

Understanding Critical Delay Events Affecting Schedule Performance in Indian Hydro-Electric Projects

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Abstract—This research paper tries to identify the various delay events that are delaying the commissioning of Hydro Electric Projects in India beyond their scheduled completion date. This study is very much relevant in the present scenario as there is no specific study has addressed the delays and related issues in the Indian Hydro Electric Projects sector. Moreover, this research is based on the primary data collected from the Applications for Extension of Time. One of the major advantage of using these data for research is, because of the temporary nature of projects it is difficult to obtain necessary past project data from personnel sources. Secondly, data sourced is even more objective than personnel survey data since it is free from contamination by respondent perceptions. This study identifies and formulates 16 delay events as the causes of delay. These 16 events were formulated by generalising similar incidents which has delayed the project at several points of time during the project execution time. Thus formulated 16 delay events are further analysed and ranked based on its merits.

Index Terms— construction project management, construction delay and hydro electric projects.

I. INTRODUCTION

Construction is the modification of nature. The architectural marvels of ancient times prove that man has indulged in construction activities. In the present day world, technical breakthroughs have revolutionized construction activity. Modern construction areas include high-rise buildings, dams and irrigation networks, environmental protection works, infrastructural facilities like roads, bridges, railways, airports and seaports, satellite launching stations, onshore and offshore oil terminals etc.

Hydro Electric Power has been the most reliable source of renewable energy of India for the since century. Electric Power is one of the most important infrastructure requirements for the development of any country.

Reassessment studies of Hydro Electric Power Potential in various river basins in India were carried out by Central Electricity Authority. As per these studies, total Hydro Electric Power potential in the country was assessed as 84044 MW (at 60% load factor) from a total of 845 number of identified H.E. Schemes which when fully developed would result in an installed capacity of about 148701 MW on the basis of probable average load factor. The total energy potential is assessed as 600 billion units per year. The identified potential of H.E schemes above 25 MW installed capacity works out to be 145320 MW from a total of 592 H.E schemes. ^[17] The share in commercial energy production by Hydro Electric Power projects is 3.10% in 2000-01, 3.71% in 2006-07 [18]

Over 40% construction projects have apparently been suffering from poor performance across the country.^[5] Construction delays became an integral part of the project's construction time. In the Indian Construction Industry, especially in infrastructure projects, it is observed that the project commissioning is un-realistically delayed in most cases. Even with today's advanced technology and better understanding of project management techniques, construction projects continue to suffer delays and project completion dates still get pushed. The causes of delays and the procedures to avoid delays or mitigate the impacts of delays are still not fully understood by project participants and various other stake holders.

Delay is defined as an act or event that extends the time required to perform the tasks under a contract.^[13] It usually shows up as additional duration of work or as a delayed start or finish of an activity.

Unlike other construction projects, construction of Hydro Electric Projects is facing severe threat of delayed commissioning. Here in this research, it is tried to identify the various delay events that attributes towards the delayed commissioning of Hydro Electric Projects in India.

Even with today's advanced monitoring methods and project management knowledge, construction projects continue to suffer delays and project commission dates still get pushed back. The unrealistic time taken for the completion of construction projects is diverting the basic intension of Infrastructure development of the country. Delayed commissioning of projects is leading to a huge unrecoverable loss to the society and loss of public money.

II. LITERATURE REVIEW

Delays in completion of Construction projects are a topic that has been widely studied by researchers worldwide. The importance of construction delays arises from the fact that it is a major determinant of the success of construction projects.

Iyer and Jha^[5] has identified 55 successes and failure attributes. Critical success factors obtained by the analyses are: project manager's competence; top management support; project manager's coordinating and leadership skill; monitoring and feedback by the participants; coordination among project participants; and owner's competence and favorable climatic condition. Iyer and Jha^[4] identified attributes responsible for impacting performance of the projects. The study concluded that two success factors and one failure factor: commitment of project participants; owner's competence; and conflict among project participants contribute significantly in enhancement of current performance level of the project. Sambasivan and Soon^[7] identified the 10 delay factors and their effect on project completion in Malaysian construction industry. Sweis et al.^[8] identified and classified the causes of construction delays in residential projects of Jordan. Doloi et al.^[14] using a selected set of 45 attributes identified the key factors impacting delay in Indian construction industry and then established the relationship between the critical attributes for developing prediction models for assessing the impacts of these factors on delay. Olusegun and Akinsulire^[15] studied the causes and effect of construction delays in Nigerian construction industry. Mizanur et al.^[16] investigated the main causes for schedule delay in construction projects of Bangladesh. Long et al.^[3] has studied the success factors of large construction projects in Vietnam. Alaghbari et al^[9] studied the significant factors causing delay of building construction projects in Malaysia. Adnan et al^[11] assessed the factors leading to time and cost overrun in Gaza Strip. Ren et al.^[10] identified the most important causes of delays in Dubai construction projects. Kaliba et al.^[12] identified the causes of schedule delay in road construction projects of Zambia. Assaf and Hejji^[6] used frequency index and severity index for giving the rank to the various risk factors of construction projects of Saudi Arabia. Odeyinka and Yusif^[1] have shown that seven out of ten projects surveyed in Nigeria suffered delays in their execution. Whereas in Ghana, Frimpong et al.^[2] investigated the causes of time and cost overrun on ground water construction projects.

From the above selected literature review, it has been apparent that Project management concepts cannot be generalized across various industries or sectors. There are variations in project management knowledge and practices between industries, countries and application areas. Literature identifies development projects as well-known for over-running cost and schedule budget. One important characteristic of most Infrastructure Development projects is the complex web of the many stakeholders involved. Thus the cause of delays for completion of construction projects varies from varies from sector to sector and also from country to country. Thus it is important to identify the delay events in Hydro Electric projects.

III. OBJECTIVE & METHODOLOGY

Though considerable research has been done on construction delays in other countries, no study has addressed the delays and related issues in the Indian Hydro Electric Projects sector. This research is based on the primary

data collected from the Applications for Extension of Time filed by the Contracting firms to their respective Clients. One of the major advantage of using these data for research is, because of the temporary nature of projects it is difficult to obtain necessary past project data from personnel sources. Secondly, data sourced is even more objective than personnel survey data since it is free from contamination by respondent perceptions. The present research attempts to bridge this gap. The objective of the research is to identify the key reasons or events that are delaying the completion of Hydro Electric Projects in Indian scenario.

It is also understood from literature that, no specific previous study was carried out to identify the causes of delays of Hydro Electric Projects. All the previous studies on constructional delays were based on questionnaire surveys conducted. However, in this study, documented delay details of nine Hydro Electric Projects were studied to identify the causes of delays. All the previous study has helped in developing the theoretical background for this research. Thorough studies of nine Hydro Electric projects were conducted. All the incidents causing the delays or disruption to the project execution has been identified and quantified. Accordingly, the delay events has been identified and are statistically analysed and ranked.

In order to identify the various delay events that are leading to the extended completion of Hydro Electric Projects, the Application for Extension of Time of nine Hydro Electric Projects are studied initially. Extension of Time (EOT) Application is a comprehensive document that records all the delay events that has occurred during the execution of a construction project. All the EOT Applications must also have the corroborative records to substantiate the occurrence of delay events.^[19]

A. Portfolio of Projects under Study

Nine projects were identified for this study. Among projects under study, four projects started during 2009-10 period, four projects in 2005-06 period and one project in 2011. Average scheduled duration of projects is 52 months, 39 months being the shortest and 84 months being the longest. The percentage increase in duration of each project is determined with respect to the original scheduled duration of each project. Among these projects, in 3 projects the percentage increase of time was below 50%, 5 projects were between 50-100% and in one project, the increase was more than 100%. Details of delays occurred in each of these projects are evaluated to understand the quantum and frequency of occurrence of various delay events on the project.^[19]

From the preliminary study, it is observed that, almost all Hydro Electric Projects are being completed late with considerable increase in time duration. The average increase in project duration is around 70%.

IV. IDENTIFYING THE CAUSES OF DELAY

Initially in the process of identifying the causes of delay, all the incidents leading to project delay occurred during the execution of each project were listed and quantified. Based on the details of actual incidents delaying the project, the similar incidents occurred during the project execution are identified and grouped together so as to formulate the delay events occurred in project. Similar incidents leading to delay are then grouped and categorized to identify the delay events. For example in Project 1, there were ten incidents of delays to project components due to interfacing of various activities. All such incidents were clubbed together and considered as a delay event "Delay due to interfacing of activities". Similarly, there were two similar incidents occurred in Project 2 and eight events in Project 4, which are put in to the category of Delay due to interfacing of activities. Accordingly, all the 49 delay incidents occurred in Project 1, have been grouped and clubbed as 11 delay events. Similarly in Project 2, 6 delay events have been identified from a total occurrence of 16 incidents. Also the duration of occurrence of each delay event is obtained by the summation all delay incidents occurred under that event. Details of such incidents occurred and identified delay events are shown in the table 2 below. The total duration of disruption/ delays accrued in each project is tabulated in table I.

TABLE I. SUMMARY OF DELAY INCIDENTS AND EVENTS

Project	P 1	P2	P3	P4	P5	P 6	P7	P8	P9
Number of Incidents	49	16	36	54	7	35	19	13	5
Number of Delay Events	11	6	8	11	5	6	5	8	3
Total Duration of Delay events occurred (days)	5460	1863	2793	5069	791	4444	3046	496	771

It is identified from the above study that, 16 delay events are there, which are mainly causing the delayed completion of Hydro Electric Projects in India. The identified delay events are enlisted herein below.

TABLE II. DELAY EVENTS IDENTIFIED

Delay Event No	Description
1	Delay in issuing drawings/ instructions by Client
2	Delay due to interfacing of activities
3	Delay due to encountering Poor Geology
4	Execution of additional works not in original scope of the Contract
5	Non - availability of encumbrance free rights of way and possession of site due to reasons attributable to Client
6	Stoppage of work by locals/ Administration
7	Delay due to extreme weather conditions viz. heavy incessant rainfall, snowfall, avalanches etc.
8	Delay due to incomplete statutory clearances by Client
9	Delay due to landslides/ shooting stones
10	Delay due to other organisations
11	Flash flood
12	Non - availability of encumbrance free rights of way and possession of site due to reasons not attributable to Client
13	Delay due to accidents caused by the unsafe act/ unsafe condition followed by the Contractor
14	Discrepancy in the technical data provided by Client
15	Obstruction of works due to leakage of gas
16	Delay due to Heavy ingress of water in Tunnels

All the delay events and their duration of occurrences are summarized and tabulated in the table III below.

TABLE III. IDENTIFIED DELAY EVENTS

Delay Event No	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9
1	714	972	651	1170	492	959	560	99	0
2	773	382	0	955	0	761	2193	0	0
3	575	88	0	326	0	2451	0	204	226
4	1178	258	0	645	257	21	0	0	0
5	514	17	1129	39	0	0	0	112	0
6	81	146	399	920	13	12	187	10	0

Delay Event No	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9
7	232	0	216	347	14	240	16	0	0
8	458	0	17	0	15	0	0	0	527
9	681	0	0	156	0	0	0	2	0
10	49	0	0	325	0	0	0	0	0
11	205	0	116	0	0	0	0	10	0
12	0	0	172	0	0	0	90	43	18
13	0	0	0	178	0	0	0	0	0
14	0	0	93	0	0	0	0	0	0
15	0	0	0	0	0	0	0	16	0
16	0	0	0	8	0	0	0	0	0

V. DISCUSSION OF THE IDENTIFIED DELAY EVENTS

Each such delay events are discussed here.

A. Stoppage of Work by Locals/ Administration

Projects suffer from various suspensions on the pretext of forced stoppage caused due to miscreants/locals residents for fulfilling their charter of demands from Client, mainly under R & R Policy. Movement of resources to work site has restrained by the local residents. During the events of said commotion and disorder in the project area, the miscreants / alleged political activists have forcefully prevented the Contracting firm from execution of works at site thus resulting in to suspension of the whole of the works. The local villagers and members of Project Affected Family (PAF), at several occasions did not heed to the request of local administration /Client / Contractor and works got affected on account non-availability of unrestricted access to site. Subsequent to resumption of work, the progress of works had further affected on account of fear psychosis amongst officers and workers on account of action of PAF's. The attrition rate of workmen & officers has been very high due to fear the psychosis.

B. Delay in Issuing Drawings/ Instructions by Client

In Item Rate Contracts, Good for Construction (GFC) Drawings are to be issued by Client. Drawing requirement schedule, which depicts the dates in which the Good for Construction Drawings needed to be issued by Client to Contractor, will be mutually agreed up by the parties in Contract. GFC Drawings are required for micro level planning and to achieve the timely completion of the project work. It is observed that, in most cases, the agreed dates are slipped and the Contractor have to communicate the site requirement of drawings. In many cases, works at fronts will be in complete suspension for the want of drawings/ instructions from Client. Another observation is that, the issued drawings mostly undergo there are frequent revisions, thus necessitating for additional time for planning and procurement. Such revision of drawings sometimes even necessitates the demolition and rework. Such delay in issuance of these GFC drawings has severely affected the planning at site and further leading to delay the overall scheduled completion.

C. Delay Due to Encountering Poor Geology

The major obstructions are being suffered by the project on the pretext of shear failure under adverse geological conditions. Huge cavity formation has caused to complete stoppage of excavation activity. There were cases of continuous loose fall from the crown portion of tunnel, which made the efforts to execute any work inside tunnel practically impossible. Also, in some cases, works were disrupted on account of collapse of constructed portal due unforeseen geological condition at Adit. Also, based on the information furnished in Contract documents

pertaining to anticipated distribution of Rock Classes throughout the tunnel sections, the detailed construction programme and methodology were formulated so as to achieve the project completion on time. However, during actual execution of the works, the rock classes encountered were in variance to those of foreseen in Contract which ultimately caused delay in construction of various underground structures. Due to constant obstructions and resistance from locals during the actual execution the layout of Adits was revised in agreement with parties. Excavation through such unexplored geology posed unforeseen difficulties which resulted in achievement of very low progress than envisaged progress.

D. Non - availability of Encumbrance Free Rights of Way and Possession of Site Due to Reasons Attributable to Client

Normally as per the provisos of Contract, Client is responsible to provide the encumbrance free right of way to construction sites. Work at site has been severely affected to perform the project work at site due to delay pertaining to non – availability of encumbrance free rights of way and possession of site. In many projects, even after the delayed handing over, the road provided by Client was in a very poor condition and could not be termed as motorable for a Project of this magnitude and the equipment usage thereto. Major equipment and material have been kept idle due to inaccessible road to site.

E. Delay Due to Extreme Weather Conditions viz. Heavy Incessant Rainfall, Snowfall, Avalanches etc.

The project sites was hit by natural avalanches during the month of January/ February. Avalanches glided to the access road leading to work sites and also to the work fronts. Several avalanches hit the area leading to submergence of work area, structures and various other resources and also blocking the connectivity to site. It has resulted into complete blockage of access to site, submergence of our resources in snow and consequent disruption of Work. Movement of manpower, equipment, essential materials and construction materials by road was also affected.

The project area experienced heavy unprecedented incessant cyclonic rains. Heavy incessant rains of such a magnitude could not be foreseen nor could its effect be controlled by any party. These heavy incessant rains further resulted into occurrence of massive landslides on approach roads connecting to work site. The blockage of said approach road resulted into the stoppage of all resource movement and works at site.

F. Delay Due to Interfacing of Activities

Project commissioning has suffered delay due to interfacing activities with E&M contractor; there were several delays in handing over the structures between the Civil and E&M agency and consequent non availability of access to site to Contractor. This has occurred due to persistent failure of interfacing Contractors to perform their obligations in adhering to the construction schedule leading to slippage of agreed progress. This delay has very badly delayed completion of works and also very badly disrupted micro level planning and scheduling of activities.

G. Execution of Additional Works Not in Original Scope of the Contract

Normally, initial Base Programme has been prepared based on the quantity estimation of tender drawings. Accordingly, contractor prepares the Construction programme and formulated the schedule, sequences of each of the activities and allocation of resources thereof based on the items and quantity provided in BOQ so that the Work could be completed within the stipulated time for completion. But as the project been started, there were several variations/changes/amendments in the respective drawings. During execution of the Work, the Engineer instructed to execute various additional Works, which was not envisaged/ foreseen earlier in the base programme. This execution of the unforeseen additional Work altered the already envisaged time programme, sequence of execution of the Work and consequences resources allocation. Accordingly, Contractor has encountered additional duration in time for completion of Work as a result of such unforeseen physical condition.

Further, some of the variations have reduction impact on quantities and works. However such envisaged delays due to reduction/increase in quantities for reason of variations/ introduction of additional/ extra items/ works are hypothetical in the middle stage of project work. In is also pertinent here to mention that the execution of these additional works are also being delayed / hindered due to various reasons.

H. Non - availability of Encumbrance Free Rights of Way and Possession of Site Due to Reasons Not Attributable to Client

The progress of works has suffered several delays on account of non-availability of unrestricted access to site, to proceed ahead with the works, due to unrest in valley of Kashmir.

I. Delay Due to Landslides/ Shooting Stones

There were several events of unforeseeable physical obstruction suffered by the project right from its commencement. These events include landslides and shooting stone. The project Work encountered severe landslides which brought the Project Work to a complete standstill and also resulted in loss & damages to Contractor's resources deployed. The aforesaid unforeseeable physical condition, had rendered the access roads completely inaccessible on account of the damage and wash-outs at several locations; and also inordinate amount of debris had piled up all along the access roads to Project sites. Consequent to massive landslides, shooting stones, subsidence of the access road to the project, the progress of Work at various work fronts remained suspended for prolonged period. Besides creating hindrances, it also created fear psychosis among the workforces, who were reluctant to work at such risk-prone workplace.

J. Delay Due to Incomplete Statutory Clearances by Client

Delay in non-providing of possession of site to the Contractor for execution of work after completing necessary statutory clearances is a major issue. In a project, the required possession of site after getting due clearance from the State Forest Dept. was not obtained by the client, which has resulted in suspension of works by the concerned authority. Another similar incident was the Delay in Shifting of 800KVA substation & Electric poles in line with the first stage road diversion by Client along with state electricity board.

K. Flash Flood

Flash flood in river or another stream due to cloud bursting and the resulting washing away of road to site were some of the major unforeseen physical obstructions due to which our project has suffered hindrances on respective work fronts affecting over-all schedule which was beyond the control of parties. In some other projects, the intensity of rain was so high that it resulted in to extraordinary Flash Floods in river. These heavy unprecedented incessant cyclonic rains resulted in heavy loss/damages to approach roads. Even newly constructed culvert could also not resist the flow of flash floods and was washed away. As a consequence of such flash floods the materials such as steel girders for fabrication of ribs stocked for the project construction works were washed away. Also, labour camps, water, electricity lines were also severely damaged in Flash Flood.

L. Delay Due to Other Organizations

The unplanned and haphazard widening work on the NH/ State road by state PWD has become a major obstruction to the construction activities. As a consequence of haphazard PWD road widening work, the progress of work has been getting affected very badly since PWD commenced widening at each and every place without any advance planning. PWD is doing excavation (slope cutting by blasting and using breaker attached with the excavator) and mucking work by keeping the road barricaded for hours and the number of times in a day at several places. Even after the opening of the blockade, vehicles and equipment get stuck in traffic jams caused due to non-clearance of the left over muck resulting in formation of humps/heaps over the surface of the road. The unplanned blasting by PWD also leaves the already weakened portions of rock susceptible to further increased landslides / rockfalls on slightest rains or another unplanned adjacent blasting. Further during rainy days, the road surface becomes slippery due to accumulation of water in pot holes, formation of slush due to accumulation of left over excavated muck, caused further delay/stoppage in the movement of heavy vehicles, shared, and spare equipment to the work fronts. Delay in transporting shotcrete, concrete from batching plant to the work fronts and transporting muck to the dumping yards. Delay in sending the shared equipment required for carrying out the works. Delay due to increase in rate of break down to the shared equipment. Consequent to the facts mentioned above, Cycle time of several works has increased and thereby the Contract methodology.

M. Obstruction of Works Due to Leakage of Gas

In a project, during the drilling of boreholes for blasting operation in Head Race Tunnel, suddenly, leakage of some gas was observed from the bore holes. All the manpower working on the said front had to run for cover. Within few moments, the gas caught fire and reached upto the junction of the said front. Consequently, as a precautionary measure of above incidence whole staff and machineries in the said front was evacuated and shifted to the safe location. As a precautionary measure works were also halted on all the other fronts operating at that time because of the severity of leakage of such highly inflammable gases.

N. Delay Due to Heavy Ingress of Water in Tunnels

Heavy seepage of water was encountered in tunnel to the surprise of all. Such heavy seepage was not envisaged during the bid and envisaged only 15 H.P capacity dewatering pumps for dewatering as per bid data. But, to tackle with above situation, Contractor had to deploy 70 H.P capacity of dewatering pumps i.e. approx. four times the considered capacity, which was not at all envisaged in Contract. This resulted in increase in time cycle of excavation and hence reduction in productivity.

O. Delay Due to Accidents Caused by the Unsafe Act/ Unsafe Condition Followed by the Contractor

Due to collapse of tower crane, the concreting work of dam has disrupted. There was delay on account of production loss in dam concreting due to collapse of Tower Crane.

P. Discrepancy in the Technical Data Provided by Client

There was a discrepancy between the two bench marks, at the dam site and at power house site. This discrepancy between benchmarks has affected the progress of works of design and calculations associated with the various Inspection gates Surge Shaft gate together with their associated hoists.

VI. ANALYSIS OF DELAY EVENTS

Descriptive analysis of the identified delay events are required to understand it in a better manner. Descriptive analysis is an important measure for ranking the attributes in terms of their criticality as experienced in the projects under study.

A. Number of Occurrences on Project

It is a matter of fact that, all delay events need not necessarily occur in each projects. This has been studied and accordingly, the number of occurrences of each delay event has been tabulated in the table 4 below. Accordingly, a frequency of 9 indicates that the delay event “Stoppage of work by locals/ administration” has occurred in 8 projects out of 9 projects under this study. Similarly, four delay events are having an occurrence frequency of 1, which means it has occurred in only one project. According to the frequency analysis, “Stoppage of work by locals/ administration and Delay in issuing drawings/ instructions by client” and “Stoppage of work by locals/ Administration” has occurred most frequently. There are five delay events, which has occurred only once in the projects under study.

B. Quantity of Occurrence

The total duration of occurrence of each delay event is computed so as to identify the impact of each delay event on the project. This will indicate the magnitude of severity each delay event has made on each project. The table below indicates the total duration of disruption suffered by each project due to each delay event. It also indicates the total duration of disruption created by each delay event. From the data below, delay event ‘Delay in issuing drawings/ instructions by Client’ has caused a total disruption period of 5960 in 9 projects altogether.

C. Data Analysis

Statistical analysis was performed on the data collected from the applications for time extensions of projects. Demographic data were analysed using descriptive statistics such as the frequency and the mean. In this, the mean, weighted average, standard deviation and relative importance index (RII) are calculated. Many researchers are of the opinion that mean and standard deviation of each individual attribute is not a suitable measure to assess overall rankings as they do not reflect any relationship between them and hence used RII which can be calculated using the following equation:

$$\text{Relative Importance Index (RII)} = \Sigma w / A \times N$$

W Total duration of delay observed for each event,

A Highest duration of delay event observed

N Total number of respondents

TABLE IV. QUANTITY AND FREQUENCY OF DELAY EVENTS

Delay Event No	Total duration of disruption	Number of Occurrences
1	5617	8
2	5064	5
3	3870	6
4	2359	5
5	1811	5
6	1768	8
7	1065	6
8	1017	4
9	839	3
10	374	2
11	331	3
12	323	4
13	178	1
14	93	1
15	16	1
16	8	1

TABLE V. ANALYSIS OF DELAY EVENTS

Delay Event No	Mean	Weighted Average	Std. Dev	RII
1	624.1	14978.7	369.2	0.229
2	562.7	8440.0	682.7	0.207
3	430.0	7740.0	736.4	0.158
4	262.1	3931.7	382.7	0.096
5	201.2	3018.3	363.4	0.074
6	196.4	4714.7	283.1	0.072
7	118.3	2130.0	130.3	0.043
8	113.0	1356.0	203.6	0.041
9	93.2	839.0	213.4	0.034
10	41.6	249.3	101.4	0.015
11	36.8	331.0	69.4	0.014
12	35.9	430.7	56.0	0.013
13	19.8	59.3	55.9	0.007
14	10.3	31.0	29.2	0.004
15	1.8	5.3	5.0	0.001
16	0.9	2.7	2.5	0.000

VII. DISCUSSIONS

The delay events are ranked based on the weighted average, Frequency, Duration of Occurrence and Relative Importance Index. The attributes are arranged in ascending order of ranks based on above said aspects. The ranks assigned are discussed in the table 6. Attribute with highest RII indicates that it has the maximum impact on the delay while the attribute with lowest rank indicates that it has the least impact on delay duration. However Relative Importance Index[RII] doesn't talk about the relationship between the various attributes.

TABLE VI. RANKING OF DELAY EVENTS

Delay Event No.	Weighted Average	Frequency	Duration of Occurrence	R.I.I
1	1	1	1	1
2	2	6	2	2
3	3	3	3	3
4	6	7	4	4
5	4	2	5	5
6	5	4	6	6
7	7	5	7	7
8	8	8	8	8
9	9	12	9	9
10	12	9	10	10
11	11	11	11	11
12	10	10	12	12
13	13	13	13	13
14	14	14	14	14
15	16	16	16	16
16	15	15	15	15

To identify if there is a relationship between the attributes, Spearman rank correlation is used. It assesses how well the relationship between two variables can be described using a monotonic function. The sign of the Spearman correlation indicates the direction of association between X and Y. A Spearman correlation of zero indicates that there is no tendency for Y to either increase or decrease when X increases. Spearman's Rank Correlation rank coefficient is calculated with respect to weighted average and duration and also between Frequency and Duration, using the formula:

$$1- \frac{6 \times \sum d^2}{N(N^2 - 1)}$$

Here,

d is the difference in ranks

N is number of attributes.

The Rank coefficient obtained for Frequency & Duration is 0.931 and for Weighted Average & Duration is 0.983. The Spearman rank correlation test revealed no significant difference among the projects on the ranking of the factors.

The results of analysis of various incidents causing delays to execution of project works were studied to identify the factors influencing delays in execution of Hydro Electric projects. Hundreds of incidents causing delay have been identified from ten projects and accordingly, 16 delay events were identified. It is revealed from the study that, Delay in issuing drawings/ instructions by Client and Delay due to interfacing activities are the critical events creating major impacts on the project's delay and also are occurring more frequently.

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