CHAPTER 8

Delay Analysis and Remedial Measures for the Project – Execution of 3 Nos Individual Rural Piped Water Supply Projects Balasore District & Mayurbhanj District in Odisha – A Case Study Approach

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ABSTRACT

The Water Supply and Sanitation Project (Name - The Water Supply and Sanitation Project, Odisha, Balasore/ Mayurbhanj Nos. 3 individual Rural Piped Water Supply Scheme, 05 years O&M under one package) faced some critical challenges that influenced its implementation. Among the main problems, one can single out Right of Way delays, as the necessity to get the approval of several departments stifled the work, and disruptions in the supply chain that resulted in a lack of materials. Lack of availability of professional manpower was also an impediment to quality and time schedules of projects [12]. Also, the site was located in the area prone to cyclones and frequent flooding especially in and around the intake well which was the recurrent source of interruption in the past 2-3 years. These issues underscore the importance of proper planning, resources management and mitigation strategies to eliminate the natural and operational barriers in infrastructure projects [8]. Project Coordinate Latitude: 21.521° N, Longitude: 87.532° E.

Keywords: Delay Analysis, Supply Chain Disruption, Environmental impact on construction project, Construction Delay, Supply Chain Management.

1.0 Introduction

This paper investigates the causes of delay through an integrated approach; the objectives of the project are:

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1. Identify and evaluate the key factors causing delays in the execution of rural piped water supply projects in Bhograi, GB Nagar, and Saraskana blocks. This includes:
   - Row material issues.
   - Supply chain disruptions.
   - Unavailability of skilled manpower.
   - Natural and site-specific challenges (cyclone-prone area and flood-affected regions).
2. Assess the impact of delays on project timelines, quality, and operational efficiency, as well as the consequences for the local population's access to water.
3. Propose and prioritize remedial actions to mitigate current and future delays in the project execution, focusing on:
   - Improved supply chain management.
   - Workforce training and allocation.
   - Contingency planning for natural disasters.
4. Suggest enhancements to the project management framework that can better address site-specific issues and integrate preventive measures into the project lifecycle.

2.0 Literature Reviews

2.1 Implementation of construction supply chain flow based on SCOR 12.0 performance standards

M. N. Sholeh, A. Nurdiana, B. Dharmo, and Suharjono [10] overviewed of the application of SCOR version 12.0 as a performance measurement tool of the construction supply chains in a building project in Indonesia. The experiment used SCOR processes of Plan, Source, Make, Deliver, Return and the Enable in the procurement and the use of ready-mix concrete and steel in a precast construction setting. With the help of SCOR Level 1 performance attributes, reliability, responsiveness, agility, cost, and asset management efficiency, the authors evaluated indicators such as perfect order fulfilment, order fulfilment cycle time, supply chain adaptability and the total cost of the supply chain management. The findings have shown that the SCOR 12.0 is applicable to the construction projects by the contextualization of manufacturing-related measures to site-related operations. The paper determined that SCOR offers a systematic and extensive means to assess construction supply chain performance and helps to make superior decisions with the assistance of project-level data and stakeholder contributions.

2.2 Managing supply chain risks and delays in construction projects

Panova and Hilletofth [7] examined how supply chain risks and delays in construction projects are managed with focus on the difficulties with uncertainties in material

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flows and disruption. Construction industry is highly complex and fragmented in its nature, and thus lean principles are hard to put into practice. The authors instead promote an agile paradigm in solving the variability and inefficiencies in a supply chain. The study is based on qualitative and quantitative approaches, such as the dynamic modelling and Monte Carlo simulation, which evaluate the effects of delays on the project schedules and costs. An imaginary construction project is adopted to illustrate how the delays in the material supply may result in huge cost-overruns and long payback time. The paper has emphasized the need to keep safety stock in distribution centres to counter the disruptions even though this would lead to additional warehousing expenses. The major conclusions show that the probability of disruptions, as well as their magnitude, is escalated by the construction delays, the discounted payback period is extended by almost five months, and the net present value (NPV) is decreased by 17%. The paper highlights the importance of highly developed risk assessment techniques, including dynamic modelling paired with Monte Carlo simulation to take into consideration the uncertainties related to the building project that can change over time.

2.3 Barriers to supply chain management implementation in construction

Kim and Nguyen [5] showcased the obstacles that prevent the adoption of Supply Chain Management (SCM) in construction sector. The authors determined that there are 22 main barriers, the most important one of them being lack of effective leadership, incompetence of the SCM parties, and missing knowledge about the concept of supply chain. These barriers were categorized into five causal factors, which include: (1) absence of knowledge and competence, (2) not being supported and actively engaged by the parties, (3) having to deal with culture and adversarial behaviour, (4) lacking the contract system, and (5) inherent challenges in SCM. This research indicated that the most important impediments were leadership and competence inadequacy, whereas industry fissures and short-term project connections were seen to be less severe.

2.4 Cyclone preparedness and response plan

Gujarat Cyclone Preparedness Response Plan [14] highlights how natural disasters like cyclones, floods and earthquakes are very susceptible to construction projects and contribute to their delays. Such incidences upset project schedules, infrastructure is destroyed, and important resources are reallocated to emergency response and recovery. Natural disasters bring about uncertainty and complexity in the construction processes and need disaster resilience strategies. With an extremely sensitive coastline that is 1,600 km long as pointed out by the Cyclone Preparedness Response Plan (2014), infrastructure in the region is particularly exposed to high-speed winds, flooding, and storm surges. Historical facts indicate that severe cyclonic storms have caused enormous destruction to infrastructure like

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the one that hit Gujarat in 1998 that resulted into the deaths of more than 1,100 people and a loss of billions of India rupees. This is because such occurrences result in construction delays caused by work in-progress destruction, disruption of supply chain, labour unavailability, and diversion of financial and human resources to reliefs. As per the plan, the risk of a 100-year return period, cyclone on about 248000 residential buildings will result, which is an example of the magnitude of the possible construction delays.

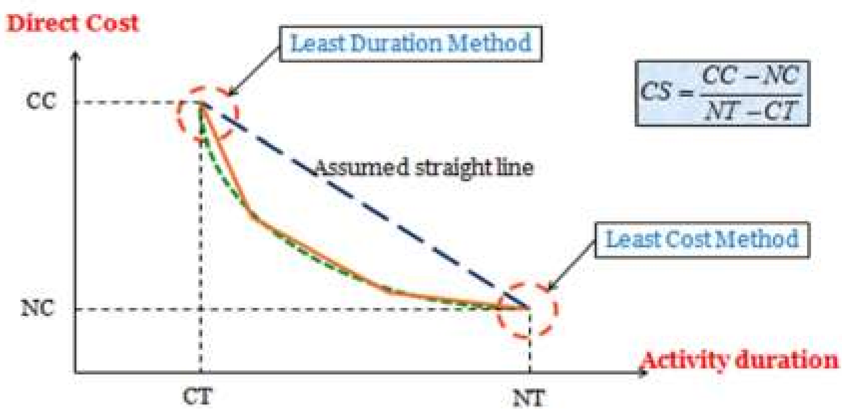
3.0 Research Methodology

This study aims to investigate how delay analysis impacts infrastructure development initiatives, identify its primary causes, and evaluate effective method based on real project evidence. To achieve this objective, the study adopts Crashing Technique [15], integrating quantitative techniques. This approach enables a comprehensive understanding of delay analysis by combining numerical project data with experiential insights from industry professionals.

3.1 Research design

The goal of this research is to study the phenomenon of postpone analysis in infrastructure projects, identify its primary causes, and evaluate effective method based on real project evidence. To achieve this objective, the study adopts Crashing Technique [15], integrating quantitative techniques. This approach enables a comprehensive understanding of delay analysis by combining numerical project data with experiential insights from industry professionals.

Figure 1: Direct Cost Curve for an Activity



Cost Slope = (Crash Cost – Normal Cost)/ (Normal Duration – Crash Duration)
Source: Created by authors

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In cost estimation developing approximation of the cost of the resources needed to complete the project activities. There are cost component those are Direct Cost, Indirect Cost (Project over head & General overhead), Markup or profit & Risk contingency. In schedule crashing reduce original CPM duration of a project to meet a specific deadline in the least manner. In crashing reduce duration by using more productive resource and extending the working hours.

Identify the critical activity with least cost slope then possible duration shorten multiply with Indirect cost. Then calculate total cost = Direct cost + Indirect cost. Reduce the duration of the activity until its crash duration is reached or until the critical path changes. Continue crashing select second minimum cost slope activity from critical path for further crashing. Continue until no further shortening is possible and then crash point reached. Then Compare delay cost data getting from site and crashing cost.

The window analysis method [8] [15], also known as the contemporaneous period analysis or snapshot method, involves breaking down the total duration of a CPM schedule into manageable time segments or windows, such as monthly intervals. The delays occurring within each of these time frames are then examined in sequence, with a focus on the critical paths As planned versus as-built (Total time) method. [15]

The as planned versus as-built method, often referred to as the "total time method" or "net impact method," essentially involves comparing two schedules. This approach operates under the assumption that the contractor does not cause any delays, while the owner is responsible for all delays. [15]

A descriptive and analytical case study approach also adopted to solve major issue related to supply chain management. The research focuses on identifying delay-related issues across the construction supply chain and mapping them to SCOR processes [9] [10] and performance attributes. The methodology follows the approach recommended in construction-based SCOR applications, where manufacturing-oriented SCOR metrics are contextualized for project-based environments.

The Supply chain operation reference model is adopted in the study as a tool to evaluate supply chain performance of the project which will helps us find and diagnose supply chain related delays in a Rural Water Supply and Sanitation (RWSS) construction project. The methodology followed a systematic, multi-stage approach integrating field-level data collection, understanding scope, performance measurement, and categorization of activities based on SCOR process attributes & SCOR performance attributes, & defining the key Performance Index for the SCOR process and Performance attributes and at last preparing a SCOR model which identifies the causes of delay measures against KPI's and suggesting actionable measures to prevent delay.

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The RWSS project located in Balasore district (Bhograi Phase-II, GB Nagar, Saraskana) faced delay due to some supply chain activities like material management issues, communication mismatch, delayed plan approvals, and other statutory approvals. The scope of the SCOR application was restricted to supply chain–related activities affecting project planning, procurement, execution, delivery [7], returns, and enabling systems. This ensured that the analysis remained focused on supply chain–induced delays rather than design or structural deficiencies.

Investigation of causes for delay:

- One of the major issues was related to land acquisition & clearance issue from the government [1], [8] which caused delay in project.
- Issues related to statutory approvals and design approvals and last-minute changes in working drawings.
- Improper planning of resources like late procurement issues [7], [6], frequent material shortages [1], [8], [11], vendor related delays, Payment clearance issues.
- Subcontractor related issues like non availability or inefficiency contributing to delay in the project.
- Productivity loss due to adverse weather conditions [11], [14] (rain, heat, flooding), ranging from 6–20%. Seasonal constraints affecting excavation, concreting, and pipe-laying activities.

3.2 Data collection methods

In our project we collect the site data like RA Bill, Contract documents, Annual operating plan, PA Bill, MSP Schedule. Then taken one segment of the project Bhograi. Going with Bhograi separated critical activity Name those critical activity Topographic Survey, Intake well, RWRM, WTP, CWRM, ESR, Distribution, Compound Wall, Testing, O&M respectively A, B, C, D, E, F, G, H, I, J. Then use crashing technique and compare the actual cost of the project with delaying cost of the project and prepare conclusion.

Data were also collected through a structured questionnaire survey administered to construction professionals actively involved in infrastructure project execution. The respondents included project managers & planning engineers,

The questionnaire included both quantitative and qualitative questions covering SCOR processes [9], [10] such as planning, sourcing, execution, delivery, and coordination, along with performance attributes including reliability, responsiveness, agility, cost, and asset utilization [12]. Responses were collected on aspects such as schedule preparation and updates, drawing and approval delays, material shortages [7] [1], [8], [11], subcontractor [5] performance, productivity losses due to weather, payment delays, rework occurrence, and cost impact of delays. The collected responses provided practical, site-level insights into real project conditions and formed the basis for SCOR-based performance analysis and delay assessment in this research Secondary Data Collection

4.0 Data Analysis

In our project we followed window analysis method [8], [15]. Where we took a part's critical path of the ongoing project. There we took that crucial activity of the projects on the critical path. Then calculate pending cost and remaining duration of the project activities to complete the project. Calculate direct cost to complete the project. Calculate approximate cost to complete the project. Then reduce the duration of the project using crashing technique [2], [4] on remaining duration. Then we show the increased cost using crashing technique [2], [4] is less than the project cost required to complete the project. In crashing technique [2], [4], we increase resource and manpower and reduce the indirect cost. But to complete the project normally indirect cost is more loss will be more.

Table 1: Project Activity Details

Activity	Progress Percentage	Remaining Percentage	Total days	Remaining Days	Total Amount (in Cr)	Remaining Amount
A	96%	4%	232	10	1.09	0.05
B	53%	47%	420	199	5.46	2.58
C	91%	9%	195	17	15.28	1.33
D	24%	76%	544	411	16.37	12.37
E	73%	27%	510	136	25.09	6.67
F	96%	4%	390	14	12.00	0.43
G	90%	10%	585	58	21.28	2.11
H	49%	51%	360	184	0.55	0.28
I	0%	100%	184	184	1.09	1.09
J	0%	100%	60	60	10.91	10.91
		Total	3480.00	1272.44	109.12	37.82

Source: Created by authors

Table 2: Indirect Cost Assumption

Indirect cost (10 % of Direct Cost)	3.782190977
	0.002972401
	29724.01103
Approximate Rs/day	30000

Source: Created by authors

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Table 3: Activity Details with Remaining Duration

Activities	IPA	Duration	Normal Cost
A	B	10	0.05
B	C	199	2.58
C	D	17	1.33
D	E	411	12.37
E	F	136	6.67
F	G	14	0.43
G	H	58	2.11
H	I	184	0.28
I	J	184	1.09
J	End	60	10.91
			37.82

Source: Created by authors

Table 4: Cost Schedule Table

Cycle No	Duration	Direct Cost (Cr.)	Indirect Cost (Cr.)	Total Cost (Cr.)	Remarks
1	212	37.82	0.636	38.4579	Crash @212 days for D
2	15	38.46	0.045	38.5029	Crash @15 days for B & D
3	48	38.50	0.144	38.6469	Crash @48 days for B & D & H & I
4	76	38.65	0.228	38.8749	Crash @76 days for B & D & E & H & I
5	2	38.87	0.006	38.8809	Crash @2 days for B & D & E & G & H & I
6	41	38.88	0.123	39.0039	Crash @41 days for B & D & E & G & H & I & J
7					
Extra Cost require to complete (In Cr.)				1.1820	

Source: Created by authors

Table 5: Crash Duration

				10000000
D	212	30000	6360000	0.636
B & D	15	30000	450000	0.045
B & D & H & I	48	30000	1440000	0.144
B & D & E & H & I	76	30000	2280000	0.228
B & D & G & H & I	2	30000	60000	0.006
B & D & G & H & I	41	30000	1230000	0.123
	394			

Required Extra cost to complete the project without crashing:

Source: Created by authors

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Table 6: Delaying extra Cost Data from Site

Project data	
Revenue	327453671
Revenue	
Turnover as per Client Billing	283487660
Differential Entry (Shadow BOQ - Client Billing)	43966011
Direct Cost	251829625
Other Income	
Other Income	0
WIP	
Direct Cost	
Material Cost	121467651
Labour Charges	325281
Composite Work Charges	90803235
Quality Expenses	1359291
Electricity Charges	355328
Diesel Expenses	3711542
Consumable Asset	29153130
Design & Consultancy Charges	1649500
Rate & Tax	2741855
Safety Expenses	87091
Water Charges	175720
Other Project Cost	42272082
Employee Cost	
Local Staff Salary	3541521
Regular staff salary	21027157
Staff Welfare Expenses	661267
Construction Expenses	
Machinery Repair and Maintenance	103255
Site Expenses	-14798
Equipment and Machine Rent	5260820
Security Expenses	2989326
Other Expenses	
Labour Charges	
General Repairs and Maintenance	63063
Sundry Expenses	1487010
Vehicles Running & Maintenance Chg.	3297081
Printing and Stationery	163736

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Business Development Charges	505
Communication Exp.	144536
Travelling Expenses	197436
Professional and Legal Charges	1971
Rates & Taxes	
Rent-Office/Guest house/Others	1482675
Insurance Charges	187327
Charity & Donation	
Bank Guarantee & Financial Charges	1678193
War. Gur Exp	3274537
War. Gur Exp	
War. Gur Exp	3274537
Interest on Capital Employed	11335829
Mob Adv Interest	
Interest on Capital Employed	
WCI Int	
Interest on Capital Employed	11359135
Int. Capital Emp.	-23306
Depreciation	4816198
Depreciation on Fixed Assets	
Depreciation on Fixed Assets	4816198
HO Exp	4420625
HO Exp.	
HO Exp.	4420625
RO/DO Exp	5468476
DO EXP	
DO EXP	5468476
Forex	14
Forex	
Forex	14
IND AS TO	-49048044
INDAS Revenue	
INDAS Revenue	-49048044
INDAS Adjustment	
INDAS Adjustment	
INDAS Adjustment	
Grand Total	-53084330

Source: Created by authors

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This section presents a detailed analysis of the data collected through the questionnaire survey and supporting project documents. The objective of the analysis is to assess the supply chain management performance and identify the most significant factors contributing to delay of the project. Collected responses were aggregated and categorized under SCOR processes. Delay issues were then linked to relevant SCOR performance attributes like Reliability, Responsiveness, Agility, Cost & asset Management. Delay issues were also categorized based upon SCOR process attributes like plan, source, make, deliver, return, and enable to identify weak areas within the supply chain.

4.1 Categorization into SCOR process

Table 7: SCOR Process Table

Score Category	Issue From RWSS Project
Plan	Forecasting challenges due to land issues; schedule updates only monthly/quarterly.
Source	Late procurement requests; vendor production delays; quality rejections.
Make	Rework due to late/changed drawings; batch rejection; low productivity during weather.
Deliver	Material delivery delays; <90% on-time delivery; restart time after stoppage: 3–7 days.
Return	Returned materials due to mismatch or site unreadiness; 5–20% rejection rate.
Enable	Lack of GPS-enabled training to drivers; lack of digital dashboards; weak supplier visibility.

Source: Created by authors

4.2 Performance attributes & issues

Table 8: SCOR Attributes Table

Attribute	Issue From RWSS Project
Reliability	Frequent delays in drawing approvals, material shortages, and subcontractor inefficiencies.
Responsiveness	Client/PMC responsiveness rated 2–3; delays in RA bill certification and drawing resubmissions.
Agility	Inflexibility in handling weather disruptions and late procurement requests.
Cost	5–10% increase in project cost; return handling costs; payment delays impacting vendors.
Asset Management	Labor & equipment utilization varied (51–90%); delays due to idle resources.

Source: Created by authors

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4.3 Suggested KPI's for RWSS project

Table 9: Key Performance Table

Score Category	KPI's
Plan	Forecast Accuracy (%), Schedule Update Frequency, Risk Anticipation Score (1–5)
Source	Supplier On-Time Delivery (%), Procurement Lead Time, Material Rejection Rate (%)
Make	Rework Rate (%), Cycle Time (days), Labor Utilization (%)
Deliver	On-Time Delivery (%), Restart Time (days), Delivery Accuracy (%)
Return	Return Rate (%), Cost per Return Load (₹), Drawing Rejection Rate (%)
Enable	% of GPS-Trained Drivers, IT Adoption Rate (%), Client Responsiveness Score (1–5)

Source: Created by authors

Table 10: SCOR Framework

SCOR Category	Key Issues Identified	Relevant KPI's	Performance Attributes Impacted	Analysis & Insights	Actionable Suggestions
Plan	- Forecast demand misaligned with actual execution - High demand variability due to land clearance delays - Schedule updates only monthly or quarterly	- Forecast Accuracy (%) - Demand Variability Index - Schedule Update Frequency - Risk Anticipation Score (1–5)	- Reliability - Asset Management	- Inflexible planning led to idle resources - Land issues not anticipated during tendering phase	- Conduct land feasibility during DPR stage. - Use rolling wave planning for dynamic updates - Use Material Resource planning with VED, ABC analysis. - Include risk registers for weather, permissions
Source	- Late procurement requests - Vendor production delays - Quality rejection of aggregates and materials	- Supplier On-Time Delivery (%) - Procurement Lead Time (days) - Material Rejection Rate (%)	- Reliability - Cost	- Procurement delays caused work-front idle time - Poor vendor coordination increased rework	- Prequalify vendors based on past performance. - Implement digital procurement tracking. - Maintain buffer stock of critical materials.

Make	- Rework due to late/changed drawings - Low productivity during weather events - Batch rejection due to mix ratio issues	- Rework Rate (% of total work) - Labor Utilization (%) - Productivity Loss due to Weather (%)	- Reliability - Cost - Responsiveness	- Rework affected 5–20% of total work - Weather caused 0–5% productivity loss - Skilled labour shortage in remote areas	- Tie-up with local ITIs for trained manpower - Use modular construction to reduce weather impact - Improve drawing approval turnaround time
Deliver	- 10–25% delays due to material shortages - Restart time after stoppage: 3–7 days - 15–30 days delay due to drawing approvals	- On-Time Delivery (% within 90 min) - Restart Time (days) - Delivery Accuracy (% of spec-compliant deliveries)	- Agility - Cost - Reliability	- Delivery delays compounded by poor site readiness - Restart lag increased idle labour cost	- GPS-enabled delivery tracking - Site readiness checklist before dispatch - Assign delivery coordinators for critical materials
Return	- Returned materials due to mismatch or site unreadiness - 5–20% rejection rate of materials - No root cause analysis system	- Return Rate (% of total loads) - Drawing Rejection Rate (%) - Root Cause Distribution (%)	- Reliability - Cost - Responsiveness	- Rejected drawings delayed execution by >30 days	- Implement root cause tagging in ERP - Use digital drawing approval workflows - Train site engineers on specification compliance
Enable	- Only 60–70% of drivers trained in GPS routing - No supplier performance dashboard - Weak digital monitoring systems	- Client Responsiveness Score (1–5) - Supplier Visibility Index	- Agility - Cost - Reliability	- Lack of digital tools reduced visibility - Client responsiveness rated 2–3 in survey.	- Develop supplier performance dashboards - Train drivers and site staff on GPS tools - Use mobile apps for client/PMC approvals

Source: Created by authors

5.0 Findings / Results

This section presents the key findings derived from the survey data, project comparisons, and case-based observations discussed in the data analysis. The findings highlight the dominant patterns, critical issues, and practical implications of cost escalation in infrastructure projects.

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Table 11: Cost Comparison for delay

From Crashing extra cost required	1.1820	Cr
Without Crashing cost required	5.308433008	Cr

Source: Created by authors

The SCOR-based analysis indicates that delays in the RWSS project occurred across multiple supply chain processes [7], [8], [11]. In the Plan stage, inadequate risk anticipation related to land, approvals, and weather resulted in 31–40% and above 40% of delays due to late drawings and permissions, affecting planning reliability. The Source process faced frequent material shortages [1], [8], [11] caused by late procurement and vendor delays, reducing supply chain reliability and responsiveness. During the Make stage, rework due to late or revised drawings and weather impacts affected 5–20% of total work, increasing time and cost. In the Deliver stage, less than 90% on-time material delivery and 3–7 days required to restart work after stoppages reflected weak responsiveness and coordination. The Return process showed 5–20% rejection rates due to specification mismatches, while limited digital tools [6], [13] and moderate client/PMC responsiveness in the Enable process reduced visibility, agility, and overall supply chain performance.

From SCOR performance perspective, Reliability and Responsiveness were the most affected attributes, followed by Cost and Asset Management Efficiency. Survey data indicated a 5–10% overall increase in project cost [3], [4] due to supply chain delays, while labour and equipment utilization [12] varied widely between 51–90%, reflecting idle resource losses during stoppages.

6.0 Conclusion

This research shows whether we employ crashing technique [15] [2], [4], adding resource and manpower then we can accomplish the project at a shorter time through cutting indirect costs of the project. We can finish that activity that are not influenced by those projects critical path and make appropriate plans. This does not necessitate the crash technique 4.2 cr. cost needed to complete the project. that would be a big figure on the part of the company to bear their indirect costs. Therefore, crashing technique [15] [2], [4] and adding resource and manpower should be embraced. And the SCOR model [9], [10] can be a useful model to analyse delays in the supply chain of construction when it is adjusted to the project-based settings. The research determined major delay drivers associated with planning, procurement, execution, and coordination using SCOR processes and site-level questionnaire information. The analysis has revealed that the primary causes of the RWSS project delays include the delay in approvals, insufficient planning on land and permissions, poor supplier

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performances, and insufficient use of digital. The paper emphasizes that the digital tools [6], [13] and the active risk management can significantly decrease the delays and the cost overruns by enhancing the reliability of planning, the coordination between the suppliers, and the responsiveness. Overall, the use of the SCOR-based performance measurement strategy helps to make decisions based on the data and enhance the efficiency of the supply chain during construction projects.

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