ANALYSIS OF CONSTRUCTION DELAYS IN MINI HYDROPOWER PROJECTS IN SRI LANKA

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ABSTRACT

The share of mini hydropower plants in electricity generation is becoming more important in modern power generation due to the national policy targets to move from the fossil fuel brown energy to sustainable green energy. Therefore, the demand for construction of the mini hydropower plants has become higher but these projects show a significant rate of delays in project delivery. This research was carried out to identify the project delay phases and the main delay factors in mini hydropower projects. Furthermore, it was expected to derive mitigating measures for mini hydropower project delay based on the findings. The data collection process was based on multiple case studies where the project planning documents of three mini hydropower projects were reviewed to extract delay information. Here, projects managers validated the information in the documents to be correct and gave an overview of what has happened during the project. Here all information extracted was discussed under the headings of the case studies (P1, P2 and P3). With information extracted, delays in ten significant phases of the mini hydropower projects were identified with its delay percentages. The most delaying phase of the mini hydro project was the weir construction while least being the fore-bay construction. Delays in hydropower projects occur mainly due to the natural consequences such as adverse weather conditions and environmental conditions such as an earth slip. Protests by the interested parties were the next major concern when it comes to delays in mini hydropower projects. Proper management of the identified delay factors and awareness of delays in relevant phases is required. Nevertheless, it was found to be essential to make the interested parties fully aware about the environmental impact even before the initiation of the project in order to successfully mitigate the significance of delays.

Keywords:*Construction Delays; Delay Mitigation Methods; Mini Hydropower Projects.*

1. INTRODUCTION

The government of Sri Lanka carries out larger power generation projects and projects that are less than 10MW capacities have been permitted to the private sector, since this permission is being allowed many private companies have shown interest in investing in hydropower projects (Wijenayake, 2016). According to Hisham and Yahya (2016), most critical problem that may occur in any construction project is delays, and authors further discuss that there is a correlation between the causes of delay and the effects on the project. Howard (2016) has mentioned that delay is no exception for the hydropower projects and that the project net present value of the investment will be affected due to delays. Moreover, Kesavan et al. (2015) state that if the project's objectives are disrupted that will certainly contribute to project delays with in turn will render adverse effects on project objectives. Delay causing incidents may include weather, unavailability of resources and design delays. However, Vidalis and Najafi (2002) is of the view that project delays occur as a result of external and internal causes and effects related to different phases of construction. According to Sambasivan and Soon (2007) the delays will lead to considerable negative effects such as lawsuits between owners and contractors, loss of productivity and revenue. Therefore, irrespective of the project types, its inevitable delays have to be identified and minimised for the project to achieve the desired objectives.

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Internationally there are many types of research carried out in order to find out the most significant causes of delays in construction projects to be aware of mitigation methods to minimise the delays. Identifying the causes of the delays is the first step when addressing a problem therefore; the corrective action can be taken (Aibinu & Odeyinka, 2006). According to a research which was conducted by the Stoy et al. (2007) in Germany, the efficiency of the construction depends on the geographical location of the project, type of the construction project and the methods of the project conducting such as turnkey project and traditional project. Agreeing to the fact that type of construction project will attribute to the efficiency of the project, Manders et al. (2015) had further considered small-scale hydropower station (hydel) as a strategically important species of construction which has to be more sensitive to the environment. The authors also emphasise that the selection of location and quantification of its effects to the project is vital in reducing errors in these types of projects done in extreme environments.

2. LITERATURE REVIEW

Presently, over 15 companies in private sector are engaged in mini hydro-power projects and supply 307 MW of power to the national grid from 154 mini hydro-power plants which amount to 17.5% of hydropower generation in the country (Ceylon Electricity Board, 2015). The Ministry of Power and Energy stated that they anticipate utilising all possible locations to contributing of 873 MW of power by the year 2020 by constructing mini hydropower plants (Ministry of Power & Energy, 2015). These factors emphasise that the mini hydropower industry is a growing industry. However, Colombo Business Reporter (2017), has mentioned in their article that the communities who are the dependents of river water are of the fear that once the water is harnessed by the hydropower projects, they might not get the same benefits as before, therefore it has been a hindrance factor for the development of mini hydropower projects in Sri Lanka and its potential is yet to be maximized.

Manders et al. (2015) stated that every construction project has unique delaying factors according to nature of the project, it is correct for the mini hydropower construction industry as well. In addition, the strategies for the causes given in the aforementioned research were mainly concentrated on the environmental concerns and the researchers have focused on water flow dynamics, where the changing environment context becomes much important in mini hydropower construction. Williams (2003) has stated that delays can be occurred due to the faults of the Client, Contractor and the Consultant, due to the fact that they have not correctly figured out the context and the special requirements of the project. Therefore, it makes the argument certain that apart from the traditional delays applicable for other construction sectors, project specific delay factors are applicable in the mini hydropower project context.

Howard (2016) had mentioned referring to the hydropower projects and mentioned that delays in those projects are of two types. Those are technical and non-technical delays. Technical delays relate to the engineering and commercial problems, while non-technical delays relate to environmental and social factors, community issues, and health and safety challenges. The researchers also of the view that, even though the technical delays can be minimised to an extent, the non-technical delays will affect the project progress in a significant way, in fact, 54% of all delays. Pathiranage and Halwathura (2010) had emphasised in their research on road construction that delays could happen from the initiation of the construction to the completion due to various reasons and some of them are delays are unique to each phase. When considering the two views, it can be hypothetically considered that even in hydropower projects delays can be analysed related to different phases of the construction. During this research, hypothesis was established through various literature by identification of major causes for delay according to the literature review (Table 1).

According to Table 1, it can be inferred that many of the delay factors are due to the poor coordination between the client/consultant and the contractor. Apart from the poor coordination inefficiency of the client and the contractors, has delayed the projects from time to time. Moreover, financial issues have also made concern while getting the project into realisation. Apart from these factors, other major concern had been adverse weather condition which has halted the projects from time to time. This was seconded in a Sri Lankan research where Jayawardena and Panditha (2003) emphasise that the main factor of delay in Sri Lankan construction projects is due to the rainy weather conditions. While identifying that the rainy weather as the main cause of delay in a tropical country like Sri Lanka, the abovementioned researcher identified that the next most concerning delay factor as the manpower shortage satisfying the requirements of the project. Mudge (2016) has made his views clear with the fact that except for the weather conditions all other factors can be minimised

simply by being aware of them and creating a contingency plan upfront. Even though Mudge (2016) is silent on the manpower shortages he identifies that proper collaboration between the client and the other stakeholders can be extracted into a contingency plan, which in turn will minimise most of the factors of delay.

Table 1: Delays in Construction projects

Delay factors identified	Reference
Contractors improper planning, Contractors improper site management, inadequate contractor's experience, Problems with subcontractors, Shortage of material, labour supply, Equipment availability and failure, Inadequate client's finance and payments for completed work, lack of communication between parties and mistake during the construction stage.	(Sambasivan & Soon , 2007)
Financing projects by contractors during construction, delay in contractor's payment by owner, design changes by owners during construction, partial payments during construction, non-utilization of professionals during construction and construction management.	(El-Razek et al., 2008)
Approval of shop drawings, delays in payment to contractors and the resulting cash problems during construction, design changes, conflicts in work schedules of subcontractors, slow decision making and executive bureaucracy in owner's organizations, design errors, labour shortage and inadequate labour skills	(Assaf et al., 1995)
Inadequate feasibility studies, errors and omissions in detail designs, improperly harmonized procurement documents, shortcomings in the contract document, stakeholder identification and management issues, Variation and scope changes, land acquisition and resettlement, extreme weather	(Jeykanthan & Jayawardena, 2012)
Natural disasters like flood and earthquake, financial problems of the clients, improper planning, poor site management, poor experience of labours and lack of materials and equipment	(Haseeb et al., 2011)
Poor risk management and supervision, unforeseen site conditions, slow decision making, client-initiated variations and work variations	(Chan and Kumaraswamy, 1996)
Change orders by owners during construction, Delay in progress payment by owner, Ineffective planning and scheduling of projects by contractor, Poor site management and supervision by contractor, Shortage of labour, Difficulties in financing project by contractor	(Assaf, & Al-Hejji, 2006)
monthly payment difficulties, poor contract management, material procurement, inflation, contractor's financial difficulties, escalation of material prices, cash flow during construction, planning and scheduling difficulties, bad weather, deficiencies of cost estimate prepared	(Fringpong et al., 2003)
Delay in delivery of materials to the site, shortage of materials, poor skills and experience of works, shortage of site labour. delayed and slow supervision in making decisions, poor weather conditions	(Alaghbari et al., 2007).

3. RESEARCH METHODOLOGY

The probable delay factors of mini hydropower projects which were identified through the literature survey had to be tested by already completed mini hydro projects. Therefore, multiple case study research method was found to be the most convenient method to arrive at conclusions. In order to meet the requirement three cases (projects) of the similar difficulty was selected, and work programmes of those cases were reviewed and later validated by the project managers, to generate more reliable results regarding the construction delays visible in mini hydropower projects.

The data collection was started by finding areas where the mini hydropower plants highly situated and found. Companies who construct mini hydropower plants, with the help of Google search engine. According to the requirement, the three projects were selected with similar difficulty in location and other specifications. Following Table 2 provides the location and technical specification of selected projects (P- Represents the word "Project").

Table 2: Technical Specifications of Mini Hydropower Plants

Project	(P1)	(P2)	(P3)
Location	Neluwa	Morawaka	Kuruwita
River Catchment	Gin Ganga	Nilwala Ganga	Kuru Ganga
Project Capacity (MW)	2.5	2	2.6
Mean Annual Energy Supply (GWH)	10.2	8.23	11.21
Channel Length (m)	660	225	1700
Penstock Length	40	68	140
Number of Turbines	2 @ 1250 KW	2@ 650, 1@ 700	2@ 650, 1@ 700
Weir Length	30	50	30
Weir Height (Av.)	2.5	1.8	2.5

Afterwards site visits were arranged to obtain details about the site and work program by getting approval from the client of the selected projects. Extracted details from the project planning documents were validated to be correct by the project managers at the site visits and made a list of delaying factors in each phase. Finally, the probable delay mitigation methods were also derived with the delayed phases with the assistance of the respective project managers for the abovementioned projects.

4. RESULTS AND DISCUSSION

The data analysis was based on three case studies as given above, data extracted from the planning schedules and programmes and the reason for the delay is tabulated as below (Tables 3 and 4).

Table 3: Delay Percentages and Reasons for Delay

Activity**	P1			P2			P3		
	Delay (days)	%*	Reasons for delay	Delay (days)	%*	Reasons for delay	Delay (days)	%*	Reasons for delay
Weir Access and road construction	4	11	Obstructions from NGOs and neighbors.	3	12	Obstructions from NGOs and neighbors.	7	21	Objections from neighbors
On ground access road construction	8	47	Labor shortages, Lack of skilled labors, poor supervision and obstructions from NGOs neighbors.	11	33	Obstructions from NGOs and neighbors.	15	22	Objections from neighbors, labor shortages.
Intake construction	25	20	Labor shortages, Lack of skilled labors, adverse weather condition (flooding) and design changes.	98	73	Labor shortages, Lack of skilled labors, obstructions from NGOs, local politicians, neighbors and Central Environmental Authority. design changes	6	5	Poor supervision, Lack of skilled labors and materials late delivery

Desisting structure and channel on ground	10	7	Material late delivery, bad weather (heavy rain and earth slip) and design changes.	15	11	Bad weather (heavy rain), Material late delivery, obstructions from NGOs, local politicians, neighbors and Central Environmental Authority and management issues.	5	4	Bad weather (heavy rain) and Material late delivery.
Weir construction	20	29	Adverse weather Condition (flooding) and design changes.	52	72	Obstructions from NGOs, local politicians, neighbors & Central Environmental Authority. Design changes due to location changes and management issues.	8	11	Bad weather (heavy rain).
Aqueduct column construction	8	31	Unforeseen ground conditions	4	29	Unforeseen ground conditions.	23	44	Unforeseen ground conditions and bad weather condition (earth slip) and design changes.
Aqueduct channel section			No Delay			No Delay	16	11	Bad weather condition (earth slip) and design changes
Fore bay construction			No Delay	3	2	Material late delivery.			No Delay
Power house construction	13	4	Unforeseen grounds conditions and objection from neighbours and irrigation department.	9	3	Unforeseen grounds conditions, poor supervision and objection from neighbours.	15	5	Unforeseen grounds conditions bad weather condition (flooding), labour shortages and poor supervision.

*Delay percentages compared to the planed duration.

4.1. IDENTIFIED DELAYING FACTORS AND THE PERCENTAGE CHANGE IN DURATION

According to the analysed data of the three case studies, many delaying factors agreed with the literature survey. Analysed delaying factors of the case studies can be categorised as external factor sand internal factors. External factors were identified to be bad weather condition, objections from protestors, objections from government authorities and unforeseen ground conditions. Internal factors were identified to be management issues, late delivery of materials, labour shortage, and lack of skilled labours, design changes, and poor supervision.

During the validation process with the project managers, it was identified that the most common and the most harmful delaying factor for mini hydropower projects as adverse weather conditions. This was suggested to be minimized through proper site investigation followed by analysing previous weather reports, flooding reports, geological reports of the site area and identifying the suspicious places which are having a tendency for an earth slip before designing.

The second major problem identified was the objection from the protestors such as neighbours, local politicians, NGOs and environmentalists and objections from the government authorities. Mainly, their objections were arisen due to the unawareness of the project. This can be minimised by community awareness programs before commencing the project. Neighbours objection also had occurred due to the noise while blasting the rocks for the excavation and while taking off the lands. By limiting the blasting into the limited time, the objection can be mitigated from the neighbours due to the noise.

The third extensive delay factor was identified to be the unforeseen ground condition according to the research. Before making schedules, the ground condition must be identified otherwise sufficient time cannot be allocated for the ground works. This can be minimised by doing soil investigation and by referring the geological reports of the project area.

4.2. IDENTIFIED DELAYING PHASES IN MINI HYDROPOWER PROJECTS

Project activities were ranked according to the delay percentage compare to the planned duration of the activities and the data was entered to Table 4.

Table 4: Ranking of the Activities According to the Extent of the Delay and Delaying Causes

Activity	Mean %*	Rank	Cause of Delay
Weir access road construction	14.8	5	Obstructions from NGOs and neighbors.
On ground access road construction	33.4	3	Labor shortages, Lack of skilled labors, poor supervision and obstructions from NGOs neighbors.
Intake construction	32.6	4	Bad weather, Poor supervision, Lack of skilled labors, materials late delivery, obstructions from NGOs, local politicians, neighbors and Central Environmental Authority, design changes, intake location changes and management issues.
Desisting structure and channel on ground	7.4	7	Bad weather (heavy rain, flooding, earth slip), Material late delivery, obstructions from NGOs, local politicians, neighbors and Central Environmental Authority and management issues.
Weir construction	37.2	1	Bad weather, Obstructions from NGOs, local politicians, neighbors and Central Environmental Authority, design changes due to weir location changes and management issues.
Aqueduct column construction	34.7	2	Unforeseen ground conditions and bad weather condition (earth slip) and design changes.
Aqueduct channel section	11.5	6	Bad weather condition (earth slip) and design changes
Forebay bay construction	2.2	10	Material late delivery.
Powerhouse house construction	3.8	8	Unforeseen grounds conditions bad weather condition (flooding), labor shortages and poor supervision. Objection from neighbors.
Penstock Laying	3.1	9	Poor supervision

According to the ranking, most delayed activities were weir construction, aqueduct column construction, on ground access road construction and Intake construction in the mini hydropower plant construction.

According to the above analysis, weir construction was found to be the phase where the most attention should be given in terms of delay; the obstructions from external parties have been the main issue. Moreover, the weir construction is done directly across the river and thereby interested parties' involvement becomes more prominent. Aqueduct column construction was found to be the next concern phase of the construction. However, aqueducts are not constructed necessarily on top of columns most parts of the considered projects were constructed on the ground as channels; therefore, the delay would not affect the overall delay of the project in a considerable scale.

Access roads to initiate the project was the third most prominent delay phase in mini hydropower construction, this was mainly due to the labour shortages and material supply delays, this is common due to the fact that it is the beginning of the project and the resource allocation has not been properly done. Especially in the given adverse environment, it is difficult to find appropriate labour. Intake construction was the next concern delay phase. What have affected the intake construction have been the external factors. Internal factors also have influenced in terms of the design changes which happen once the construction has begun. Other phases in mini hydropower construction have very low delay percentages. However, those delay factors identified have to be addressed, as the total duration of phase will change with the project scope.

5. CONCLUSIONS

In this multiple case study, an attempt was made to identify the important delaying factors of the mini hydropower construction, and mitigate measures were proposed concerning the mini hydropower plants in construction industry of Sri Lanka to mitigate the delays and its impacts on the time, cost, quality and the safety of the project. The study revealed that the adverse weather condition, objection from protestors and government authorities, and unforeseen ground conditions are the most significant delay factor among the three case studies. Moreover, weir construction, aqueduct column construction, on ground access road construction, and intake construction were the most delayed phases of the mini hydro power plant construction according to the research findings.

Based on the extracted information of this study, few recommendations can be made to mitigate the causes of delays which can be attributed to the clients and contractors with respect to mini hydropower plants construction projects in Sri Lanka. It seems to be important that the client will have to make measures to educate the villagers, local politicians, NGOs and environmentalists about the project clearly and the advantages of the project to the country and the villagers before starting the project. Even though the adverse weather cannot be addressed lack of proper management with weather schedules, also had increased the severeness of delay. Moreover, it was found that proper site investigation should be done to mitigate the structure break down due to earth slips, this is important due to the challenging environmental conditions where hydro power plants are situated.

Additively, attention must be focused on the weir construction, aqueduct column construction, on ground access road construction and intake construction; thereby the contractor has to be informed to take extra care in these phases. Interestingly the delays observed in these phases had some relation with the technicality/ difficulty of workmanship. Frequent design changes in the weir construction, aqueduct channel and the intake construction is an evidence of that fact. However, overwhelming the technical difficulty, other common delays like weather conditions and objection from third parties have affected the delay in these phases as well.

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