Project Schedule Delays and Associated Circular Impacts of Socio-Economic and Environmental Issues that can Affect Sustainability Footprint of Mega-Projects.

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ABSTRACT

The Padma Multipurpose Bridge and the Dhaka Metro Rail mega-projects in Bangladesh have significantly influenced regional identity and culture. Both projects, with costs of US$3.6 billion and US$2.8 billion respectively, experienced substantial schedule delays of up to 9 years. This study examines the socio-economic and environmental impacts of these delays, focusing on the circular effects they create. Circular effects refer to reinforcing feedback loops between socio-economic factors (such as employment, income, and displacement) and environmental factors (such as land use and resource depletion) that exacerbate delays and hinder sustainable development.

A qualitative approach was employed, using a multiple case study design to ensure depth and context. Data were collected through semi-structured interviews with 20 engineers and 40 beneficiaries, selected via purposive sampling to represent diverse stakeholder perspectives. In addition, sentiment analysis was conducted on media reports to capture public perception of the project delays. The data were analyzed using thematic analysis, allowing for the identification of recurrent patterns, including the socio-economic and environmental impacts contributing to the delays.

The analysis revealed seven key factors contributing to delays: inadequate project planning, frequent design changes, miscommunication among stakeholders, and lack of contractor engagement, among others. Each of these factors created a ripple effect, wherein socio-economic disruptions (such as job losses and reduced income) exacerbated environmental impacts (such as extended land use and resource depletion). This cycle, in turn, led to further project delays.

Addressing these circular effects is essential for breaking the chain of delays and their compounding impacts on sustainability. Based on the findings, the study recommends the adoption of advanced technologies, the use of sustainable materials, and the implementation of robust project monitoring systems. These recommendations are grounded in the evidence collected, which showed that addressing the root causes of delays could significantly reduce both the socio-economic damage and the environmental footprint of mega-projects. By implementing these solutions, future projects can achieve more efficient timelines and promote sustainable development.

keywords: Mega-Project's schedule delays and cost overrun, socio-economic and environmental issues and their circular impacts, sustain-ability footprint

INTRODUCTION

The construction process is influenced by highly changing and unexpected variables, which could result from

different sources. These sources include financial, social, and environmental conditions and a multi-directional look at them is essential. Researcher was interested in a better understanding of the factors affecting schedule delays and especially their cross-linkage of the problems associated with social, environmental, and economic issues; these circular impacts could create more significant problems to affect the sustainability of the project performance. Investment of BDT 40,000 crore in Bangladesh to implement 10 mega-projects were to strengthen the country's communication network, and to develop the power and energy sector to boost the economy *(The Daily Star, n.d.).*

This research focused on environmental and socio-economic impacts and also talked about Poverty reduction, Human resource development, Social transformation, Electricity, Gas, and telecommunication connections for the Padma Multipurpose Bridge Project (PMBP) and Dhaka Metro Rail Project (DMRP). After finding the factors of schedule delay of these two projects with qualitative analysis on the site survey data and sentimental analysis on open media sources, research also looked into the risk factors and their possible mitigation via Project Management means.

For the purpose of deriving an understanding of the demographic makeup of the respondents, the respondents were given questions within the questionnaire to mark their respective demographic information. Accordingly, demographic data such as Gender, Age, Occupation, Marital Status, District of Residence, Average Monthly Income were collected from the respondents. Participants groups were the citizens living at both sides of the Padma bridge and near the Dhaka Metro Rail Project in Bangladesh. These are the people, who are affected by construction by different ways like manufacturing, assembling, trading, importing and exporting, transporting etc, and over the age of 18.

DESCRIPTIVE STATISTICS

Researcher was interested in better understanding of the factors affecting project schedule delays and especially on their cross linkage of the problems associated with the social, environmental, economic issues. These circular impacts are shown in the figure 1 - Conceptual Framework.

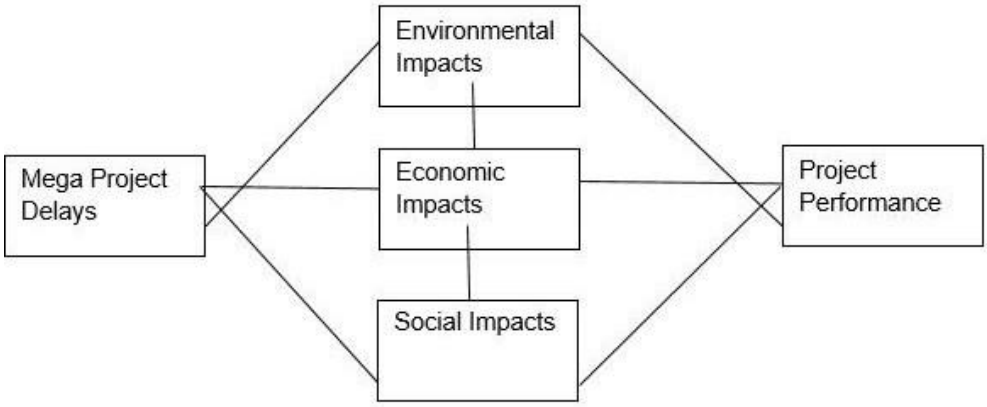

Figure 1: Conceptual Framework

"Sustainability footprint" in a broader term captures environmental and social impacts *(Singh, 2010).* This created bigger problems that affect the sustainability of the project performance.

An overview of descriptive coefficients were summarized and from which the nature of the data set of the data collected from a sample of respondents were understood. Accordingly, researcher intended to provide a synopsis of measures of central tendency (mean, mode, median, etc.), measures of dispersion (standard deviation, variance, minimum and maximum variables) after a qualitative analysis.

The major research ethical issues were data confidentiality and data privacy. Since government project's data are very sensitive, researcher kept all data confidentiality and privacy strictly according to oxford university rules and regulations. Data analysis had been done in a way that would eliminate ethical problems in this

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research. In addition, we had collected open media information on the DMRP project for Sentiment analysis.

LITERATURE REVIEW

By going through the above focused literature review, there is ample evidence for the factors contributing to schedule delays and their impacts on the socio-economic aspects of different countries. The construction industry plays a vital role in the socioeconomic development of a country and generates substantial employment. The issues of time overrun and cost overrun are global challenges in the construction industry.

Shahid et al. (2017) identified that this study reviews the rural residents' perception of public construction project delays and aims to explore economic and social challenges confronted by residents, especially in rural areas in Pakistan *(Shahid, 2017)*.

Manal & Samia Ali et al. (2017) argued that materials delivery is generally blamed for overall project delays, and many studies rank it at the top of the causes of project delays. In an international setting, materials delivery was ranked as the sixteenth technical delay cause in construction projects *(Ali & Ali, 2017; Yates, 2007)*.

Assaf et al. (2006) outlined the main causes of delay in Saudi construction projects in large building projects and their relative importance. Delay factors were categorized into nine groups: Materials, Financing, Government, Manpower, Environment, Contractual relation, Equipment, Changes, and Scheduling and controlling techniques *(Assaf & Al-Hejji, 2006)*.

INFERENTIAL ANALYSIS

The Padma Multipurpose Bridge Project (PMBP) and the Dhaka Metro Rail Project (DMRP) in Bangladesh had overall positive impacts and some negative impacts related to project schedule delays. Most of these negative impacts were mainly construction-related, which would be mitigated by the successful implementation of the environmental management and monitoring plan in a feasibility study report, which contain an assessment of the adverse project impacts, including the extent of land acquisition and resettlement of the affected population.

The recommended resettlement framework would provide measures for mitigation, including restoration of income and livelihoods of the affected people. The Resettlement Policy Framework (RPF) considered the framework and composed a complete inventory of affected persons and assets to prepare for the detailed design period. The RFP should address institutional aspects, including capacity building for resettlement management and monitoring. The timely construction of the bridge project was mainly dependent on land acquisition and resettlement management in this project.

Schedule delay considering Environmental (weather) conditions

Stumpf (2000): Delays are acts or events that extend the time necessary to finish activities under a contract. Halpin (2005): These delays make it difficult or impossible to meet the project completion date. David Thorpe (2008) as construction work is affected by weather and so predicting schedule delay for it is necessary. This is to help planners to make decisions on the optimum construction approach to meet the project schedule under the expected weather conditions.

The work here then targeted on two mega-projects (PMBP and DMRP) for research to evaluate and refine the methodology for circular effects as in research questions to assist all parties involved to make better estimates of project time and deliver cost savings as a result of less uncertainty of Environmental (weather) conditions.

The conceptual framework was justified with empirical data or earlier collected data from a mega-project (PMBP) for two years by using equation-1, as proposed by Thorpe (2008) *(Thorpe & Karan, 2008)*.

$$SD = \sum S_i \times P_i \times D_i \quad \text{(Equation 01)}$$

Where, SD = Schedule Delays,

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S_i =-sensitivity factor of activity i based on its category,

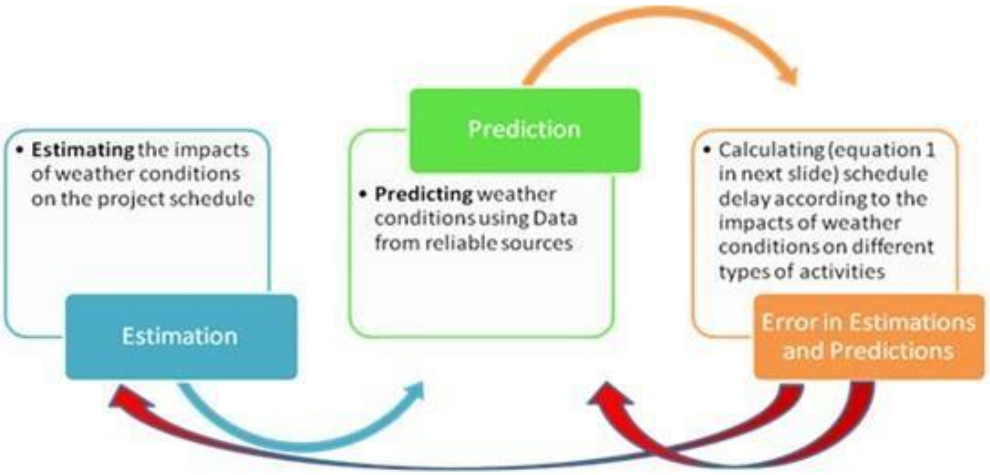
P_i = probability of occurrence of the weather condition,

D_i = duration of activity I during the period of weather condition, and

n = number of activities.

Thorpe D (2008) proposed a process that provides the prediction of the potential schedule delay as a result of environmental (weather) conditions.

Based on above approach, it is postulated that schedule delay could be re-calculated for cascading impacts by equation - 1 for the data collected from PMBP and DMRP projects for circular effects (indicated by red back arrows) as in the research questions:



Environmental Impact Assessment

The weighting of the environmental components to the overall environment, which was based on the consultation among the environmental impact assessment expert members, Md. Faisal et. al. (2015) for Padma Multipurpose Bridge Mega-Project. The degree of impacts on environmental components due to project activities had been measured by qualitative consultations of EIA expert members and the concept and environmental setting of similar large projects, for instance, Jamuna, Paksey, and Paira in Bangladesh *(Faisal et al., 2018).*

An Expert's consultation needed with the Professionals, who specialized in wildlife, ecology, river morphology etc. Secondary data were collected from Bangladesh Bureau of Statistics, bridge construction authorities, construction manager, project manager, chief engineer of this bridge construction project, Local government and engineering department (LGED) and from relevant articles, Md. Faisal et. al. (2015). Potential impacts on various environmental components (e.g., Land Acquisition and Resettlement, Flora/Fauna diversity, Waste, Agriculture, Noise quality, Health safety and hygiene, Employment and poverty reduction, Transport and road accidents, Air quality, Erosion, Water quality, Land use etc) due to different project activities during pre-construction, construction, and operation and maintenance stages had been identified and prioritized through interaction matrix.

Environmental management and monitoring plan

Mega-projects (PMBP and DMRP) in research as well, had overall negative impacts. Most of these negative impacts are mainly construction related which could be mitigated by the successful implementation of the environmental management and monitoring plan. The Padma bridge project had been proposed by the government of Bangladesh for increasing the communication system in southern part of the country. However the project subjected to its nature of activities falls under Red category as per ECA, 1995 and required prior environment clearance from DoE, Bangladesh.

Although the project got delayed by nine years but somewhat successful environmental monitoring plan had been provided for monitoring the air, water, and noise quality; flora and fauna diversity, waste, traffic safety risk, plantation, and health safety during the construction and now in operation and maintenance stages. The project expected to have overall positive impacts and few negative impacts. As most of these negative impacts were mainly construction related which should be mitigated by the successful implementation of the ongoing environmental management and monitoring plan in near future.

ANALYSIS OF THE SOCIO-ECONOMIC IMPACTS

The Padma Bridge Multipurpose Project is one of the large-scale infrastructure projects in Bangladesh and its construction and operation resulted in significant impacts on the various sectors of the economy at the national and regional levels. Research tried to deal with impacts of the PMBP focusing on the national / regional economic growth, promotion of international transport between surrounding countries, distribution of project benefits to poor groups and, influence on the Government financial balance due to the huge amount of investment expenditures. Here socio-economic impacts would be assessed and, as far as possible, quantified based on the available data.

The benefits such as savings in vehicle operating costs and travel time savings accruing from the opening of Padma Bridge are defined, in general, as the “direct benefit or direct impact”, which would be enjoyed by the direct users of Padma Bridge. On the other hand, impacts such as the increase in production and income based on the improvement of accessibility resulting from the direct benefits above are defined as “indirect impacts or induced impacts”. Although the Southwest Region is the area benefiting the most in the country, the impacts of the PBBP would spread over the whole country through the induced effects by its construction. These are multiplier effects of the huge amount of investment in Padma Bridge Multipurpose Project. These impacts would result in additional demand/output of production in related economic sectors, generation of additional factor income (Value Added) and creation of new job opportunities. These kinds of impacts were generated from the demand of input necessary during the construction of Padma Bridge and attributed not only to the Southwest Region but also to the whole country of Bangladesh. It should be noted, however, that the same type and the same volume of impacts would be possible by projects other than Padma Bridge if the same scale of investment is executed.

In addition to the above impacts, induced economic impacts after opening of Padma Bridge Multipurpose Project are more important now because they are induced by using the PMBP itself for daily economic activities and depend heavily on the function of Padma Bridge to integrate the Southwest Region with other areas of the country .This is particularly the case with the Central Region in which Dhaka is located. Induced (or indirect) impacts of this kind were estimated by specifying such a sector (transport sector, in this case) that the demands of the sector are expected to increase immediately after opening of Padma Bridge Multipurpose Project. Initial increase of demand in that sector would stimulate production demands in other related sectors and result in an increase of output, factor income, and creation of new additional job opportunities as well.

Estimation of Multiplier Effects of Investment

Construction of Padma Multipurpose Bridge Project required a huge amount of investment. When such an autonomous or independent investment is executed, demands on intermediate inputs of other sectors of the national economy were stimulated and ripple effects would spread over the whole country. These effects are called Multiplier effects through which increases in production, factor income and job opportunities are expected to be realized.

The formula of multipliers is given by;

<Balance formula>

$$X=AX+F(D) + F(E) - M(AX+F(D))$$

<Model formula>

$X=[I-(I-M)]^{-1}[(I–M)F(D) + F(E)]$

Where,

X = Output vector of sectors

A = Input-Output Coefficient Matrix

F(D) = Final Demand Matrix (except for Export)

F(E) = Export vector

M = Import Coefficient vector associated to domestic demands (AX+F(D)

I = Unit Matrix

$[\ ]^{-1}$ = Inverse Matrix

In the above formula, an inverse matrix different from the "Leontief inverse (I – A)-1" is applied considering the leakage of import. The balance formula indicates that the total output (=X) is equal to the sum of intermediate demands (= AX), final domestic demands (= F(D) and Exports (= F(E) minus Imports (= M(AX+F(D)) *(Zeng, 2001).* Since the economic structure of Bangladesh depends largely upon imports, it is necessary to reflect the influence of imports in the balance formula. Not all the domestic demands can be supplied by domestic output and some portions come from outside the country (imports). In the formula above, output (X) is an endogenous variable and the final demands (F(D) and F(E)) are exogenous variables.

Padma Bridge is not a simple rural road. Therefore, input structure of construction and required quantities/amounts of major material necessary for the construction of Padma Bridge were calculated as below.

Input Structure of Construction of Padma Bridge:

Table 1 : Required Quantities and Amount of Major Material

Major Materials	**Unit**	**Required Quality**	**Basic Price**		**Amount**	
			Local (TAKA)	Foreign (USD)	Local (TAKA)	Foreign (USD)
Rock	Ton	1,400,000		35	0	49,000,000
Cement	Ton	750,000	4570		3,427,500,000	0
Sard	Cum	2,200,000	480		1,056,000,000	0
Aggregate	Cum	210,000	1600		336,000,000	0
Reinforcement	Ton	45,000	37000		1,665,000,000	0
PC strand	Ton	12,000		3500	0	42,000,000
Steel pipe pile (3.0mdiameter)	Ton	68,000		2200	0	149,600,000
Steel pipe pile (0.8m diameter)	Ton	17,000		1500	0	25,500,000
Geotextile	Sqm	840,000	90		75,600,000	0

Bitumen	Lit	2,500,000	20		50,000,000	0
Total					**6,610,100,000**	**266,100,000**
Total(USD)					**110.168.333**	**266,100,000**
Total(USD)						**376,268,333**

Total material costs were estimated at 376 million US Dollars (22,576 million Taka).

Simulation Scenario

The above amounts of major material were applied to the model formula as final demands (investment). In addition to the investment multipliers, demand increase in the transport sector of the Southwest Region was also taken into account. The induced traffic demands of trucks on the Padma Bridge will increase by about 50% compared to normal traffic. It is estimated that the Southwest region accounts for 42% of the national transport services. This percentage was applied and considered a 20% increase (=50% x 0.42) in the final demand of national-level transport services. This 20% increase in final demand in the transport sector was also applied to the exercise of national 'Input – Output model'.

Simulation Results

1. **Induced Output :**Results of the simulation for Induced Output shows that the investment of 22,576 million Taka for the major material will induce an additional output of 54,486 million Taka and would push up the GDP growth rate of the country by 1.2%.

2. **Induced Value Added:** The construction of Padma Bridge would generate induced Value Added of 32,638 million Taka, which is higher by 1.4% than the base case (Without Project case).

3. **Induced Employment:** Induced employment under the same simulation scenario was estimated applying the Labor Coefficient (Man-year per output) to the induced output estimated above. The labor coefficient data were taken from the 'Input-Out Tables for Bangladesh, 1993-94'. Investment for Padma Bridge and demand increases in the transport sector would generate additional employment opportunities of 743,000 man-year (= 271.2 million man-days). This increase of employment corresponds to about 1.2 % of the total labor force of Bangladesh in FY 2000 (60.3 million). It should be noted that the above induced impacts were not realized in a single year. It took 4-5 years because the construction of Padma Bridge requires 4-5 years. Ultimately it took over 9 years delay to complete. It is also noted that adopted Input-Output simulations were carried out under the assumptions of fixed prices even if output increases and no capacity constraints to produce induced demands exist.

IMPACT ON REGIONAL ECONOMY

The Southwest Region would sustain the biggest impacts as a result of the construction of Padma Bridge and provided with a smooth and permanent/all-weather road link over the Padma River to connect with the largest market (Dhaka city). Direct benefits such as savings in travel time (elimination of long waiting time at ferryghats and reducing of river crossing time) will result in remarkable improvement of accessibility to/from other important cities and core facilities in the opposite side of the Padma River. This improvement of accessibility would contribute to regional economic development in terms of Gross Regional Development Product (GRDP).

Due to the lack of available data on the regional Input – Output table and in order to reflect the factor of improvement of accessibility explicitly in a model, a regression analysis was carried out for the alternative methodology to estimate the impacts on the Southwest Region's GRDP. The relationship between the travel time to/from Dhaka and GRDP by district is GRDP/km^2 is a kind of index for "Productivity of land". In addition to this relationship, it is necessary to take into account one more factor to reflect the condition of regional infrastructures such as feeder roads. Therefore, an equation was estimated by the regression analysis as outlined

below:

Ln (G) = 3.0453-0.5482 Ln (T) + 0.4926 Ln (F) (R = 0.902)

Where,

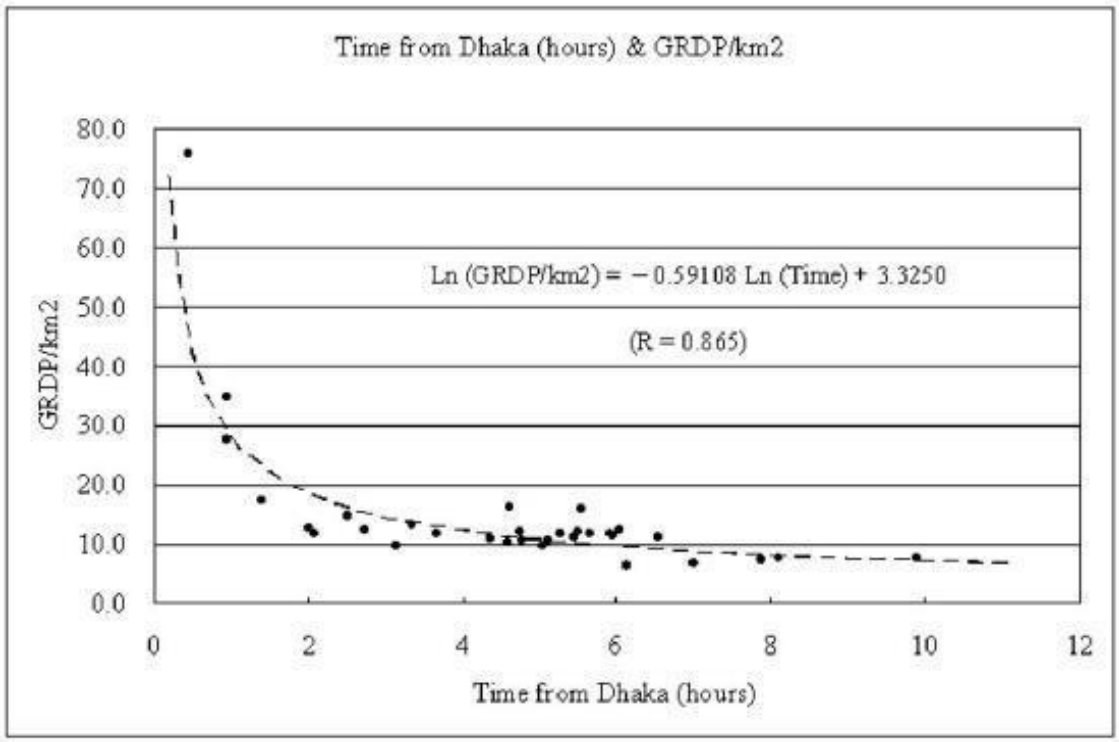
G= GRDP/km2

T = Time to Dhaka from districts in Southwest region (hours)

F = Density of feeder roads (km/km2)

Ln = Natural Logarithm

Based on the above equation and applying the travel time in the "With Bridge Case" (density of feeder roads is fixed), the impact on the change in GRDP was estimated. The results indicate that if the Padma Bridge constructed, GRDP of the Southwest Region will increase by 35% compared to the "Without Bridge Case". However, these impacts will not be realized in the first few years after the Bridge is opened and will require a long term period, 10 to 20 years after opening, before becoming fully apparent. If the Padma Bridge is fully utilized within 15 years of opening, impact rates would be 2.3% per year.



Ln (GRDP/km2) = −0.59108 Ln (Time) + 3.3250 R = 0.865

Figure 2 : Relationship between Time from Dhaka and GRDP

Cost overrun and their prediction of construction projects for socioeconomic impacts

Researcher had considered international research journals to analyze the cost overrun and their prediction of construction projects for socioeconomic impacts and circular affects of schedule delay using methodology with: Regression analysis [Thaseena.T1 , Vishnu. K2 (2017)] and Fuzzy logic / AI network analysis [Karan Gotlur et. al3 (2020) (Gotlur et al., 2020).

SUMMARY

Since Bangladesh is set to graduate out of the group of least develop countries (LDCs) on November 24, 2026, about 50 years after it first become a member of this cohort of developing countries in December 1975. Hence

all mega-projects are playing a significant role in this regard. This motivated researcher to investigate into the factors those affect the overall outcomes of the two mega-projects in Bangladesh – Padma Multipurpose Bridge and Dhaka Mertorail Projects. By ensuring sustainability footprint effects, we can significantly impact the outcomes of mega-projects in various ways. Here are some key considerations:

To optimize mega-project outcomes, it is crucial to integrate sustainability considerations from the planning stage through project execution and operation. This includes implementing robust environmental and social management systems, engaging with stakeholders effectively, complying with relevant regulations, and continuously monitoring and adapting sustainability practices. By addressing the sustainability footprint effects proactively, project outcomes can be improved, leading to greater environmental, social, and economic benefits.

To enhance mega-project outcomes, it is crucial to integrate sustainability considerations into the project planning, design, and implementation stages. This includes proactive stakeholder engagement, robust environmental and social impact assessments, compliance with sustainability standards and regulations, and ongoing monitoring and evaluation. By prioritizing sustainability, mega-projects can improve their chances of success, mitigate risks, and contribute positively to social, environmental, and economic objectives.

Sustainability-related delays can affect the overall timeline and completion of mega-projects. These delays can result in missed deadlines, extended construction periods, and operational delays. Consequently, the project may not deliver its intended benefits on time, leading to lost opportunities and potential economic and social impacts. Mega projects are typically undertaken with the expectation of generating economic benefits. However, sustainability footprint effects can influence the project's return on investment (ROI). Increased costs, delays, and reputational damage can impact the project's financial performance, potentially reducing the ROI or making it more challenging to achieve the desired economic outcomes. Sustainability considerations are becoming increasingly important in long-term project planning for viability. Mega-Projects that fail to address sustainability concerns adequately may face challenges in the future, such as changing regulatory requirements, evolving stakeholder expectations, or shifting market demands. This can impact the long-term viability and adaptability of the project, potentially leading to operational and financial risks.

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Conflict of Interest

The author (Syed Mahmud Husain, Singapore Citizen, Faculty of MBA Programme (Bangladesh), Faculty of Graduate Studies UoK Sri lanka) declares no conflict of interest.

Author Contribution

The author hereby confirms his contribution in the paper by conceptualizing the research, proposing the methodology, collecting and analyzing the data, and drafting this manuscript.

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