Application of Safety by Design for the Hazards Identified at the site of Burtibang Paudi-Amarai Tamghas Sandhikharka Gorusinghe 132 kV Transmission Line Project, Nepal

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ABSTRACT

Purpose: *Construction of Transmission lines is complicated and hazardous as they are mostly located in difficult hilly terrain. The study is aimed to identify the hazards during the construction and determine how the approach of Safety by Design can be used to eliminate/control such hazards in the project under implementation at the site of Burtibang Paudi-Amarai Tamghas Sandhikharka Gorusinghe 132 kV Transmission Line Project, Nepal.*
Design/Methodology/Approach: *The Safety by design guidelines, regulations, and manual were consistently referred and Observation with Checklist, KII (Key Informant Interview), Likert scale- based Questionnaire survey were conducted to apply safety by design followed by Chi-square test, Kendall rank correlation coefficient analysis. Cronbach's alpha assures reliability and literature comparison assures validity.*
Findings/Result: *Erection, Stringing & Excavation were found as most risky activities followed by Lifting & transportation and Concreting. These activities constituted of various hazards. Mechanical hazard was found to be the most prevailing hazard of all followed by Physical, Physiological, Psychological, Biological and Chemical hazard. Working location (top of tower), Slippery surface & Hand tools were the major mechanical hazards whereas Heat & humidity was the major physical hazards. Also Working posture/Bad ergonomics and Carrying overload were the major physiological hazards whereas working pressure/deadlines/target, Wages & leave and food & accommodation were the major psychological hazard. Similarly Mosquito & Snake bites were found to be the major biological hazards whereas Silica, Sand & Cement dust were the chemical hazards in the site. Despite most of the Clients and Contractors have responded that they have heard about SbD, it was found that SbD was not implemented in the site. Most of these hazards can be prevented by adopting the SbD approach in early design phase.*
Originality/Value: *It is action research. This study helps to identify the possible hazards in transmission line construction and use the concept of SbD approach to eliminate or control (if not possible) those hazards.*
Paper Type: *Ex-Post Facto Research*
Keywords: Activities, Hazards, Identification, Analysis, SbD approach

1. INTRODUCTION :

Construction is one of the industries with a high hazard and includes several activities such as planning, designing, constructing, maintaining and repairing of the structures. These activities basically comprises civil engineering works, mechanical and electrical engineering and other similar works [1]. Construction of Transmission lines are complex in nature as it covers civil, electrical and mechanical works. Also most of the hydropower are located at hilly area, so evacuation of powers requires construction of towers at difficult hilly terrain. So the overall process of construction from excavation for tower foundation to stringing of conductors till final testing becomes risky in nature until and unless the construction hazards are mitigated completely or reduced if not possible using the concept of safety by design.

Construction site safety has become more of a concern of the employers in the modern days. The concern for safety has increased in the last two decades, primarily because of higher injuries and fatalities rates in the construction industry in compare to other industries, financial burden due to workers' compensation and loss of productivity, increase in number of liability suits, the intensification of safety regulations, and compulsion made by owners to address worker injuries. Due to these reasons, the rate of fatalities and disabling injuries has decreased to some extent. However the construction industry still continues to lag behind all other industries, except for agriculture and mining, with regard to safety [2].

2. PROBLEM STATEMENT :

Safety of a construction site can be improved by addressing the safety issues early in the design process. Hazards can be eliminated or reduced during construction by properly identifying, assessing and designing the risk control methods in the design phase. In transmission line construction, it is common to see a construction worker working at greater depths as tower foundations are deep in nature as well as at greater heights with equipment, tower and tower parts for tower erection and conductor stringing. Such scenarios create dangerous situations and workers continue to work in poor working conditions leading to increased chances of workplace accidents. It becomes necessary to plan and implement the safety measures in early design phase in order to mitigate or control (if not possible) the hazards related to them. Thus it becomes necessary to assess if safety by design can be applied during the construction of transmission line project.

3. OBJECTIVES :

The overall objective of this research is to identify the hazards during the construction and determine how the approach of Safety by Design can be used to eliminate/control such hazards in the project under implementation.

4. LITERATURE REVIEW :

If designers incorporate the construction safety early in design phase safety hazards can be eliminated or minimized and thus construction accidents and injuries can be reduced. Research shows that the early decisions regarding safety made in the design phase contributes to effective management of the hazards [3].

Table 1: Literature Review

S. N.	Title of paper	Country	Characteristics and focused area	Published on /By	Year of Publication
1	"Safety in Design"	Australia	Identifies design as having the potential to reduce the risk of accidents in construction	Helen Lingard Payam Pirzadeh James Harley Nick Blismas Ron Wakefield	2014 [4]
2	"Structural Steel Design, Instructor's Manual"	USA	Introduction to Prevention through Design with examples of Ptd	NIOSH	2013 [5]
3	"Architecture Design and Construction, Instructor's Manual"	USA	Introduction to Prevention through Design with examples of Ptd	NIOSH	2013 [6]
4	"Mechanical-Electrical Systems, Instructor's Manual"	USA	Introduction to Prevention through	NIOSH	2013 [7]

			Design with examples of Ptd		
5	"Reinforced Concrete Design, Instructor's Manual"	USA	Introduction to Prevention through Design with examples of Ptd	NIOSH	2013 [8]
6	"Addressing construction worker safety in the design phase Designing for construction worker safety"	USA	Accumulation of suggestions for improving construction worker safety while in the design phase	John A. Gambatese Jimmie W. Hinze	1999 [3]
7	"Safe design of structures, Code of Practice"	Australia	An approved code of practice to achieve the standards of health, safety & welfare required under WHS Act & Regulations.	Safe Work Australia	2012 [9]
8	"Safety In Design In Construction: An Introduction"	New Zealand	Helps in understanding the basics of safety in design, so that anyone's health and safety is not at risk.	Site Safe New Zealand	2019 [10]

5. RESEARCH GAP :

Safety by Design is quite familiar and practiced in construction industry in European countries, US and Australia. However in Nepal the concept is relatively new and not used in construction industry or any other industry. The designers should be made familiar to the concept of safety by design and encouraged to use the SbD in the design phase. In this research, SbD approach for civil, mechanical and electrical works related transmission line construction are listed. Same can be done for other construction works related to different engineering fields.

6. RESEARCH METHODOLOGY :

6.1 Study Area

BPTSG Project starts from Motipur, Kapilvastu to Burtibang, Baglung in two different sections namely Motipur-Sandhikharka section and Sandhikharka-Burtibang Sections. The length of Motipur-Sandhikharka Sections was around 38 Km and Sandhikharka-Burtibang was around 47.5 Km in length. BPTSG also included five substations located at Motipur (Kapilvastu), Sandhikharka (Arghakhanchi), Tamghas (Gulmi), Paudi-Amarai (Gulmi) and Burtibang (Baglung) for the collection and evacuations of electric power generated within the Uttarganga River and other different Hydropower project located nearby to the National Grid. BPTSG passes through four different districts namely Kapilvastu, Arghakhanchi, Tamghas and Baglung District.

Fig. 1: Study Area

6.2 Primary Data:
Primary data was collected through observation checklist, questionnaire surveys and Key Informant Interview (KII).
Observation Checklist: To identify the different occupational hazards, observation checklist as well as questionnaire was used.
Key Informant Interview: The Key informant interviews (KII) of the transmission line experts was taken to determine how safety by design approach can be used for preventing transmission line hazards. The KII was based on the snowball sampling.
Questionnaire Survey: Different set of questions was prepared to identify the hazards in transmission line construction at the site of BPTSG 132 kV TLP. The questionnaires was distributed to the Clients, Contractors and Workers for questionnaire Survey. The questionnaires was distributed by visiting them in person.

6.3 Secondary Data:
Secondary data was collected from the literature study of national and international articles, published journals, reports, manuals and internet/websites about the ways to incorporate concept of safety by design concept of safety by design for preventing hazards during transmission line construction.

6.4 Analysis of Data:
Computer software such as MS Excels and SPSS software package was used for the derivations of the data and the logically interpreted outcomes was presented in tables. MS Excel was used to calculate sample size, Reliability Test, Chi-square Test and Kendall rank correlation coefficient. Similarly SPSS was used to calculate Reliability Test, Descriptive Statistics and Ranking of factors/hazards.

7. RESULTS AND DISCUSSION :

Overall, from the questionnaire administration, 51 responses were received. The 51 respondents include 5 technical persons from Clients, 4 from Contractors and 42 Workers working in the project.

7.1 Familiarity with controls for hazards:
Clients and Contractors were asked to give their opinion regarding the familiarity with corresponding controls for different hazard. It was found that about 33.33% of respondents from Clients and 26.39% from Contractors are unfamiliar with control of hazards while 37.78% respondents from Clients and 51.39% from Contractors are familiar with control of hazards. The remaining 28.89% respondents from Clients and 22.23% from Contractors were neutral regarding the familiarity with control of hazards. The results shows that more than one-third of Clients and half of the Contractors were familiar with the control of the hazards.

7.2 Chi-Square (χ^2) Test on Familiarity with Hazard Control:
Chi-square test was performed to test if the responses from the Clients and contractors were dependent on each other or not. The Null Hypothesis (H_o) is "There is no relationship between the responses from Clients and Contractors, i.e., responses from the Clients and Contractors are independent" and Alternative Hypothesis (H_1) is "There is relationship between the responses from Clients and Contractors i.e. responses from the Clients and Contractors are dependent to each other". Here ($\chi^2{}_{cal}$

=2.58) < (χ^2_{tab}=11.07), so Null hypothesis (H_o) was accepted which means there is no relationship between the response of the Clients and Contractors.

7.3 Ranking the Values Based on Mean:

The respondents were asked to rank the hazards and activities causing hazards with 1 indicating the most prevailing hazards. Since the lowest number is used to rank the most prevailing hazards, the hazards with least mean value shall be the most prevailing hazards. The ranking by different respondents group was evaluated in individual and was also verified by using Kendall's coefficient of concordance. Kendall's coefficient of concordance was performed for the analysis of ranking data. It is used to determine the degree of association among several (k) sets of ranking by N individuals [11]. We have $\bar{R}j = \frac{\sum Rj}{N}$ and $W = \frac{s}{\frac{k^2(N^3-N)}{12}}$.

Table 2: Critical values of s at 5 % level of Significance

k	N					Some additional values for N = 3	
	3	4	5	6	7	k	s
3			64.4	103.9	157.3	9	54.0
4		49.5	88.4	143.3	217.0	12	71.9
5		62.6	112.3	182.4	276.2	14	83.8

Kendall's coefficient of concordance has been conducted for following questions i.e. Rank the activities causing hazards, Rank the overall hazards and Rank the each type of hazards in isolation.

A. Activities involving hazards

Before discussing the possible hazards in transmission line, the activities that could cause hazards were considered. Basically there are five major activities in transmission line as listed in the Table 3 below. The respondents were asked to rank these activities with 1 indicating the most hazardous activities.

Table 3: Ranking of Activities Causing the Hazard

Activities	Clients			Contractors			Workers		
	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank
Excavation	40%	2.4	**2**	0%	4.0	**5**	11.9%	3.07	**4**
Concreting	0%	4.6	**5**	25%	3.5	**4**	14.3%	3.12	**5**
Lifting and transportation	0%	4.0	**4**	25%	2.5	**2**	23.8%	2.81	**1**
Erection	60%	1.6	**1**	25%	2.75	**3**	26.2%	3.0	**2**
Stringing	0%	2.4	**3**	25%	2.25	**1**	23.8%	3.0	**3**

From the above table, it was found that Clients have responded Erection as the riskiest activity followed by Excavation, Stringing, Lifting & loading and Concreting. Also the Contractors have responded that Stringing as the most risky activity followed by Lifting & loading, Erection, Concreting and Excavation. Similarly Workers have responded that Lifting & loading as the most risky activity followed by Erection, Stringing, Excavation and Concreting. Also, from the observation checklist and KII, it was found that Erection was the riskiest activity followed by stringing, excavation, lifting and transportation and concreting. Kendall's coefficient of concordance was performed for determining the degree of association among the sets of ranking done by different respondents groups.

Table 4: Matrix for Hazardous Activities

k = 3	Ranking of Hazardous Activities					
Respondents	Excavation	Concreting	Lifting & Transportation	Erection	Stringing	N = 5

Clients	2	5	4	1	3	
Contractors	5	4	2	3	1	
Workers	4	5	1	2	3	
Sum of Ranks (R_j)	11	14	7	6	7	Σ Rj = 45
$(R_j - \bar{R}j)^2$	4	25	4	9	4	s = 46

The value of W calculated is 0.51. To judge the significance of this W, value of s was determined from the Table 2 at 5% level for k = 3 and N = 5. This value was 64.4 and thus for accepting the null hypothesis (H_0) that k sets of rankings are independent the calculated value of s should be less than 64.4. Here the worked out value of s is 46 which is lower than the tabulated value which shows that W = 0.51 is not significant. Hence, the null hypothesis was accepted and it was concluded that the different groups of respondents were applying different standard in ranking the N factors i.e., there was not significant agreement in ranking by different groups of respondents at 5% level in the given case. The lowest value observed amongst R_j was 6 for erection and as such erection was considered as the most hazardous activities followed by lifting and transportation, stringing, excavation and concreting based on value of R_j.

B. Ranking of Overall Hazards

The ranking of hazard by different groups of respondents are given in the Table 5 below.

Table 5: Ranking of Hazards

Hazard Types	Clients			Contractors			Workers		
	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank
Physical	40%	3.4	**3**	100%	1.0	**1**	9.5%	3.24	**3**
Biological	0%	5.2	**5**	0%	4.0	**3**	28.6%	2.69	**1**
Chemical	0%	4	**4**	0%	5.5	**4**	16.7%	3.21	**2**
Psychological	0%	2.8	**2**	0%	4.0	**3**	14.3%	3.36	**4**
Mechanical	60%	2.8	**1**	0%	2.5	**2**	14.3%	3.98	**5**
Physiological	0%	2.8	**2**	0%	4.0	**3**	14.3%	4.62	**6**

As per Table 5 above it was found that Clients have selected Mechanical hazard as the most important hazard followed by Physiological hazard, Psychological hazard, Physical hazard, Chemical hazard and Biological hazard. Also Contractors have selected Physical hazard as the most important hazard followed by Mechanical hazard, Physiological hazard, Psychological hazard, Biological hazard and Chemical hazard. Similarly Workers have selected Biological hazard as the most important hazard followed by Chemical hazard, Physical hazard, Psychological hazard, Mechanical hazard and Physiological hazard. However, through the observation checklist and KII it was found that Mechanical hazard was the most important hazard followed by Physical hazard, Physiological hazard, psychological hazard, biological hazard and Chemical hazard.

Kendall's coefficient of concordance was performed for determining the degree of association among the sets of ranking done by different respondents' groups.

Table 6: Matrix for Ranking of Hazards

k = 3	Ranking Hazards						
Respondents	Physical	Biological	Chemical	Psychological	Mechanical	Physiological	N = 6
Clients	3	5	4	2	1	2	-
Contractors	1	3	4	3	2	3	-
Workers	3	1	2	4	5	6	-

Sum of Ranks (R_j)	7	9	10	9	8	11	$\Sigma R_j = 54$
$(R_j - \bar{R}j)^2$	4.00	0.00	1.00	0.00	1.00	4.00	s = 10

The value of W calculated is 0.06. To judge the significance of this W, value of s was determined from the Table 2 at 5% level for k = 3 and N = 6. This value was 103.9 and thus for accepting the null hypothesis (H_0) that k sets of rankings are independent the calculated value of s should be less than 103.9. Here the worked out value of s is 10 which is much lower than the tabulated value which shows that W = 0.06 is not significant. Hence, the null hypothesis was accepted and it was concluded that the different groups of respondents have different opinions in ranking the N factors i.e., there was not significant agreement in ranking by different groups of respondents at 5% level in the given case. The lowest value observed amongst R_j was 7 for Physical hazard and as such Physical hazard was considered as the most prevailing hazard followed by Mechanical, Psychological & Biological, Chemical and Physiological.

C. Ranking of Mechanical Hazards:

As per Table 7 below, among the Mechanical hazards, Clients have selected Working locations as the most important Mechanical hazard followed by Hand tools, slippery surface, Rock mass falling, Struck by machines and Rock sliding. Also Contractors have selected Rock sliding as the most important Mechanical hazard followed by Working locations, Slippery surface, Rock mass falling, Hand tools and Struck by machines. Similarly Workers have selected Rock mass falling as the most important Mechanical hazard followed by Struck by machines, Rock sliding, Working locations, Hand tools and Slippery surface. From the observation checklist and KII, it was found that Working locations was the most important Mechanical hazard followed by Slippery surface, Hand tools, Rock sliding, Rock mass falling and Struck by machines.

The ranking of Mechanical hazard by different groups of respondents are given in the Table 7 below.

Table 7: Ranking of Mechanical Hazard

Hazard Types	Clients			Contractors			Workers		
	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank
Slippery surface	40%	3.0	**3**	0%	4.0	**3**	7.1%	3.76	**6**
Rock mass falling	0%	3.8	**4**	0%	4.25	**4**	16.7%	3.0	**1**
Rock sliding	0%	5.2	**5**	75%	1.75	**1**	11.9%	3.48	**3**
Struck by machines	0%	3.8	**4**	0%	4.5	**5**	19%	3.4	**2**
Working locations i.e. top of tower	40%	2.4	**1**	25%	2.25	**2**	23.8%	3.6	**4**
Hand tools	0%	2.8	**2**	0%	4.25	**4**	21.4%	3.76	**5**

Kendall's coefficient of concordance was performed for determining the degree of association among the sets of ranking done by different respondents groups.

Table 8: Matrix for Mechanical Hazard

k = 3	Ranking Mechanical Hazards						
Respondents	Slippery surface	Rock mass falling	Rock sliding	Struck by machines	Working locations	Hand tools	N = 6
Clients	3	4	5	4	1	2	
Contractors	3	4	1	5	2	1	
Workers	6	1	3	2	4	5	

Sum of Ranks (R_j)	12	9	9	11	7	8	Σ Rj = 56
$(R_j - \bar{R}j)^2$	7.11	0.11	0.11	2.78	5.44	1.78	s = 17.33

The value of W calculated is 0.11. To judge the significance of this W, value of s was determined from the Table 2 at 5% level for k = 3 and N = 6. This value was 103.9 and thus for accepting the null hypothesis (H_0) that k sets of rankings are independent the calculated value of s should be less than 103.9. Here the worked out value of s is 17.33 which is lower than the tabulated value which shows that W = 0.11 is not significant. Hence, the null hypothesis was accepted and it was concluded that the different groups of respondents were applying different standard in ranking the N factors i.e., there was not significant agreement in ranking by different groups of respondents at 5% level in the given case. The lowest value observed amongst R_j was 7 for Working locations i.e. top of tower and as such it was considered as the major Mechanical hazard followed by Hand tools, Rock mass falling & Rock sliding, Struck by machines and Slippery surface.

D. Ranking of Physical hazards:

The ranking of physical hazards by different groups of respondents are given in the Table 9 below.

Table 9: Ranking of Physical Hazard

Hazard Types	Clients			Contractors			Workers		
	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank
Electric Shock	40%	2	**1**	25%	3.25	**3**	11.9%	3.88	**6**
Lighting	0%	4.4	**5**	0%	2.50	**2**	21.4%	2.98	**1**
Vibrations	20%	3.2	**3**	0%	4.50	**5**	9.5%	3.64	**5**
Noise	20%	2.8	**2**	0%	4.50	**5**	14.3%	3.31	**2**
Heat and Humidity	20%	3.4	**4**	50%	2.50	**1**	23.8%	3.64	**4**
Radiation	0%	5.2	**6**	25%	3.75	**4**	19%	3.55	**3**

From Table 9 above, among the Physical hazards, Clients have selected Electric shock as the most common Physical hazard followed by Noise, Vibrations, Heat and humidity, Lighting and Radiation. Also Contractors have selected Heat and humidity as the major Physical hazard followed by Lighting, Electric shock, Radiation and Noise, Vibrations. Similarly Workers have selected Lighting as the most prevalent Physical hazard followed by Noise, Radiation, Heat and humidity, Vibrations and Electric shock. From the observation checklist and KII it was found that Heat and humidity was the most important Physical hazard followed by Electric shock, Lighting, Noise, Vibrations and Radiation.

Kendall's coefficient of concordance was performed for determining the degree of association among the sets of ranking done by different respondents groups.

Table 10: Matrix for Physical Hazards

k = 3	Ranking Physical Hazards						
Respondents	Electric Shock	Lighting	Vibrations	Noise	Heat & Humidity	Radiations	N = 6
Clients	1	5	3	2	4	6	
Contractors	3	2	5	5	1	4	
Workers	6	1	5	2	4	3	
Sum of Ranks (R_j)	10	8	13	9	9	13	Σ Rj = 62
$(R_j - \bar{R}j)^2$	1.00	1.00	16.00	0.00	0.00	16.00	s = 34

The value of W calculated is 0.21. To judge the significance of this W, value of s was determined from the Table 2 at 5% level for k = 3 and N = 6. This value was 103.9 and thus for accepting the null hypothesis (H_0) that k sets of rankings are independent the calculated value of s should be less than

103.9. Here the worked out value of s is 34 which is lower than the tabulated value which shows that W = 0.21 is not significant. Hence, the null hypothesis was accepted and it was concluded that the different groups of respondents have different perceptions in ranking the N factors i.e., there was not significant agreement in ranking by different groups of respondents at 5% level in the given case. The lowest value observed amongst R_j was 8 for Lighting so Lighting was considered as the most prevailing physical hazard followed by Heat and humidity, Noise, Electric shock, Vibrations and Radiations.

E. Ranking of Physiological hazards

The ranking of Physiological hazard by different groups of respondents are given in the Table 11 below.

Table 11: Ranking of Physiological Hazard

Hazard Types	Clients			Contractors			Workers		
	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank
Bad ergonomics	20%	2.4	**1**	0%	5.25	**5**	26.2%	3.48	**3**
Working posture	0%	4.2	**5**	0%	3.5	**3**	26.2%	3.24	**2**
Carrying overload	20%	3.2	**3**	25%	1.75	**1**	21.4%	3.19	**1**
Extra working hours	20%	2.8	**2**	0%	3.5	**3**	11.9%	3.76	**6**
Machine design and installation	20%	3.8	**4**	75%	2.25	**2**	23.8%	3.71	**5**
Layout	20%	4.6	**6**	0%	4.75	**4**	16.7%	3.62	**4**

As per Table 11 above, among the Physiological hazards, Clients have selected Bad ergonomics as the most important Physiological hazard followed by Extra working hours, carrying overload, Machine design and installation, Working posture and Layout. Also, Contractors have selected carrying overload as the most important Physiological hazard followed by Machine design and installation, Working posture, Extra working hours, Layout and Bad ergonomics. Similarly Workers have selected Carrying overload as the most important Physiological hazard followed by Working posture, Bad ergonomics, Layout, Machine design and installation and Extra working hours. From the observation checklist and KII, it was found that Working posture was the most important Physiological hazard followed by Bad ergonomics, Carrying overload, Extra working hours, Layout and Machine design and installation. Kendall's coefficient of concordance was performed for determining the degree of association among the sets of ranking done by different respondents groups.

Table 12: Matrix for Physiological Hazard

k = 3	Ranking Physiological Hazards						
Respondents	Bad Ergonomics	Working Posture	Carrying Overload	Extra Working Hour	Machine designs & Installation	Layout	N = 6
Clients	1	5	3	2	4	6	
Contractors	5	3	1	3	2	4	
Workers	3	2	1	6	5	4	
Sum of Ranks (R_j)	9	10	5	11	11	14	$\Sigma Rj = 60$
$(R_j - \bar{R}j)^2$	1.00	0.00	25.00	1.00	1.00	16.00	s = 44

The value of W calculated is 0.28. To judge the significance of this W, value of s was determined from the Table 2 at 5% level for k = 3 and N = 6. This value was 103.9 and thus for accepting the null hypothesis (H_0) that k sets of rankings are independent the calculated value of s should be less than 103.9. Here the worked out value of s is 44 from Table 4.55 below which is lower than the tabulated value which shows that W = 0.28 is not significant. Hence, the null hypothesis was accepted and it was concluded that the different groups of respondents have different visions in ranking the N factors i.e., there was not significant agreement in ranking by different groups of respondents at 5% level in the given case. The lowest value observed amongst R_j was 5 for carrying overload and as it was considered as the most prevailing physiological hazard followed by Bad ergonomics, Working posture, Extra working hours, Machine designs & installation and Layout.

F. Ranking of Chemical hazards

The ranking of Chemical hazard by different groups of respondents are given in the Table 13 below.

Table 13: Ranking of Chemical Hazard

Hazard Types	Clients			Contractors			Workers		
	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank
Cement dust	40%	1.8	**1**	75%	1.25	**1**	9.5%	2.93	**3**
Sand dust	40%	1.8	**1**	250%	1.75	**2**	19%	2.88	**2**
Silica dust	20%	2.8	**2**	0%	3.5	**3**	33.3%	2.55	**1**
Chemicals for accelerating agent	20%	4.60	**4**	0%	4.25	**4**	14.3%	3.38	**5**
Painting and galvanizing	20%	4.00	**3**	0%	4.25	**4**	23.8%	3.29	**4**

As per Table 13 above, among the Chemical hazards, Clients have selected Cement and Sand dust as the most important Chemical hazard followed by Silica dust, Painting and galvanizing and Chemical for accelerating agent. Also Contractors have selected Cement dust as the most important Chemical hazard followed by Sand dust, Silica dust, Painting and galvanizing and Chemical for accelerating agent. Similarly Workers have selected Silica dust as the most important Chemical hazard followed by Sand dust, Cement dust, Painting and galvanizing and Chemical for accelerating agent. From the observation checklist and KII, it was found that Silica dust was the most important Chemical hazard followed by Sand dust, Cement dust, Chemical for accelerating agent and Painting and galvanizing. Kendall's coefficient of concordance was performed for determining the degree of association among the sets of ranking done by different respondents groups.

Table 14: Matrix for Chemical Hazard

k = 3	Ranking of Chemical hazards					
Respondents	Cement Dust	Sand Dust	Silica Dust	Chemical for accelerating	Painting & galvanizing	N = 5
Clients	1	1	2	4	3	
Contractors	1	2	3	4	4	
Workers	3	2	1	5	6	
Sum of Ranks (R_j)	5	5	6	13	13	Σ Rj = 42
$(R_j - \bar{R}j)^2$	11.56	11.56	5.76	21.16	21.16	s = 71.2

The value of W calculated is 0.79. To judge the significance of this W, value of s was determined from the Table 2 at 5% level for k = 3 and N = 5. This value was 64.4 and thus for accepting the null hypothesis (H_0) that k sets of rankings are independent the calculated value of s should be less than 64.4. Here the worked out value of s is 71.2 which is greater than the tabulated value which shows that W = 0.79 is significant. Hence, the null hypothesis was rejected and it was concluded that the different groups of respondents were applying same standard in ranking the N factors i.e., there was significant agreement in ranking by different groups of respondents at 5% level in the given case. The lowest value observed amongst R_j was 5 for Cement & Sand dust and as such they were considered as the most stringent Chemical hazard followed by Silica dust and Painting and galvanizing and Chemical for accelerating agent.

G. Ranking of Psychological hazards:

Table 15: Ranking of Psychological Hazard

Hazard Types	Clients			Contractors			Workers		
	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank
Job dissatisfaction	0%	2.4	**2**	0%	4.5	**5**	7.1%	4.19	**6**
Alcoholism	20%	4.6	**5**	0%	4.75	**6**	19%	4.14	**4**
Working pressure/Deadlines/Target	20%	3.0	**3**	25%	2.75	**1**	16.7%	3.69	**2**
Wages and leave	40%	2.2	**1**	0%	4.0	**4**	11.9%	3.79	**3**
Job insecurity	0%	5.2	**6**	25%	3.0	**2**	11.9%	3.6	**1**
Management behavior	20%	4.2	**4**	25%	5.0	**7**	26.2%	4.17	**5**
Food and accommodation	0%	6.4	**7**	25%	4.0	**3**	4.8%	4.52	**7**

From Table 15 above, among the Psychological hazards, Clients have selected Wages and leave as the most important Psychological hazard followed by Job dissatisfaction, Working Pressure/Deadlines/Target, Management behaviour, Alcoholism, Job insecurity and Food and accommodation. Also Contractors have selected Working Pressure/Deadlines/Target as the most important Psychological hazard followed by Job insecurity, Food and accommodation, Wages and leave, Job dissatisfaction, Alcoholism and Management behaviour. Similarly Workers have selected Job insecurity as the most important Psychological hazard followed by Working Pressure/Deadlines/Target, Wages and leave, Alcoholism, Management behaviour, Job dissatisfaction and Food and accommodation. From the observation checklist and KII, it was found that Working Pressure/Deadlines/Target was the most important Psychological hazard followed by Wages and leave, Food and accommodation, Job insecurity, Job dissatisfaction, Alcoholism and Management behaviour. Kendall's coefficient of concordance was performed for determining the degree of association among the sets of ranking done by different respondents' groups.

Table 16: Matrix for Psychological Hazard

k = 3	Ranking Physiological Hazards							
Respondents	Job dissatisfaction	Alcoholism	Working pressure/deadline/target	Wages & leave	Job insecurity	Management behaviour	Food & accommodation	N = 7

Clients	2	5	3	1	6	4	7	
Contractors	5	6	1	4	2	7	3	
Workers	6	4	2	3	1	5	7	
Sum of Ranks (R_j)	13	15	6	8	9	16	17	Σ Rj = 84
$(R_j - \bar{R}j)^2$	1.00	9.00	36.00	16.00	9.00	16.00	25.00	s = 112

The value of W calculated is 0.44. To judge the significance of this W, value of s was determined from the Table 2 at 5% level for k = 3 and N = 7. This value was 157.3 and thus for accepting the null hypothesis (H_0) that k sets of rankings are independent the calculated value of s should be less than 157.3. Here the worked out value of s is 112 which is lower than the tabulated value which shows that W = 0.44 is not significant. Hence, the null hypothesis was accepted and it was concluded that the different groups of respondents have different visions in ranking the N factors i.e., there was not significant agreement in ranking by different groups of respondents at 5% level in the given case. The lowest value observed amongst R_j was 6 for Working pressure/deadlines/target so it was considered as the most prevailing psychological hazard followed by Wages & leave, Job insecurity, Job dissatisfaction, Alcoholism, Management behaviour and Food & accommodations.

H. Ranking of Biological hazards:

The ranking of Biological hazard by different groups of respondents are given in the Table 17 below.

Table 17: Ranking of Biological Hazard

Hazard Types	Clients			Contractors			Workers		
	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank	Percent ranking First choice	Mean	Rank
Snakes	40%	2.6	**2**	0%	3	**2**	4.8%	3.76	**4**
Bacteria	20%	3.0	**3**	0%	3.25	**3**	38.1%	2.5	**1**
Virus	0%	3.4	**4**	25%	4.25	**4**	19%	3.31	**2**
Mosquito	40%	1.8	**1**	75%	1.5	**1**	7.1%	3.83	**6**
Poisonous plants	0%	5.4	**6**	0%	4.25	**5**	16.7%	3.83	**5**
Fungus	0%	4.8	**5**	0%	4.75	**6**	16.7%	3.69	**3**

From Table 17 above, among the Biological hazards, Clients have selected Mosquito as the most important Biological hazard followed by Snakes, Bacteria, Virus, Fungus and Poisonous plants. Also Contractors have selected Mosquito as the most important Biological hazard followed by Snakes, Bacteria, Virus, Poisonous plants and Fungus. Similarly Workers have selected Bacteria as the most important Biological hazard followed by Virus, Fungus, Snakes, Poisonous plants and Mosquito. From the observation checklist and KII, it was found that Mosquito as the most important Biological hazard followed by Snakes, Bacteria, Virus, Fungus and Poisonous plants.

Kendall's coefficient of concordance was performed for determining the degree of association among the sets of ranking done by different respondents' groups.

Table 18: Matrix for Biological Hazard

k = 3	Ranking Biological Hazards						
Respondents	Snakes	Bacteria	Virus	Mosquito	Poisonous plants	Fungus	N = 6
Clients	2	3	4	1	6	5	
Contractors	2	3	4	1	5	6	
Workers	4	1	2	6	5	3	

Sum of Ranks (R_j)	8	7	10	8	16	14	Σ Rj = 63
$(R_j - \bar{R}j)^2$	6.25	12.25	0.25	6.25	30.25	12.25	s = 67.5

The value of W calculated is 0.43. To judge the significance of this W, value of s was determined from the Table 2 at 5% level for k = 3 and N = 6. This value was 103.9 and thus for accepting the null hypothesis (H_0) that k sets of rankings are independent the calculated value of s should be less than 103.9. Here the worked out value of s is 67.5 from the Table 4.61 below which is lower than the tabulated value which shows that W = 0.43 is not significant. Hence, the null hypothesis was accepted and it was concluded that the different groups of respondents have different perception in ranking the N factors i.e., there was not significant agreement in ranking by different groups of respondents at 5% level in the given case. The lowest value observed amongst R_j was 7 for Bacteria and as Bacteria was considered as the most prevalent Biological hazard followed by Snakes, Mosquito, Virus, Fungus and Poisonous plants.

7.6 SbD Approach to Eliminate/Control Hazards

Safety by Design is the most effective way to eliminate/control the hazards occurring in the site. The recommendations made below should be strictly followed in order to eliminate/control the hazards.

Table 19: SbD Approaches to eliminate/Control the hazards

Hazards	**SbD Approach to eliminate/control these hazards**
Mechanical Hazards	
Falling from height/work place	Prefabrication, Step bolts, Member size, Holes for gin pole, Anchor points, Bolted Connections safer and easier at top, Self-supporting connections, Bolt sizes, Minimum numbers of bolts, Immediate Stability with bolts
Excavation hazards	Take into consideration the design parameters in geotechnical report, Warn against exposure to electrical hazards in a trench
Crush injury	Design the adequate protection system while working in trenches five feet or more; Daily inspections of the excavations, adjacent areas, and protective systems by a competitive person; Provide requisite training to all in recognition of the hazards associated with excavation and trenching
Falling from edge of excavation	Provision for warning lines/guardrails around the edge of foundation pit
Falling of object from edge of excavation	Place excavated materials, equipment, and construction materials at least 2 feet away from the excavation edge
Collapse of side wall	Decide for the sloping, shoring or shielding
Slippery surface	Selection of safe route: Easy access to tower locations
Hand tools	Dummy holes in members, Welded wire fabric
Falling of an object	Dummy holes in members
Tripping hazards	Mesh size of 4" X 4", Avoid sharp edges in the members
Cuts and wound	Avoid sharp edges in the members, Sufficient space for Anchor bolt placing
Rock mass falling/ Rock sliding	Selection of safe route: Stable geological region, Avoid landslide prone areas
Drowning	Selection of safe route: Avoid marshy land and water bodies
Physical Hazards	
Electric shock	Designer should recommend the employers to ensure that employees follow the necessary clearance to be made in between the powerlines and the equipment to be used in the site. Designer should recommend the employers to contact the nearby electricity distribution centre when working in proximity to overhead powerlines.
Lighting	Provisions for proper Earthing system (Pipe Earthing and Counterpoise)
Physiological Hazards	

Hazards	**SbD Approach to eliminate/control these hazards**
Carrying overload	Member size, Avoid sharp edges, Lifting the loads within the limit
Bad ergonomics/Working posture	Avoid Awkward connections, Tying rebars using Power tier with and without extension handle, Holes for tying wires to lift
Layout	Designer should recommend the employers to identify the proper space for storing the materials, size and type of equipment to be used along with placing of equipment during operation.
Psychological Hazards	
Threat from local people	Avoid settlement and wild life habitat
Biological Hazards	
Snakes	Avoid wild life habitat

Details of SbD approaches are explained activities wise starting from Survey to Stringing of conductors and OPGW as below:

1. Selection of safe route:

(a) Stable geological region

There is less chances of Rock mass falling and Rock sliding in the stable geological region thus preventing the Mechanical hazards that could occur due weak and unstable regions.

(b) Avoid marshy land and water bodies

There is possibility of drowning in the small water bodies during the monsoon as well as dry season in case of large perennial sources when working near to water. So such places should be avoided in order to eliminate the possible hazards.

(c) Avoid landslide prone area

Landslides are possible areas of hazards that could cause greater damage to the lives and property of the people. There is possibility of rock mass falling or entire rock sliding in such areas. So landslide prone areas should be avoided for the construction of transmission line tower to prevent the possible hazards.

(d) Avoid settlement and wild life habitat

The route of transmission line should avoid the settlement area as well as wildlife habitat. Re-locating the settlement may cause issues with the local people and there is high possibility of local people threatening the Workers, Contractors and Clients. This could lead to the psychological hazard in the site. Also there is chance of wild animal attack while selecting the route along the wild life habitat. Thus to prevent the Psychological and Biological hazard, it is better to avoid the settlement area as well as wildlife habitat.

(e) Easy access to tower locations

One of the major problems of constructing the transmission line in hilly areas is transporting the construction materials to the site. There may not be the access road to each tower location, thereby needing the construction materials to be manually transported to tower location. There is chance of slippery surface, carrying overload and extra working hours. So easy access to tower locations is must to prevent the Physiological and Mechanical hazards.

2. Design parameters:

a. Consideration to be given to weight span and wind span
b. Tower configuration should be given due consideration
c. Proper electrical clearance should be provided
d. Proper wind load (wind zone) should be considered
e. Proper earthquake load should be considered
f. Adequate factor of safety should be considered during design
g. Use of appropriate design codes

3. Excavation:

a. Designers need to study the geotechnical report thoroughly and take into consideration the design parameters in geotechnical report.
b. Designers should decide for the sloping, shoring or shielding required as per geotechnical report. Designers should indicate the sloping angle at which soil should be excavated for self-supporting condition.
c. Designers should design the adequate protection system for all employees, subcontractors, and site workers working in trenches five feet or more in depth to protect from possible cave-ins [7].
d. Designers should be make a provision for warning lines/guardrails around the edge of foundation pit to prevent the possible fall hazards.
e. Designers should clearly state in the drawing that excavated materials, equipment, and construction materials should be placed at least 2 feet away from the excavation edge.
f. Designer should recommend the employers and contractors to keep a competent person who conducts daily inspections of the excavations, adjacent areas, and protective systems and takes appropriate measures necessary to protect workers [7].
g. Designers should recommend the employers and contractors to provide requisite training to all employees and subcontractors properly in recognition of the hazards associated with excavation and trenching[7].
h. Designers should warn employers and contractors regarding protection from exposure to electrical hazards in a trench [7].

4. Concreting:

(a) Tying rebar: Pliers and tie wires are used to tie the reinforcement bars in Nepal. Power tiers (PT) and power tiers with extension handle (PTE) used for tying rebar are not widely used in Nepal. Use of pliers and power tiers to tie the rebar at ground level requires working in stooped posture causing pain in lower backs and hands/wrist. Nowadays power tiers with height adjustable extension handle (PTE) are available that enables the worker to tie the rebar while standing. These power tiers with adjustable extension handle helps to reduce the work related musculoskeletal disorders[8]. Power tiers with extension handle should be held close to the body to avoid unnecessary stress and strain on the wrist, arm, and shoulder (see Fig. 2 below).

(b) Mesh size: While preparing the foundation for concreting, a mesh of rebar are placed at the bottom of the foundation pad. During the construction, the workers walk through the exposed rebar before pouring the concrete. There is possibility of tripping hazards if the mesh size is larger. So the mesh size should be so designed that it provides easier platform to walk. For this a mesh size of 4" X 4" can be provided on the top surface which allows workers to walk easily [8].


Fig. 2: Rebar tying using power tier with extension handle

(c) Welded Wire Fabric: For foundation works, mesh of rebar are prepared in the site. However in large projects, it may be economical to use the prefabricated rebar cages for foundation pad and chimney [8]. Welded wire fabric (WWF) can be made in a controlled environment. Use of welded fabric eliminates unnecessary field work, reduces the construction costs and also improves the quality of the work. Utilizing prefabricated wire mesh eliminates the need to form wire mesh on the site and therefore reduces construction hazards.

(d) Anchor bolt placing: It should be considered how the workers are going to install the rebar and anchor bolts. There should be sufficient clearance for placing the anchor bolts so that workers can do their job safely as congested space could cause injury to hand. Also if possible size of anchor bolts should be standardized.

(e) Foundation Shapes: Shapes of foundation play vital role in safe construction. The shapes should be as simple as possible and irregular shapes should be avoided. Irregular shapes require complicated formworks and as such works become complicated as well as risky [8].

(f) Standardize Foundation size: The workplace should be standardize as to reduce the hazards. Standardization prevents unexpected conditions to be faced by the workers [8]. This can be achieved by using similar foundation size for a particular tower type despite of any soil conditions or by classifying the soil to limited soil type. There is a common practice in transmission line projects to classify the soil into following type: Normal Dry Soil, Wet Soil, Fully Submerged Soil, Sandy Soil, Dry Fissured Rock, Wet Fissured Rock, Submerged Fissured Rock and Hard Rock. This can be reduced to fewer type after conducting geotechnical investigation and lesser type of foundation needs to be designed.

(g) Avoid driven piles: The foundation of transmission line tower are usually deep in nature. In case of loose backfilled soil, driven piles should be avoided as they can cause cave-ins. Foundation should be designed such that there is minimum soil vibration. Battered piles can also cause safety hazards because of the horizontal nature of the implied forces. So batter piles should also be avoided in areas of loose or backfilled soil [8].

5. Lifting and loading:

(a) Small member size

Small size of members helps in easier lifting and transportation of tower members, thereby reducing the possibility of hazards.

(b) No sharp edges

Sharp edges can cause cuts and wounds while carrying the tower members from store to the site, so avoiding sharp edges helps to reduce the hazards.

(c) Easier access to tower locations

Easier access to tower locations helps to lift and transport the tower members to the site easily and with less chances of injuries to the workers. If possible, road access to tower location would be more preferable.

(d) Holes for tying wires to lift

There is tendency of workers to carry two or more small members at a time, which becomes risky as there is possibility of slipping members and workers getting injured. Provision of holes helps in tying the members together and lifting them at once.

(e) Lifting the loads within the limit

Care should be taken that, workers should not be allowed or forced to carry the load beyond the limit prescribed by the Labour Act, 2074. Carrying loads within the limit helps to eliminate the physiological hazards.

6. Tower Erection:

a. Prefabrication

Prefabrication are generally done in factories/workshops in controlled environment using machines and automated equipment. This reduces the number of connections to be made in the field i.e. lesser field work implies lesser exposure to hazards. Also Prefabrication are done in ground level rather than at dangerous heights. So less work is done at higher elevations i.e. fewer connections to make in the air, which reduces the risks of falls and falling objects [5].

b. Step bolts

Easy access to the top during erection prevents slips and trips thereby preventing fall hazard. Step bolts can be provided in the leg of tower to climb up in the tower safely.

c. Member size

The member size of tower members should be limited such that it becomes easier for transportation as well as prevent buckling of member i.e. failure of steel members. This means that the towers are erected using small members rather than one large leg member. Heavy, long members possesses dangers to workers both during transportation and erection. So selection of member size is also important to prevent the hazards.

d. Holes for Gin Pole

A gin pole is a supported pole that is used to lift the loads with the help of a pulley and tackle on the top of it. These are generally secured with three or more guy-wires. In tower construction, a gin pole is shifted above the completed sections of a tower to lift the sections higher for erection. So the provisions of holes for gin pole helps in safer tower erection works.

e. Holes for safety lines

Safety lines are essential for fall protection. Safety lines includes steel cables strung between holes provided in the various members of tower. Holes can be provided on the members for fixing guardrails and lifelines. Number and locations of holes should be clearly marked in the structural drawing.

f. Base plates

There should be provision for at least four anchor rods bolted in the column base plates as per OSHA Requirement even if the required number of anchor bolts as per design is less than four.

g. Anchor points

Anchor points should be provided for fall protection systems such as body harnesses and lanyards. Size, numbers and positioning of anchor points should be fixed before the structures are constructed so that they can be used during construction as well as afterwards.

h. Connections

Basically there are two types of connection in steel structure i.e. welds and bolts. Bolts are easier to make connections rather than weld in the field at greater heights. Bolted connections are cheaper as well as faster than welds. It is quite difficult and takes longer time to make welded connections in air. Also good quality of welding is difficult to obtain in the site if they require awkward positioning. Welding are preferably done in ground in case of prefabricated truss whereas bolted connections are used in air.

i. Self-supporting connections:

Designers should focus on self-supporting connections rather than hanging connections. Self-supporting connections are those in which member can rests on other member or support easily with any connection for short period of time. This helps the erection team to make connections easily in the air whereas in case of hanging connections, members hang through the other members and are not stable until connections are made. Thus hanging connections should be avoided and self-supporting connections should be prioritized.

j. Dummy holes:

A "dummy hole" is a spare hole used for erection purposes and has nothing to do with structural strength. While making the bolted connections, it is necessary to place the wrench aside to install the bolts before final tightening. These dummy holes provide space to insert the wrench. Also they can be used as anchor points to fix the safety belts.

k. Bolt sizes

The size of bolts should be as few as possible. Large number of bolt size creates confusion about which bolt size shall be used to make the connections while in the air.

l. Minimum number of bolts

As per OSHA Requirement, minimum two number of bolts shall be provided for each connections as single bolt may cause some rotation of the member. Also advantage of two bolts system is that if one bolt fails, the members may shake but will not fall. So even the design requires less than two bolts, a minimum of two number of bolts per connection should be provided.

m. Immediate stability

Bolted connections become stable as soon as the bolts are placed in the holes. However welding requires more time compared to bolts. If the weld is not done properly, there is chance of members being displaced and in such case welding needs to be redone.

n. Avoid awkward connections

As far as possible, awkward positioning during making connections i.e. bolting or welding should be avoided because it is both time-consuming and dangerous. Connections which are made overhead require workers to strain to reach them and results in injuries to the back. These situations can be avoided by simply designing the structures in a way that a better position is provided for making the connections.

o. Sharp corners

Sharp corners should be avoided as they cause cut to the body parts as well as tearing of clothes resulting in falling or tripping hazards. The sharp corners should be cut off or covered with the bracing.

p. Temporary bracing

Temporary bracing may be designed such that they are installed just for facilitating the erection works and later removed and used in erection of other towers.

7. Stringing Works:

a. Provision of holes in Tension plate

In addition to the holes required, extra holes needs to be provided in the tension plate used in the cross arm to fix pulley to facilitate laying and final stringing of the conductor.

b. Maximum pull and release force

Designer needs to calculate and provide the pull and release force with which conductor should be released from one end and pulled from the other end during conductor stringing.

c. Maximum conductor tension

Maximum conductor tension should be specified by the designer which can be applied to the conductor during stringing.

d. Design of Pilot wire

Pilot wire of appropriate material suitable for stringing of conductor should be recommended by the designer.

8. Electrical works:

a. Designers should provide the provisions for proper Earthing system. Pipe Earthing and Counterpoise should be designed with care.
b. Designer should recommend the employers to ensure that employees follow the necessary clearance to be made in between the powerlines and the equipment to be used in the site [6].
c. Designer should recommend the employers to ensure to designate a worker as a signal person if it is difficult for the crane operator to maintain clearance by visible means.
d. Designer should recommend the employers to identify the proper space for storing the materials, size and type of equipment to be used along with placing of equipment during operation [6].
e. Designer should recommend the employers to contact the nearby electricity distribution centre when working in proximity to overhead powerlines [6].

8. CONCLUSION AND RECOMMENDATION :

8.1 Conclusion:

Erection, Stringing & Excavation were found as most risky activities followed by Lifting & transportation and Concreting. These activities constituted of various hazards. Mechanical hazard was found to be the most prevailing hazard of all followed by Physical, Physiological, Psychological, Biological and Chemical hazard. Working location (top of tower), Slippery surface & Hand tools were the major mechanical hazards whereas Heat & humidity and Electric shock were the major physical hazards. Also Working posture/Bad ergonomics and Carrying overload were the major physiological hazards whereas Working pressure/deadlines/target, Wages & leave and food & accommodation were the major psychological hazard. Similarly Mosquito & Snake bites were found to be the major biological hazards whereas Silica, Sand & Cement dust were the chemical hazards in the site. Despite most of the Clients and Contractors have responded that they have heard about SbD, it was found that SbD was not implemented in the site. Most of these hazards mentioned above can be prevented by adopting the SbD approach recommended below.

8.2 Recommendation:

Safety by Design is the most effective way to eliminate/control the hazards occurring in the site. The recommendations made below should be strictly followed in order to eliminate/control the hazards.

1. Selection of safe route a. Stable geological region b. Avoid marshy land and water bodies c. Avoid landslide prone area d. Avoid settlement and wild life habitat e. Easy access to tower locations	2. Design parameters a. Consideration to be given to weight span and wind span b. Tower configuration should be given due consideration c. Proper electrical clearance should be provided d. Proper wind load (wind zone) should be considered e. Proper earthquake load should be considered f. Adequate factor of safety should be considered during design g. Use of appropriate design codes
3. Excavation a. Designers need to study the geotechnical report thoroughly and take into consideration the design parameters in geotechnical report. b. Designers should decide for the sloping, shoring or shielding required as per geotechnical report. Designers should indicate the sloping angle at which soil should be excavated for self-supporting condition. c. Designers should design the adequate protection system for all employees, subcontractors, and site workers working in trenches five feet or more in depth to protect from possible cave-ins.	

<table>
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e. Designers should clearly state in the drawing that excavated materials, equipment, and construction materials should be placed at least 2 feet away from the excavation edge.
f. Designer should recommend the employers and contractors keep a competent person who conducts daily inspections of the excavations, adjacent areas, and protective systems and takes appropriate measures necessary to protect workers.
g. Designers should recommend the employers and contractors to provide requisite training to all employees and subcontractors properly in recognition of the hazards associated with excavation and trenching.
h. Designers should warn employers and contractors regarding protection from exposure to electrical hazards in a trench.</td></tr>
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b. Mesh size
c. Welded Wire Fabric
d. Anchor bolt placing
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e. Designer should recommend the employers to contact the nearby electricity distribution centre when working in proximity to overhead powerlines [6].</td></tr>
</table>

8.3 Recommendation for Further Study:

The safety by design approach discussed above are mainly for civil and mechanical works related to transmission line. The electrical works are discussed surfacely. So safety by design approach can be discussed in detail for electrical works. Also SbD approach can be used for various civil, mechanical and electrical works related to substation.

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