Study on the Impact of Cost Controlling Techniques in Mini Hydropower Projects in Sri Lanka

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ABSTRACT

Due to the worst economic crisis, Sri Lanka is currently facing sporadic power failures. There is a lack of dollar reserves to pay for the fuel suppliers and the existing national grid network has failed to power the whole nation. The prevailing situation is becoming quite challengeable since there is a huge power crisis due to the shortage of fuel oil which causes to fail whole operations of oil power plants. Therefore, Sri Lanka has relied on hydropower for a majority of its electricity needs. The share of mini hydropower power plants is performing a significant role in contemporary electricity generation considering national policy targets in order to move with sustainable green energy. Consequently, the necessity of the establishment of MHP plants has become higher but there are significant cost overrun factors identified in the construction phase of MHP projects. This research was carried out to identify the cost overrun factors in MHP projects in Sri Lanka. As a result, efficient cost-control measures will be required to address the above matter. Therefore, it was expected to explore the current practices of cost control techniques used in infrastructure projects based on the findings. Various cost control approaches have been created from time to time throughout the last few years. These may include Earn Value Management (EVM), performance reviews, variance analysis, value engineering, site meetings, work programmes, daily material and labor controlling, etc. The data collection process was conducted through questionnaire surveys which are distributed between industry professionals who have enough knowledge and experience regarding the MHP projects. The set of data was converted into quantitative values and collected data from the questionnaire surveys were evaluated by using percentage analysis and weighted score analysis. The results indicates the challenges in current cost control practices and identify the mechanisms to overcome those challenges and determine their effectiveness in mini hydropower project delivery in Sri Lanka.

KEYWORDS: *Mini hydro power, renewable energy, cost overrun, cost control, cost controlling techniques*

1 INTRODUCTION

As a tropical country, Sri Lanka is exalted with abundant renewable energy resources that have fueled the economic growth of the country for decades. (Salim & Rafiq, 2012) Renewable energy is derived from naturally renewable but finite flow sources. Renewable resources have an endless lifespan, but a finite amount of energy per unit of time. (Anon., 2000). Major variants of renewable energy are wind, sunlight, bioenergy, geothermal, solar, hydropower and ocean power that are currently consumed in the major sectors such as electricity, heating, cooling, and transportation. The perceived risks of utilizing fossil fuels have fueled interest in renewable energy (Moriartya & Honnery, 2012) .Though big hydro resources played a major role in the past in terms of renewable energy share, variable renewable resources such as wind and solar are now becoming major contributors in the future (Bull, 2001). Governments in both developing and developed countries have encouraged the utilization of renewable energy sources because of their high level of productivity, less contamination, and maintenance costs. (Li , et al., 2022)The aforementioned variables combine to promote the global renewable energy market by increasing demand for renewable energy.

In the current practice, different cost controlling methods are utilized in the construction industry. But the common problem is that lack of awareness about those cost controlling techniques. (Senanayake, et al., 2021)Hence, it is important to have better insight on the challenges of current cost control practices

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and identify mechanisms to overcome the challenges and determine on MHP projects in Sri Lanka. Controlling project costs is a difficult undertaking that necessitates an understanding of cost-controlling approaches. As a result, construction industry professionals must have a theoretical understanding of cost control approaches. Accordingly, the findings of this study will assist in evaluating the applicability of cost control techniques in the construction phase of MHP projects in Sri Lanka.

2 RESEARCH PROBLEM STATEMENT

Sri Lanka is currently facing a number of issues due to the economic crisis. Since there is a severe shortage of fuel, the authorities of Sri Lanka failed to fulfil the electricity needs of the whole nation. However, most foreign countries have overcome such issues to a certain extent by developing hydropower projects which are considered the least-cost electricity source. As a solution for the power crisis in Sri Lanka, generating electricity using mini hydropower projects is an ideal solution. But still, one of the key challenges of a mini hydropower project can be identified as cost overruns. Most of the mini hydropower plant developers are facing financial problems because of project expenditure exceeding the budget during the implementation stage. These financial challenges prevent the project from being implemented and eventually starting projects. Delay in contracting projects deprives the developer of revenue and the country loses energy. Most of the mini hydropower developers in Sri Lanka face this challenge. As a result, during the feasibility study, it is essential to identify the cost overrun factors and cost controlling techniques applicable in mini hydropower projects in Sri Lanka. (Malkanthi, et al., 2017) Most of the studies have focused mainly on cost overruns, associated with the development of mini hydro power projects. (Górecki & Płoszaj, 2019)Nevertheless, there has been very few research on the study of applicability of cost control techniques on mini hydropower projects especially in Sri Lanka. Therefore, this research gap is yet to be explored. (Hafez, et al., 2015)

3 AIM AND OBJECTIVE

The aim of the research study is intended to be achieved by the following specific objectives.

1. To identify the cost overrun factors in construction phase of mini hydropower projects
2. To explore the current practices of cost control techniques used in the infrastructure projects
3. To investigate the challenges of current cost control practices
4. To identify the mechanisms to overcome challenges in current cost control practices and determine their effectiveness with respect to the construction of mini hydropower projects in Sri Lanka

4 LITERATURE REVIEW

This chapter has discussed the existing literature regarding the areas associated with mini hydropower projects including the electricity demand in Sri Lanka, the importance of renewable energy in Sri Lanka, the contribution of mini hydropower projects in the power sector, the importance of cost controlling, main cost elements in MHP projects, the current practices of cost controlling methods used in the infrastructure projects and cost overrun factors influencing on the final project delivery.

4.1 Electricity Demand in Sri Lanka

Electricity can be considered as the backbone of modern society. It has become an integral part of the daily lives of all the people around the earth. As a result, the demand for electricity is increasing rapidly every year. Fossil fuels are used extensively around the world to meet this demand. (Ceylon Electracity Board, 2021)

As a developing country in the Asian region, Sri Lanka is currently facing challenges in meeting the electricity demand of the country's population. As a country with a low economic growth rate, restricting the use of fossil fuels is a crucial decision that will not only save money on fossil fuel exports from other countries, but also help reduce harmful emissions. It is observed that Sri Lanka's participation in the use of renewable energy resources for the power generation is relatively low compared to

European countries. Thus, an overview of the viability of fully renewable resources to meet the country's energy needs is crucial. (Umayangani, 2019)

4.2 The Importance of Renewable Energy in Sri Lanka

Renewable energy resources are those that can last forever compared to human life. Primary renewable resources include solar energy, planetary energy, and geothermal energy, while secondary renewables include wind, wave energy, biomass, and hydropower.

To mitigate its adverse effects, such as man-made climate change and global warming, it is necessary to reduce usage of fossil fuel and shift from the renewable resources to green energy production. Many governments and environmental groups have taken the lead in reducing carbon emissions by adopting standards and agreements for each country. Furthermore, many developed countries are conducting large-scale experiments and research to improve the efficiency of renewable energy extraction for energy production. As it has become essential for the conservation of the environment, the energy contribution of renewable resources to the overall energy generation of many countries is increasing. (Mittal , et al., 2021)

As a developing country, Sri Lanka has recently embarked on a renewable energy initiative. Due to its geological location, Sri Lanka is in good condition for solar, wind and hydro resources. It receives considerable amount of sun radiation across the country due to its vicinity to the equator, and since it is an island, coastal areas experience a significant wind flow rate. There are significant number of rivers originated and flowing in all directions towards the sea because of the hill-side is in the center of the country which makes perfect for the hydropower generation. It is important to use all available renewable energy sources, as the rising energy demand will lead to an energy crisis in the coming years. (Sri Lanka Sustainable Energy Authority, 2021).

4.3 The Definition of Hydropower

Hydropower is one of the primary sources of converting the compressive energy and kinetic energy of water into more easily usable electrical energy. The prime mover in the case of hydropower is a water wheel or hydraulic turbine which transforms the energy of the water into mechanical energy. Hydropower is a key source of electricity generation in Sri Lanka and practically contributed to all of this until the early 1990s. A significant percentage of the country's vast hydro potential has already been developed, providing the country with significant low-cost power. Hydropower facilities are now used to meet peak and basic energy output requirements. The Standardized Power Purchase Agreement (SPPA) includes a significant number of mini hydropower plants and is expected to join another force in the coming years. (Egre & Milewski, 2002)

4.4 The Contribution of Mini Hydropower Projects in Power Sector in Sri Lanka

Apart from mega solutions such as the establishment of major hydropower plants, the solution to the power shortage is to implement mini hydropower plants. Therefore, the Ceylon Electricity Board has invited private sector investors to generate mini hydropower plants. The CEB provided assistance in the 1990s for the development of the mini hydropower industry, including training and capacity building, pre-feasibility studies and resource assessment as well as essential assistance to the private sector. Since 1997, it has been formalized with the publication of the CEB's Standardized Power Purchase Agreement (SPPA) for the purchase of electricity from Small Power Producers (SPPs). (Ceylon Electracity Board, 2021)

While the power shortage is hampering economic growth, the provision of electricity infrastructure by mini hydropower plants has provided new opportunities for local enterprises. As a developing country, Sri Lanka is experiencing a rapid increase in electricity demand. Compared to fossil fuels, hydropower has long been considered an environmentally friendly and cost-effective source of electricity. Hydropower generation plays an important role, and as the exploitation of large hydropower sources reaches its limits, smaller streams can play a significant role in meeting demand at lower cost. (Morimoto & Munasinghe, 2005) As a result, there is an urgent need to investigate the difficulties of the existing mini hydropower plant and to conduct research on strategies to enhance power generation from these resources. The exiting literature reveals that there is a risk of construction costs for MHPPs.

Therefore, this study was conducted to investigate the challenges of current cost control practices and identify the mechanisms to overcome the challenges and their effectiveness on MHPPs. (Gunatillake & Thiruchelvam, 2003)

4.5 Main Cost Elements Involved in Mini Hydropower Projects

The main cost elements of a mini hydropower projects are identified as preliminary expenses which consist of the cost for getting approvals, the cost of the land, civil construction cost, electromechanical equipment expenses, taxes, contingencies and so on. (Mishra, et al., 2012)

Preliminary expenses

Getting approvals from different authorities such as Local Government, CEB LOI, Central Environmental Clearance, is identified as preliminary expenses. Getting approvals is a time-consuming task which comes as the cost at the end of the process. A common problem in a mini hydropower project is that during the construction phase, the structure has to be altered because of the design problems. Therefore, it is safe to give more consideration in the design stage to get better design rather than spending more time and money on future consequences.

Civil construction cost

According to different feasibility factors, most of the hydropower sites are unique from each other. Therefore, the construction cost for civil works mainly includes cannel construction, powerhouse construction, dam construction and the cost for the access road. Apart from that, the cost for weir, forebay, desilting tank and intake are included.

Electro mechanical equipment expenses

This is the major cost element which makes a big impact on the project cost of mini hydropower. Under electromechanical equipment expenses, the cost component for all the necessary accessories such as turbines, controls, generators, transformer, and switchyard are included. The cost for this equipment is very high due to its high efficiency, fully automated and sophisticated features.

The cost for penstocks

The cost of the penstock includes the fabrication of the penstock with installation and transportation.

Other cost headings

Although most of the hydropower projects are financed through long-term loans, the developer also has to pay interest which is covered as the operative cost. In addition to that, the taxes, project management cost and cost for contingencies are incorporated as other cost components.

4.6 Cost Overrun Factors in Mini Hydropower Plants

Cost has proven to be the most important determinant in project success. Cost overruns in the construction industry are common, and It is common for construction costs to be high and they happen in almost every project. When the actual cost of a project is higher than the original estimate, the cost overrun happens. (Azhar, et al., 2008) The majority of cost overruns occur during the construction stage when forecasting numerous unanticipated events during the design and planning stages. Inadequate site management and monitoring, decision-making disagreements, and client-driven changes have led to project costs exceeding during the construction. (Doloi, 2013)

In the case of mini hydropower projects, the major costs are involved in build up the power plant. In general, initial costs for construction and machinery are higher than the operational and maintenance costs of hydropower projects. As a result, exceeding any project cost has a negative effect on the profitability and financial feasibility of the project. If the additional costs are not for the benefit of the final output of the project, any increased primary investment will result in longer payback periods. With time overruns, project costs will increase due to the price escalation of materials and rising labor rates.

Lack of adequate supervision, inexperienced contractors, inefficient project management team, political interference, external consequences like weather conditions, natural disasters, changes in technical design and pre-feasibility studies, inadequate geological and technical investigations at the project start-up, initial cost estimates based on inadequate information and impractical assumptions, lack of material or transport facilities and the shortage of labor were identified as major cost overrun factors in mini hydropower projects. In addition to that, in case of significant change in the economy of a country or regulatory aspects will impact on cost overruns. (Awojobi & Jenkins, 2016) Design changes, schedule delays and exchange rate fluctuations were the three main factors that had the highest impact on project cost overruns. When comparing these three variables, design changes and schedule delays are the most common cost overrun factors identified in the mini hydropower projects. Due to the high share of import costs associated with mini hydropower projects, exchange rate fluctuations have been identified as specific to the mini hydropower industry, especially in Sri Lanka. Therefore, the study on applicability of cost controlling techniques to manage the final project delivery is a significant research area as a solution for cost overruns. (Jaber, 2012)

4.7 The Importance of Cost Controlling in Mini Hydropower Projects

Cost control is the process of limiting spending in order to avoid excessive spending that affects profits. The construction sector is critical to any country's economic progress because it provides a safeguard for interests in terms of economic and social aspects as well as infrastructure facilities to ensure that these activities run smoothly. (Bahaudin, et al., 2012) Despite the complicated nature of the work performed by the construction sector, cost and time must be effectively controlled and managed if the contractor's expected profit margin is to be met and the project to be done within the budget of the client. Due to the severe economic crisis, there is a potential to impact both clients and contractors' stance toward project cost control. (Chigara, et al., 2013)

The project cost control commences at an early stage of the project life cycle, from formation to construction and beyond. The best time to save money is during the pre-construction phase, when the project is still in its early stages and no significant costs have been incurred. (Bahaudin, et al., 2012) Cost management is the procedure of designing and planning a project to ensure that its construction is valued and tailored to the client's expectations. (Potts, 2008) Current project cost control and monitoring processes are largely used to assess and correct cost deviations from the scope of work, implying that cost overruns have occurred. (Bahaudin, et al., 2012)

Sri Lanka would need to install large capacity to fulfill present and future power demand, which is expected to grow at a rate of roughly 5% per year. (Ceylon Electracity Board, 2021) Most of the large scale water resources have already been used. Therefore, this is the best time to look at other alternative energy sources. Solar energy, thermal energy and mini hydropower are such possible energy sources that can be used to address the problem. Perennial streams and sudden elevation drops in the river valleys create excellent conditions for the MHP generation.

The government of Sri Lanka needs the country to be energy self-sufficient state by 2030. By 2025, the goal is to boost the country's power generation capacity from 4,043 MW to 6,900 MW, with a major increase in renewable energy. Sri Lanka is very rich in terms of water resources and has a proud history over the last 2500 years. (Ceylon Electracity Board, 2021) Low-cost energy is a requisite for almost all the developing countries in the world including Sri Lanka. Adequate power has been an important issue over the last 25 years. Fortunately, there were enough water resources in the country to address the problem at the initial stage.

Due to the capital-intensive technology, hydropower generation requires a substantial feasibility study, a good design and civil engineering works that take a long time to develop and construct. Hydropower projects involve two major cost elements which are identified as costs for the civil works and electro-mechanical equipment costs. Under civil works, the cost should be mainly concerned with dam and reservoir construction, powerhouse construction and canal construction. The electro-mechanical equipment cost includes for turbines, cabling, transformers, and control systems, etc. The capital cost for hydropower projects vary greatly based on site conditions, design choices, and material and labor costs. (Mishra, et al., 2012)

The existing literature reveals that the construction cost of mini hydropower projects cannot be managed since the technical evaluation and financial evaluation of electrical and mechanical equipment

is very critical. Cost control should be handled wisely in a mini hydropower project where quality is not compromised, and the result will never be achieved unless the project is disrupted. The project can be delivered on time with proper planning and cost control. (Paish, 2002) When considering the mini hydropower development, the project cost variation is very sensitive. Many projects are implemented by using external funding sources (70% of the project cost is funded by the bank) Therefore, the project cost management is required to run the project smoothly and manage cash flow until the end of the project. Due to the economic crisis, all the tariff rates and expenses are getting increased with inflation. Therefore, it is required to control the cost involved in the construction phase of mini hydropower projects. Furthermore, by controlling the cost of the project, it can provide significant financial benefits to working communities as well. Since there are many unforeseen circumstances involved in mini hydropower developments, it is important for controlling cost. Moreover, cost controlling is a key task to achieve quality and timely delivery of the mini hydropower projects. Therefore, it is crucial to establish proper systematic and comprehensive cost controlling methods. (Saad & Al-Jibouri, 2003).

4.8 Current Practices of Cost Control Techniques Used in the Infrastructure Projects

The progress of a country depends heavily on the construction industry. The success of an individual project is defined by how well it can meet project objectives, including the timely completion of the project and the estimated budget while maintaining the appropriate quality. Project planning and monitoring are both necessary in achieving above mentioned objectives. Cost overrun is a key issue that many contractors face, resulting in lower-guaranteed profits for the contractor and a slew of other issues for all parties involved.

In terms of fuel resources, hydropower has a significant advantage over other major power plants that generate electricity by burning fossil fuels. The establishment of the MHP generation is also gaining popularity around the world due to its abundance of resources. The construction phase of MHPPs involves a variety of costs in conducting pre-feasibility studies. (Hafez, et al., 2015) It is crucial to practice cost controlling techniques to solve these issues. As a result, it is important to investigate the challenges of current cost control practices and identify the mechanisms to overcome challenges and their effectiveness on mini hydropower projects.

Project management involves both project progress and cost control. In MHP projects, there are several cost management methods that can be implemented. It is important for contractors to have an understanding of the effectiveness of cost control measures as well as how to apply them to reduce cost overruns. Controlling project costs is a difficult undertaking that necessitates an understanding of cost-controlling techniques. (Premalal, et al., 2013) There is a primary need to boost construction work while lowering costs at the same time. Theoretical and practical knowledge of cost management approaches is required for the industry experts. There are a multitude of cost-cutting approaches and project management software available, yet they still fall short of meeting the basic target requirements of a project. Cost overruns are widespread all around the world, despite various cost management strategies. (Azhar, et al., 2008) Management should take the appropriate procedures to keep human resources under control. To achieve the objectives, it is important to explore the foundation of knowledge by determining the influence of existing cost-cutting measures on selected management approaches in the Sri Lankan context. (Kawmudi, et al., 2018)

Cost control is the process of managing the construction cost of the project using effective methods and techniques so that the contractor does not lose money while carrying out the project activities. According to available literature, contractors in infrastructure projects use a variety of cost control approaches such as performance reviews, MS project, variance analysis, site meetings, forecasting, work programs, daily material & labor controlling etc. All above listed cost control methods are using very often to monitor the health of the project and to take remedial measures. In addition to that, those techniques are used to control EOT (Extension of time) and control payments on extra works. It is important that the project implementation program should be finalized with contractors, client, and engineer prior to the commencement of construction work. Daily material & labor controlling is used to manage available resources, reduce wastage, and parallel resource allocation. (Hafez, et al., 2015)During the monthly review meetings, it should be discussed the balance works estimation. It will indicate the position of the total cost. In MHP projects, variance analysis, site meetings and work programmes are most commonly used for cost controlling. Since the scale of MHP projects are small, very few staff are

being used, and this will limit usage of special techniques for cost control. High level forecasting is another popular technique applied in MHPPs. Since the critical works are engaged in the construction stage of MHPPs, it is safe to assign cost targets for each of structure like dam, canal, forebay, powerhouse, etc. (Górecki & Płoszaj, 2019)

5 RESEARCH METHODOLOGY

The aim of the research paper is to improve the modern cost control techniques for managing the final project delivery of MHPPs in Sri Lanka. The research study relied on quantitative data collected from a questionnaire survey which is distributed among industry professionals working at the MHP projects in Sri Lanka. The questionnaire is prepared with structured questions (close-ended questions) related to cost overrun factors and cost control techniques and open-ended questions related to the impact of cost controlling techniques on final project delivery, challenges in current cost control practices and mechanisms to overcome the challenges in current cost control practices. The questionnaire was given to selected participants who are responsible for cost controlling and who are experiencing the current cost control practices in the MHPPs. This ensured that the data collection methodology addresses the rich information relevant to the study. Since the MHP projects are not widely ongoing in Sri Lanka, the population we can assess is limited. Therefore, only 30 questionnaires were distributed among management personnel with substantial expertise in the MHP sector.

6 RESULTS & FINDINGS

6.1 First Stage of Findings - Descriptive Analysis for Close-Ended Questions

Questionnaire surveys were used to obtain data for the research study. Respondents have been asked multiple scale questions regarding cost overrun factors and current practice of cost controlling techniques in construction phase of MHPPs. The results of the structured questions were studied using descriptive analysis to gain a better knowledge of the data distribution, which made it easier to come up with conclusions.

Details of the sample

It can be challenging to select the most appropriate sample of respondents for a questionnaire survey. When conducting the questionnaire survey focused on the experience of the respondents, hence selective sampling technique was utilized. (D'Addabbo & Maglietta, 2015) Survey participants were selected from professionals who are experienced in mini-hydropower generation in Sri Lanka and were mainly in the professional categories of project managers, quantity surveyors, and engineers. Further, special attention was paid to ensure the reliability of the data by employing more experienced respondents for this survey. The experience of the respondents in their profession is depicted in the pie chart in figure 3.

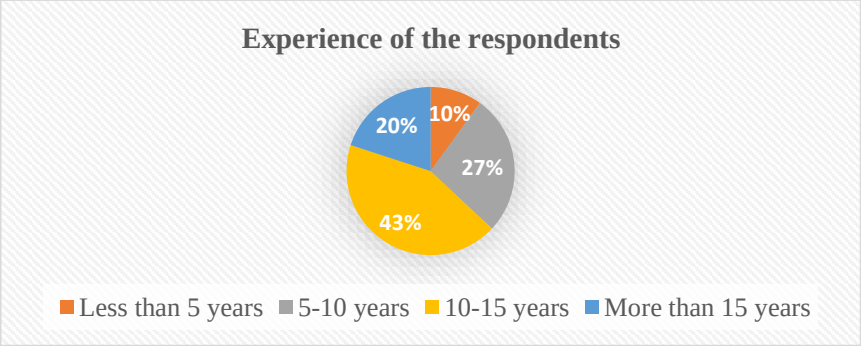

Figure 3: Experience of the respondents

Figure 3 shows that the majority of respondents had worked for more than 5 years in MHPPs, indicating that the survey data was extremely reliable.

Identification of the gravity of cost overrun factors identified in mini hydropower projects

Based on the information obtained from the existing literature, the researcher have identified 13 number of cost overrun factors in MHP projects in Sri Lanka. They are unforeseen circumstances during the project duration, the high cost of imported turbines and generators due to transportation costs and taxes, price escalation of raw materials, significant design changes during the construction stage, low tariff rates from the government, inappropriate government policies, difficulties in approval process, lack of technology and experience, changing the scope of work, fluctuation of exchange rates, and unstable interest rates. The questionnaire survey was used to get the feedback regarding how the professionals are experiencing above mentioned cost overrun factors in construction phase of MHP projects by indicating the gravity of each factor. The opinions of professionals of the industry were evaluated based on the criteria of which they agree on a scale (strongly agree, agree, neutral, disagree and strongly disagree).

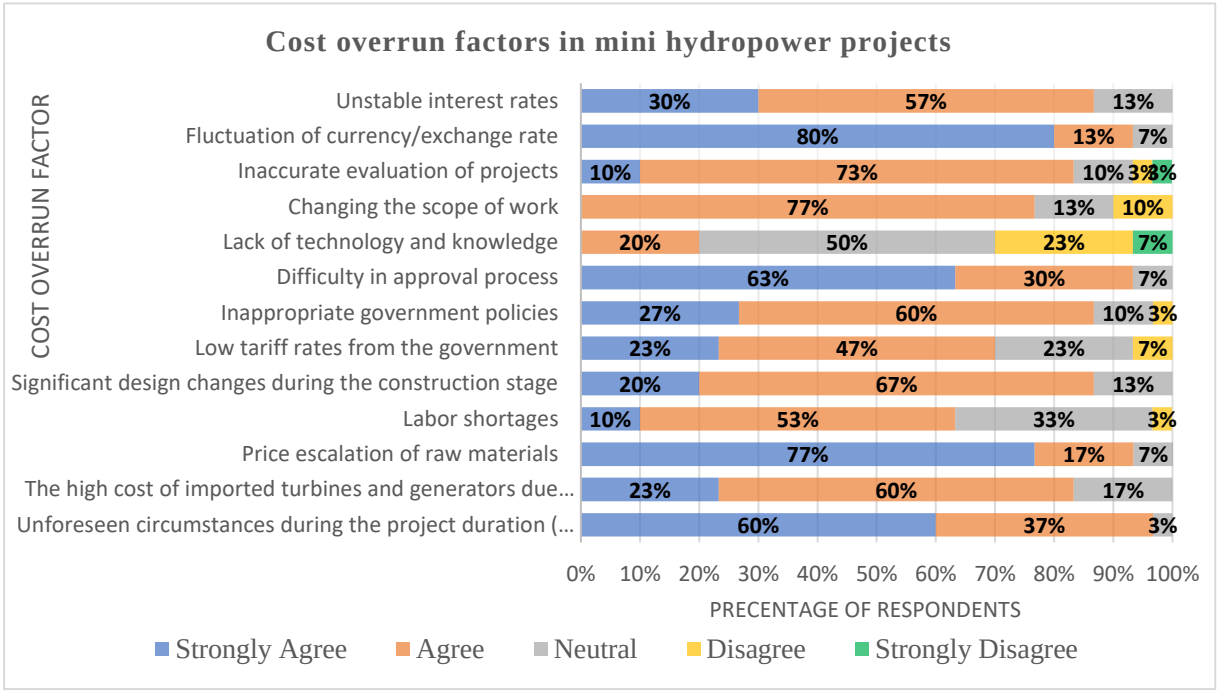

Figure 4: Analysis of the gravity of the cost overrun factors in MHP projects

According to figure 4, it reveals that fluctuation of exchange rates and price escalation of raw materials are the critical cost overrun factors which are 80% and 77% strongly agreed respectively by the respondents who are working in MHP projects. The 63% of respondents are strongly agreed with the difficulty in approval process as second critical cost overrun factor. According to the respondents, 60% of respondents strongly agreed with the unforeseen circumstances during the project duration which is considered as a critical cost overrun factor. Significant design changes during the construction stage has a significant impact on cost overruns in MHPPs which is agreed by 67% of respondents. Not only that, 60% of respondents are agreed with the high cost of imported turbines and generators due to the transportation costs and taxes which is significant effect on cost overruns. Apart from that, other factors also has considerable impact on cost overruns in MHPPs in Sri Lanka.

Identification of the applicability of current practices of cost control techniques in the construction phase of mini hydropower projects

The focus of research study was on the applicability of cost controlling techniques on the construction phase in mini hydropower projects in Sri Lanka. According to the existing literature, 9 cost controlling techniques used in mini hydropower projects have been identified. (Awojobi & Jenkins, 2016)Those techniques are performance reviews, MS project, variance analysis, forecasting, earned value management, site meetings, work programmes, daily material and labor controlling and Building

Information Modelling (BIM). The opinions of participants were taken on scale ranging from very often, occasionally, rarely, very rarely and never to the point being made. By analyzing this data, the study explored the current practices of cost control techniques used in the infrastructure projects and investigated the applicability of those cost control techniques on the mini hydropower project delivery.

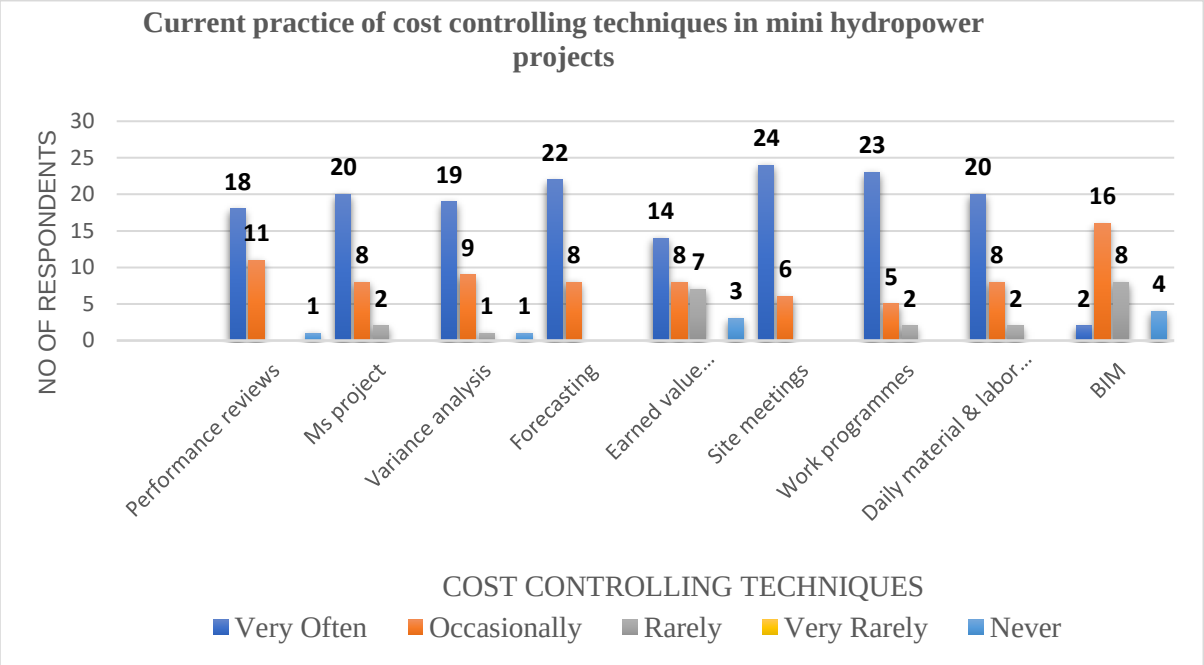

Figure 5: Analysis of applicability of cost controlling techniques in MHPPs

The results of the survey suggest that most industry professionals are aware of the cost control measures available in the MHP sector, however their correct application is not always visible. Techniques for cost control have been highlighted as a method for reducing cost overruns. Forecasting, site meetings, and work programmes were identified as the most prevalent cost control approaches currently being employed by industry professionals. In addition, survey responses revealed that the MS project and daily material and labor controlling were the most widely used techniques in mini hydropower projects. The cost control techniques that are currently used are summarized in Figure 5.

6.2 Second stage of findings – collecting more data on responses to open-ended questions obtained from the first stage of questionnaire survey

The responses to the open-ended questions in the first stage of the questionnaire survey were converted into close-ended questions in the second stage of the questionnaire survey and the questionnaires were sent back to the same 30 number of respondents and feedback was obtained from them.

In the second stage, respondents had been asked structured questions about the challenges of current cost control practices and effectiveness of mechanisms to overcome challenges with respect to the construction of mini hydropower projects in Sri Lanka. The descriptive analysis was used to assess the outcome of close-ended questions to get an understanding of the distribution of quantitative data which has helped to produce the best outcomes for the research study.

Identification of the gravity of suggested challenges of current cost control practices in construction phase of mini hydropower projects

A questionnaire was developed to identify the gravity of challenges using 30 number of responses in order to acquire a fair response based on the information gathered from the literature review. From here on out, a code system will be utilized to signify identified challenges for the ease of the presentation.

Technical Challenges - TC
Social Challenges - SC
Environmental Challenges - En C
Financial Challenges - FC

Table 1: Codes of challenges

Challenge	Code	Challenge	Code
Poor attitude towards ICT usage	TC1	Complexity of the project	TC9
Traditional thinking pattern and inertia for Innovative ideas	TC2	Lack of resources	TC10
Lack of experienced industry professionals	TC3	Difficulty in approval process	TC11
Improper planning and scheduling	TC4	Rate fluctuation in materials, fuel, taxes & payments	FC1
Wastage of materials	TC5	Unpredictable exchange rates	FC2
Quality aspect of cost information	TC6	Unstable government regulations	FC3
Lack of knowledge on the use of available tools and technology	TC7	Critical ground conditions	EnC1
Rural locations	TC8	Contractor and labor conflicts	SC1

During the second phase of the questionnaire survey, 16 challenges were identified in the data collection. The following line graph consists of the identified challenges represented by the codes as illustrated in the above table 1.

The results from the questionnaire survey was evaluated using the RII (Relative Importance Index), and respondents were given a scale from 1 to 5 to rate the severity of the challenges in current cost control practices and identify the strategies to overcome challenges in current cost control practices and their effectiveness on MHP projects . The survey used a scale since it allows the researcher to simply quantify the responses and determine their actual opinion about the question.

Table 2. Response Scale used in Questionnaire Survey

Response	Scale (A)
Lowest	1
Low	2
Moderate	3
High	4
Highest	5

The formula used for the analysis is given below;

$$\boldsymbol{RII = \Sigma W / A \times N}$$

Where;
ΣW = Sum of all responses
A = Highest weight
N= no. of Respondents

Table 3: Categorization of RII Values

Weighted value (RII)	Gravity of Challenge	Effectiveness of the Mechanism
0.0-0.6	Insignificant	Insignificant
0.6-0.8	Significant	Significant
0.8-1.0	Critical	Highly Effective

Ex: Calculation of RII value for TC7

TC7 - Lack of knowledge on the use of available tools and technology

Table 3: Number of Respondents for TC7

Gravity option		Number of Respondents
Highest	N_1	24
High	N_2	6
Moderate	N_3	0
Low	N_4	0
Lowest	N_5	0

RII $= \Sigma W / A \times N$

$= (5N_1+4N_2+3N_3+2N_4+1N_5)/ A \times N$

$= (5 \times 24+ 4 \times 6+ 3 \times 0+ 2 \times 0+ 1 \times 0) / 5 \times 30$

$= 144 / 150$

$= \underline{0.9600}$

Weighted value (RII) for TC7 – 0.9600

Similarly, the calculated weighted values for all the challenges are as follows.

Table 4: Calculated Weighted Values for Challenges

Challenge	Code	Weighted values
Lack of knowledge on the use of available tools and technology	TC7	**0.9600**
Unpredictable exchange rates	FC2	**0.9067**
Critical ground conditions	EnC1	**0.9000**
Lack of experienced industry professionals	TC3	**0.9000**
Rate fluctuation in materials, fuel, taxes & payments	FC1	**0.8867**

Wastage of materials	TC5	**0.7933**
Poor attitude towards ICT usage	TC1	**0.7867**
Difficulty in approval process	TC11	**0.7733**
Complexity of the project	TC9	**0.7600**
Improper planning and scheduling	TC4	**0.7467**
Unstable government regulations (low tariff rates from government)	FC3	**0.7400**
Traditional thinking pattern and inertia for Innovative ideas	TC2	**0.5933**
Quality aspect of cost information	TC6	**0.5867**
Rural locations	TC8	**0.5467**
Contractor and labor conflicts	SC1	**0.5200**

X-axis of the graph represents the gravity of each challenge by indicating the scale of 0-1 (RII value) and Y-axis shows the challenges in current cost control practices.

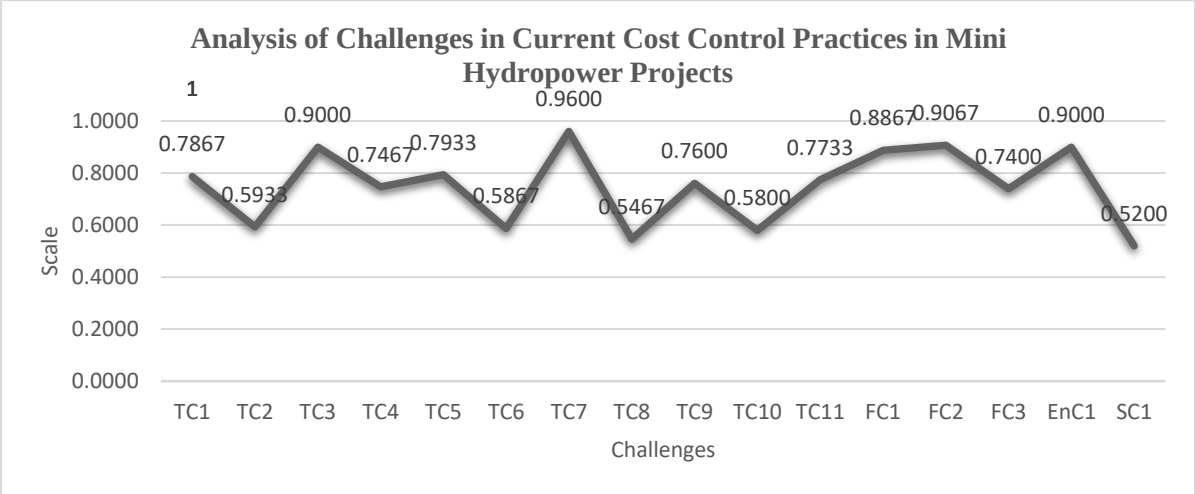

Figure 6: Analysis of challenges in current cost control practices in MHP projects

According to figure 6, it can be clearly seen that the most critical challenge in current cost control practices of mini hydropower projects is the lack of knowledge on the use of available tools and technology which is indicated using (TC7), showing the value of 0.96. Apart from that, lack of experienced industry professionals (TC4), Rate fluctuation in materials, fuel, taxes & payments (FC1), unpredictable exchange rates (FC2), and critical ground conditions (EnC1) are also cause critical challenges showing more than 0.80 RII value. There is an environmental challenge which shows an insignificant effect in current cost control practices in mini hydropower projects. According to the result obtained for the social challenge, contractor and labor conflicts shows insignificant challenge in current cost control practices in mini hydropower projects showing 0.52 RII value. According to the graph, most of the technical challenges show significant and critical challenges towards the current cost control practices of mini hydropower plants in Sri Lanka. Among them poor attitude towards ICT usage (TC1), Improper planning and scheduling (TC4), wastage of materials (TC5), complexity of the project (TC9) and difficulty in approval process (TC11) show significant challenges whereas Lack of experienced industry professionals (TC3), lack of knowledge on the use of available tools and technology (TC7) show critical challenges in current cost control practices of mini hydropower plants. When considering financial challenges, two challenges cause critical challenge in current cost control practices of mini

hydropower plants. They are rate fluctuation in materials, fuel, taxes & payments (FC1) and unpredictable exchange rates (FC2) which show the higher value of 0.89 and 0.91 respectively. Unstable government regulation is a challenge which shows significant impact on current cost control practices in mini hydropower projects. However, its RII values is in between the range of 0.6-0.8.

Identification of the effectiveness of mechanisms to overcome challenges of current cost control practices in construction phase of mini hydropower projects

A code system has been employed to represent mechanisms for the convenience of presentation, as mentioned in the previous section.

Mechanisms for Technical Challenges - MT

Mechanisms for Financial Challenges – MF

Table 5: Codes of Mechanisms

Mechanisms	Code	Mechanisms	Code
Proper planning of the time and sources	MT1	Enhancement the awareness of employees	MT8
Use of BIM	MT2	Keep relevant spare parts at site	MT9
Use experts in the subject to get advices	MT3	variance analysis and cost value reconciliation	MT10
Conduct monthly detail review meetings	MT4	Cash-flow analysis and work programs	MT11
Use proper ERP system	MT5	Improve simple systems based on excel or basic software	MT12
Hire the skill workmanship to avoid double work and addition structures	MT6	Government incentives	MF1
Improve the knowledge of project staff	MT7	Publish equations for rate variance in bill payments by CIDA	MF2

The first phase analysis of the questionnaire survey identified 14 mechanisms to overcome challenges in current cost control practices. The following line graph shows the effectiveness of the proposed mechanisms represented by codes, as explained above Table 6.

Ex: Calculation of RII value for MT8

MT8 - Enhancement the awareness of employees

Table 6 Number of Respondents for MT8

Gravity option		Number of Respondents
Highest	N_1	21
High	N_2	6

Moderate	N_3	3
Low	N_4	0
Lowest	N_5	0

RII $= \Sigma W / A \times N$
$= (5N_1+4N_2+3N_3+2N_4+1N_5)/ A \times N$
$= (5 \times 21+ 4 \times 6+ 3 \times 3+ 2 \times 0+ 1 \times 0) / 5 \times 30$
$= 138 / 150$
$= \underline{0.9200}$

Weighted value (RII) for MT8 – 0.9200
Similarly, the calculated weighted values for all the mechanisms are as follows.

Table 7: Calculated Weighted Values for Mechanisms

Challenge	Code	Weighted values
Enhancement the awareness of employees	MT8	**0.9200**
Use experts in the subject to get advices	MT3	**0.8867**
Conduct monthly detail review meetings	MT4	**0.8600**
Cash-flow analysis and work programs	MT11	**0.8267**
variance analysis and cost value reconciliation	MT10	**0.8133**
Publish equations for rate variance in bill payments by CIDA	MF2	**0.7533**
Proper planning of the time and sources	MT1	**0.7133**
Improve the knowledge of project staff	MT7	**0.7400**
Improve simple systems based on excel or basic software	MT12	**0.7333**
Government incentives	MF1	**0.7000**
Use of BIM	MT2	**0.5933**
Use proper ERP system	MT5	**0.5867**
Hire the skill workmanship to avoid double work and addition structures	MT6	**0.5800**
Keep relevant spare parts at site	MT9	**0.4933**

X-axis of the graph represents the effectiveness of each mechanism by indicating the scale of 0-1 (RII value) and Y-axis shows the suggested mechanisms to overcome challenges.

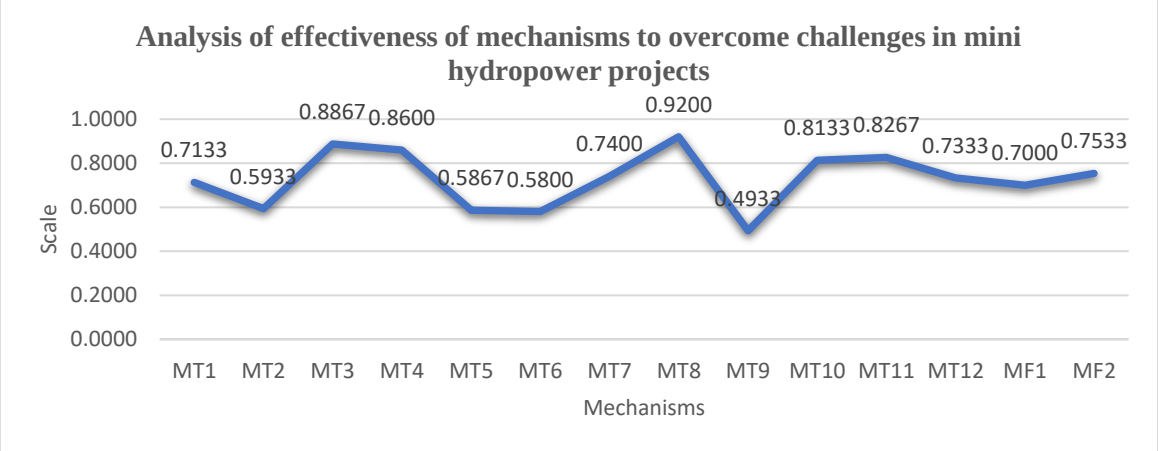

Figure 7: Analysis of effectiveness of mechanisms to overcome challenges in mini hydropower projects

According to the figure 7, it can clearly see that most of the strategies are highly effective but some technical challenges such as using of BIM (MT2), using proper ERP system (MT5), keeping relevant spare parts at site (MT9), hiring the skill workmanship to avoid double work and addition structures (MT6) show an insignificant effectiveness towards the mitigation showing a RII value of under 0.6. Apart from that proper planning time and sources (MT1), improve the knowledge of project staff (MT7), improve simple systems based on excel or basic software (MT12), and provide government incentives (MT13) show a significant effectiveness towards the mitigation of technical challenge by showing a RII value more than 0.6. However, among highly effective challenges variance analysis and cost value reconciliation (MT10) shows a lesser RII value than other challenges. Apart from those, all other mechanisms under each and every aspect show RII values more than 0.82.

7 CONCLUSION

Sri Lanka is plagued by energy shortages, and government investments in large-scale energy development projects are not viable due to the current country's economic downturn. As a result, harnessing renewable energy sources to their full potential through private-public partnerships will help to alleviate the energy crisis to some extent. Many countries are moving toward renewable energy solutions through privatization, and Sri Lanka appears to be following renewable energy solutions in terms of future energy generation plans. Mini hydropower has been considered as the most reliable energy source among renewable energy sources in Sri Lanka. As a result, the demand for MHP plants has increased but these projects show a considerable cost overruns during the construction phase.

Therefore, the first objective of the research was to identify the cost overrun factors in mini hydropower plants. That objective was achieved partially through the literature review and those factors were evaluated through questionnaire survey. It was revealed that most of the mini hydropower projects have faced cost overruns due to the fluctuation of the exchange rates and price escalation of raw materials. As import materials have to be used in the construction of MHP projects, the issue of exchange rate fluctuations will be affected. Not only that, another critical cost factor identified when engaging in MHP projects is the fact that changing the scope of work. Since MHP projects involves critical works, it is difficult to make changes once those work is completed. Moreover, unforeseen circumstances during the project duration is also identified as a major impact on cost overruns. By identifying those factors, there was a need for cost controlling techniques to control costs in the construction of MHP projects. Therefore, it is required to have better understanding on the applicability of cost controlling techniques within the construction of MHP projects.

However, the effectiveness of those mechanisms in Sri Lanka is highly practical but still it is difficult to predict the effectiveness of the mechanisms associated with the speedy approval process and government incentives due to the political instability.

8 RECOMMENDATIONS

This research has explored the impact of cost controlling techniques in mini hydropower project delivery in Sri Lanka through cost overrun factors, applicable cost controlling techniques, challenges in current cost control practices and mechanisms to overcome the challenges. Therefore, the developers should consider to keep the cost of the project within the estimated cost as possible. Otherwise, return on investment will be lower. Apart from that, the return on investment of hydropower projects are fixed, thus only way to optimize profit is by reducing construction and maintenance cost. Further, when a private investor is on board, the main objective of the project will be to reduce the project cost and get a decent IRR. Developer should prepare price escalation since no one know 100% undergrounds soil condition. This can minimize with proper investigation and design before do the project but it is not practical to fully addressed. Therefore, cost controlling should be handle more wisely in hydro project where not compromise the quality ,if not eventually disaster for the project and final outcome will never reach. Furthermore, it is crucial to check the land requirement before executing the project. It has to be followed a community meeting and obtain their expectations. This will help minimize resettlement action plan, expensive commitment with villagers, change of project path and huge cost of alternative design. Experienced estimators shall be worked together with project managers and top level

management to fix the budget for projects as the cost is depending on ground conditions, location, technology etc.

9 LIMITATIONS

The research study has mainly focused on the impact of cost controlling techniques in mini hydropower projects in Sri Lanka. Therefore, the research findings are limited to projects in between 1-10 MW. Further, the study has only considered the cost controlling practices used during the construction phase of mini hydropower projects.

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