects of change orders. The top five effects of change orders from the contractor's point of view are as extension of completion schedule, higher cost, higher contractor's overhead, reduced productivity of labour and additional payment whereas consultants' point of view was as higher project cost, extension of schedule, higher payments for contractors, dispute between client and contractor and Demolition and re-work.

5. METHODOLOGY :

The research objective is to find out the issues related to the reviews/changes done in the approved bridge designs, before and after contract of the projects under Bridge Branch, DoR. The research included both -Case study and Survey research.
The cases of bridge changes done in both SRN and LRN roads under Division Road Offices of DoR and Bridge Branch were studied. In addition to the case study, the field survey using questionnaires was done with the Clients, Contractors and Consultancy Firms.
The research included both quantitative and qualitative approaches by taking questionnaire survey and discussion with the stakeholders and experts. The data and information were collected and analyzed to get the reasons of design changes and its effect on the projects.

5.1 Study Area

All the bridges under DoR, except in Postal highways (*Hulaki Rajmarg*), are managed by the Bridge Branch-of-DoR. It is-responsible-for the overall management-of bridges through -5= regional offices and 32 division offices. In last decade, the number of bridge design and construction works has rapidly increased. With this increase in numbers of bridge designs, the design changes cases are also increasing. The study area covers the bridges having design change under Bridge Branch from different regional offices and Division Road Offices (DRO). Also, the Consultants and Contractors involved with bridge design and construction of bridges under DoR were involved in this research.

5.2 Sample Size and Selection

For the questionnaire survey, the sample size of 65 respondents was estimated comprising of 25 clients (DoR engineers at different posts from officer), 20 engineers of consulting firms and 20 representatives from contractors as shown in table below. For the case study, total 30 numbers of bridge designs (as recorded) from above available designs; have been reviewed. Among these cases, 5 case studies were selected to represent different development region and terrain.

Table 1: Sample size

Category of Respondents	Sample selection
Clients (Government employees)	25
Consultant	20
Contractors	20

Total	65

The samples were selected by two procedures due to the nature of the respondents to be involved in the study. List of consultants was obtained from bridge branch, DoR and Purposive sampling was used to select the consultants who are involved in bridge design. Twenty firms from a list of local registered consulting firms located in Kathmandu were selected. Clients and contractors were also selected using purposive sampling. Hence, twenty respondents each from clients and contractors were purposively selected. As mentioned above, for case study, five samples were selected purposively to represent different development region and terrain.

5.3 Collection of Data:

5.3.1 Primary data:

The data were collected through questionnaire survey, meetings and discussion with experts and stake holders. A set of questionnaires for three stakeholders was designed first and then pre-tested by consulting and distributing to two experts involved with design and approval of the bridge projects. Then the questionnaire was finalized so that the questions and ranking system choices were supposed to be unbiased.

5.3.2. Secondary data:

The secondary data collection was done through Literature review from previous researches from relevant text books regarding variation orders, design change, publications of DoR. related Acts and Regulations, published and unpublished literature, reports and journals. Online search for various journals by using various websites such as sciencedirect.com, sci-hub.org, sci-hubio, sci-hub.cc to read journal articles etc. were done. Also, the case studies of approved bridge design reviewed projects under DoR were done for data collection.

5.4 Analysis of Data:

The qualitative data collected from the secondary sources was compiled, analyzed and presented to develop the logical sequence. The quantitative data collected from primary sources ie. Questionnaire survey and discussions with the experts and stakeholders was also compiled, analyzed and represented with statistical tools. The interpretation and analyzed data are presented in table, figures, percentage by using Importance Index calculation, graphical tools as pie charts, bar charts, etc as required.

Analysis of Responses of Questionnaire

A structured questionnaire consisting of four sections was prepared on Likert's scale as 1= Never, 2= Seldom, 3= Sometimes, 4= Often and = Always. the Importance Index was calculated using the equation as follows:

$$\text{Importance Index (II)} = \frac{\text{Weighted Average} \times 100}{\text{Highest Weight}}$$

Weighted Average =

Where, Wi weight is assigned to the ith option of cause,

Xi=is the number-of respondents who selected the ith option and

N is the total number of respondents.

To better understand the Importance Index percentage is calculated as follows:

$$\text{Importance Index} = \frac{4(x1) + 3(x2) + 2(x3) + 1(x4)}{x1 + x2 + x3 + x4} \times \frac{100}{y}$$

Where, y is the highest weight,

Out of 65 questionnaires distributed, 46 (71%) questionnaires were received. There were 19 (41%) out of 25 questionnaires from clients (DoR engineers at-different post), 14 (31%) from consultants and 13 (28%) from contracts involved in bridge design and construction under DoR bridge projects. The education level of the respondents is given in table 2.

Table 2: Education level

Education Degree	Clients	Consultants	Contractors
Doctor	1	0	0
Masters	10	6	2
Bachelor	8	7	9
10 + 2	0	0	0

Others	0	1	1
Total	19	14	12

6. RESULTS AND DISCUSSION :

6.1 Case Study:

The purpose of the case studies is to identify the types of design change, its real causes, effects and impacts on bridge project and validate the results concluded from the quantitative method (i.e., questionnaire). The case study and analysis were carried out on five designs changed, officially approved by the client and either on implementation or near to completion projects as summarized.

Table 3: Results of Case Study

Description	1. Koshi bridge, Chatara	2. Bagmati bridge, Kathmandu	3. Bagmati bridge, B.P Museum Sundarijal road	4. Gachhe khola bridge, Sandhikharka	5. Bheri bridge, Surkhet
Brief Information	Steel truss type, L =261.3m, 4 span -and 2 types-of foundation open and pile	RCC slab type, L=40m with two span, well foundation	RCC slab type, L=20m single span, well foundation	RCC T- beam, 2 span with 24m each, open foundation	4 span bridge, each span of 45m, well type foundations
Problem	3 foundations completed, 2 had problem	Sinking of well foundation couldn't be done	Sinking of well foundation couldn't be done	Foundation depth insufficient to reach the firm strata	Well foundation couldn't be done
Solution	Micro-piling technique used for foundation	Design revised with pile foundation and work completed	Design revised with pile foundation and work completed	Foundation depth increased, substructure height also increased	Micro-piling technique used for foundation
Causes	Unforeseen or Difficult site conditions	Lack of soil investigation _	Improper soil investigation	Improper soil investigation and design	Improper soil investigation/ Inappropriate design
Effects	Cost reduction & Time overrun	Time & Cost overrun	Time & Cost overrun	Cost overrun	Time & Cost overrun
Remarks	ADB project and International Consultant or design and supervision	Initially design was approved with condition of "confirmatory drilling"	Initially design was approved with condition of "confirmatory drilling"		work completed after 10 years

The causes and effects of these cases are identified and presented in table 4 below. The major causes for design changes are Non-compliant design with site requirement, Errors in design, Differing site conditions. The major effects due to design change are Time overrun and Cost overrun.

Table 4: Causes, Effects and Impacts identified from Case Study

S. N.	Name of the bridge project, location	Causes	Effects	Impacts	Origin of Cause
1	Koshi bridge, Chatara	Unforeseen and differing site conditions	Time overrun	Light	Unforeseen
2	Bagmati bridge, Bouddha-Tamaaancra road	Lack of soil investigation	Time & Cost overrun	Major	Client/ Consultant

3	Bagmati bridge, B.P Museum Sundarijal road	Non-compliant design with site requirement	Time & Cost overrun	Major	Client/ Consultant
	Gachchhekhola bridge, Sandhikharka	Error in design	Cost overrun	Light	Consultant
5	Bheri Bridge at border of and Salyan Surkhet	Non-compliant design with site requirement/Error in design	Time overrun	Major	Consultant

6.2 Perception regarding importance of SbD:

The Importance Index of each cause, effects respectively were calculated. The data collected from different stakeholders were analyzed separately and also combined causes and effects were analyzed and compared

6.2.1 Current state of bridge design change

The table 5 below shows the frequency and ranking of the types of activities encountered during the redesign in bridge projects. Redesign for change in types of bridge is ranked V' by both consultant and contractors while clients ranking list is for Redesign for change in scope and location.

Table 5: Ranking of Instructions Encountered

S. N.	Activities	By	By	By
1	Redesign for change in quality	5	3	5
2	Redesign for increase in quantity	2	5	3
3	Redesign for decrease in quantity	4	4	4
4	Redesign for change in types of bridge	3	1	1
5	Redesign for change in scope &location	1	2	2

The three major stakeholders involved in questionnaire survey agree that the design change and variations are done for the purely technical reasons. Although few agree that design changes are also done for the vested interest of other stakeholders (local demands, political, etc.) and for the reason of the force majeure (Acts of God).

Table 6: Origin Agent

S. N.	Origin Agent	By Clients	By Consultants	By Contractors
1	Contractor	4	1	3
2	Consultant	1	2	1
3	Client	3	3	2
4	Others	2	4	4

The table 6 below shows the ranking done by three types of respondents. Clients and Contractors have ranked Consultant as first for origin of bridge design change but Consultants on other hand have ranked Contractor first as origin agent.

Table 7: Ranking of Origin Agent of Design change

S.N.	Origin Agent	By Clients	By Consultant	By Contractors
1	Contractor	4	1	3
2	Consultant	1	2	1
3	Client	3	3	2
4	Others	2	4	4

Also, respondents were asked about the reason for their choice of ranking these stakeholders but only few have replied. Clients and Contractors explanation regarding ranking the Consultant are such as:

- Fault in design by consultant who overlooked design procedures, site specific requirement, no detail soil investigation, inappropriate hydrological analysis
- Lack of competence of original design

Due to time gap between design and implementation, the river regime changes etc.
Although not many explanations were given by Consultants and Contractors but few explanations by consultants regarding ranking, the Contractor and Client are such as:
- Contractor holding the implementation project for long time brings changes in site conditions making the approved design inappropriate due to natural changes at site.
- Client doesn't get satisfied with the design and cost estimate

6.2.2 Causes of Design Change

Table 8: List of Causes of Design Change

1	Causes of Design Change, Change of plans or scope
2	Replacement of materials or procedures
3	Errors in design
4	Inadequate working details
5	Technology change
6	Lack of experience
7.	Lack of knowledge of available materials & equipment
8	Lack of required data
9	Non- compliant design with site requirement
10	Differing site conditions
11	Unfamiliarity or Unawareness of local condition
12	Lack of Communication
13	Weather Conditions
14	Health and safety Consideration Socio- cultural factors
16	Political Interference
17	Unforeseen Problems

Analyzing the ranking of most frequent origin agent corresponding to each cause, the frequent causes ranked is summarized in following table 9:

Table 9: Frequent Origin Agent corresponding to causes

	Origin Agent Corresponding to Causes			
S.N.	**Client**	**Consultant**	**Contractor**	**Others**
1	Change of plans or scope	Errors in design	Lack knowledge of available materials & equipment	Unforeseen Problems
2	Lack of Communication	Lack of required data	Health and safety Consideration	Socio- cultural factors
3	Political Interference	Non- compliant design with site requirement	Replacement of materials or procedures	Political Interference
4	Replacement of materials or procedures	Technology change	Technology change	Weather Conditions
5		Differing site conditions	Differing site conditions	
6		Inadequate working details	_	

The respondents were requested to rank the 17 causes by using 5-point scale viz Never, Seldom, Sometimes, Often and Always. The data were analyzed calculating the Importance Indices as mentioned earlier for three respondents separately and overall, as well.
Now, the common causes of design changes in bridge projects from clients, contractors and consultant point of view with respective importance score is shown in table 10.

Table 10: Causes of design changes in bridge projects from clients, contractors and consultant point of view

S.N.	**Causes**	**Client**	**Consultant**	**Contactor**

1.	Errors in design	71	66	73
2.	Differing site conditions	63	58	58
3.	Non-compliant design with site requirement	61	62	66
4.	Unfamiliarity or Unawareness of local condition	61	55	52
5.	Inadequate working details.	59	49	78
6.	Lack of Experience	59	49	66
7.	Lack of Knowledge of Available materials	57	52	64
8.	Unforeseen Problems	56	50	58
9.	Political interference	56	53	64
10.	Lack of Required Data	55	50	75
11.	Socio-Cultural Factor	49	42	62
12	Health and Safety Consideration	40	48	55
13	Weather Condition	40	45	56
14	Lack of Communication	45	47	64
15	Technology Change	45	57	54
16	Replacement of materials or procedures	44	51	53
17	Change of plans and Scope	53	48	49

The ranking of the causes calculated by Clients, Consultants and Contractors separately and in overall is shown in table 10 and 11. Top ten ranked causes listed by Clients, Consultants and Contractors are similar but the ranking of these causes by the Contractors are different in ranks compared to others as discussed above. The table 11 below shows the ranking by Clients, Consultants and Contractors separately and the overall as well. Among top ten causes, all three respondents agree with the common three causes viz: Errors in design 1st, non-compliant design with site requirement (3rd) and Lack of required data (4th). "Inadequate working details" cause ranked as second in overall is not ranked by consultants in top ten causes. Similarly, "Differing site conditions" ranked as fifth cause is also not ranked in top ten causes of Contractors. Similarly, there is difference in the ranking of the 6th and 9th causes from the overall ranking.

Table 11: Ranking of Causes

S. N.	Causes of Design Review	By Clients	By Consultants	Contractors	Overall
1	Change of plans or scope	11	14	17	14
2	Replacement of materials or procedures	15	8	15	15
3	Errors in design	1	1	3	1
4	Inadequate working details	5	12	1	2
6	Lack of experience	6	11	4	6
7	Lack of knowledge of available materials &equipment's	7	7	7	8
8	Lack of required data	10	9	2	4
9	Non- compliant design with site requirement	3	2	9	3
10	Differing site conditions	2	3	11	5
11	Unfamiliarity or Unawareness of local condition	3	5	16	9
12	Lack of Communication	13	15	6	12
13	Weather Conditions	16	16	12	17
14	Health and safety Consideration	16	13	13	16
15	Socio- cultural factors	12	17	8	13
16	Political Interference	9	6	5	7
17	Unforeseen Problems	8	9	10	10

6.2.3 Effects and Impacts of Design Change

The design change and variation orders have been an inherent part of the bridge projects, it normally arises as a result of causes as listed above. And the design change has been resulting in cost overrun or time overrun and other complexities. Thus, design change cannot be completely ignored, so the respondents were asked about the nature of design changes done in past. They were asked to choose that the design changes done were for benefit of project or detriment of project. The responses are as follows:

Table 12: Ranking of Nature of design changes

S.N.	Nature of Design changes	By clients	By consultants	By Contractors	Overall Ranking
a	Beneficial design change	77	62	73	1
b.	Detrimental Design Change	48	58	44	2

The respondents were requested to rank the 8 different effects and intensity of impacts identified as listed below.

The table 13 below shows the ranking of the effects by the Clients, Consultants, and Contractors separately and in overall as well. As discussed earlier, the top five effects ranking by Clients and Consultants are same whereas Contractor's ranking is somehow different when compared to each other. The Client and Consultants have ranked "Time overrun" as first effect but Contractors have ranked "Cost overrun" as first effect. Then second, third and fourth effects ranking are same whereas the fifth and sixth effects are ranked differently by Contractors.

Table 13: Ranking of Impacts

S. N.	Outcome	By Clients	By Consultants	By Contractors	Overall
1	Time overrun	1	2	1	I
2	Time reduction	8	8	6	8
3	Cost overrun	2	1	2	2
4	Additional specialist/ equipment/ personnel	4	3	3	3
5	Optimum cost reduction	7	6	8	7
6	Additional health and safety equipment/measure	6	4	5	5
7	Degradation of quality standards	5	6	6	6
8	Enhancement of quality standards	3	4	4	4

6.3 Legal Provision regarding Design change and Variation Order:

There is a provision in revised Procurement Act that the design change should not change contract price more than 25%, else the concerned person will be penalized. The respondents were asked to rank this provision towards successful delivery of the project in the scale of Excellent, Good, No effect, May be Detrimental and Very much Detrimental.

As seen in table 14, the ranking by clients and contractors is of mixed type where clients have ranked both Good and Excellent and contractors have ranked Good and No Effect while most of the consultants have ranked this provision as Good.

Table 14: Importance Index of Legal Provision

Provisions Ranking	By Clients	By Consultants	By Contractors
Excellent	31	8	18
Good	44	75	36
No effect	6	0	45
May be detrimental	19	17	0
Very much detrimental	0	0	0

6.4 Comments and Suggestions from Respondents

The discussions were made with the expertise and respondents were also requested to make some comments on the questionnaire forms and put their opinions for further improvement and decreasing the frequency of bridge design changes. Not many comments were received from consultants and contractors but the most important ones are listed below:

By Clients

1. The bridge design but it should be done and made cost and time effective and should introduce bring new technology.
2. Due to unforeseen conditions, design changes can't be eliminated but can be decreased with detail survey and soil investigation works before contract award.
3. The basic design related data should be collected and analyzed for the best design practice. The ignorance by consultants during survey and design should be minimized.
4. Required time during survey and design, appropriate payment to designing consultants should be made, lower bidding system should be minimized and design audit system should be made mandatory before design approval.

By Consultants

1. Feasibility study should be done in proper way with frequent visit with the team of bridge expert, geo-tech engineer, structural engineer, hydrologist as per requirement.
2. Clients should provide proper guidelines, materials, norms & codes for bridge design to consultants.
3. The client should properly supervise during design phase and construction phase and control the quality standard by frequent testing of construction works as per requirement.

By Contractors

I. Bridge projects should be handover to the contractor for full liability at the site investigation and design works (like design and build contract system).
2. Employer should panelize the designer –for fault design and faulty soil investigation. design change and approval should not be delayed.
3. The design of bridge projects should be made to be easy to construct, economic, fast and must meet the criteria according to site condition for the better performance and quality of the project.

7. CONCLUSION :

The causes of bridge design changes, and their effects on projects in terms of cost and time schedule is found to be complex and are influenced by numerous interrelated factors. The risk and uncertainties associated with project changes made predictions and planning for changes a difficult task.

The design change is found to be done mostly in the foundation of the bridges. Sometime the redesign is done for change in scope and location of the bridge due mostly due to social and political interference and interest rather than value engineering. Though, most of the respondents reported that the bridge design changes are done for the purely technical reasons.

The results showed that the Consultant is the main origin agent for design changes of bridge projects as they are the most responsible for the detail survey, soil investigation and design and estimate of the bridge. The lack of required data, change of plans or scope by Clients concludes that the clients are second origin agent for design change.

The combined study of results from Case study and Questionnaire survey shows that Non complaint design with site requirement and Errors in design are another main cause for the design change in bridge projects. Unforeseen problems and Differing site conditions are also the major causes for design change. The unpredictable geotechnical condition and changing morphology of the river results in the unexpected and unforeseen problems during bridge project construction works.

Inadequate working details and Lack of required data for bridge design is also important cause for design change and review. Similarly, the following causes ranked low but might be important causes are Lack of Experience, Political Interference, Lack of Knowledge of available materials and equipment's, Unfamiliarity or Unawareness of local condition.

Time overrun and Cost overrun are the two main effects being noted for the design change in bridge projects. The case study and survey results show that there is increase in project cost and duration in most of the projects having design change and review. The requirement of additional specialist/equipment/personnel and Enhancement of quality standards due to bridge design change are other less important effects.The legal provision limiting variation order by Department chief at 15% is helpful for design review condition but sometime, it constraints the site requirement.

8. RECOMMENDATION :

Bridge design reviews are affecting the bridge projects especially in the construction phase of project. The solution to avoid the cost and time overrun is to address the causes related to the bridge design reviews during design phase itself.

It is recommended that the problems related to consultants should be addressed focusing strictly on the detail soil investigation, proper design practice as per individual site requirements and design audit by a team of experts, in house as well as external.

During design, concurrent engineering should be adopted in core and extended team internal or outsourced expert to reduce over the wall syndrome to design for construction.

It is also recommended that the clients give required time for supervision of each bridge design from surveying to finalizing the design.

9. LIMITATIONS OF STUDY :

The bridges have been constructed by different projects and Bridge branch under DoR. But the study is limited to the bridges whose changes have been done under Bridge Branch, DoR only. This is the initial stage of study, so it was not be possible to study all the problems of all types of bridges of different designers and Consultant/Firms. So, the study mainly focused on the issues related to the design changes of the few bridge projects. Any design changes done in Value Engineering as a part of contract system has not been included in this study.

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