



COST OVERRUN ANALYSIS OF WATER RESOURCES PROJECTS

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ABSTRACT

Rising population, industrialization, urbanization, and agricultural expansion are expected to drive up demand for irrigation projects. This study focuses on analyzing cost overruns in dam projects in Maharashtra's Konkan area, specifically in the basin of west-flowing rivers. Based on data from a few chosen projects, cost overruns and project underperformance have been determined. It has become extremely challenging to execute infrastructure projects on time and within the budget allocated, which frequently creates a burden on the state treasury. Determining the primary root causes of cost overruns in water-sector construction projects and proposing improvements are the main goals of this study. Issues with site acquisition, excess quantity execution, and project scope variations require priority. To prioritize the influencing factors, Garrett's ranking technique was employed. A detailed questionnaire was circulated among contracting agencies and officials from the irrigation department. The analysis highlighted major causes of cost escalation, including paucity of funds, excessive costs due to high tender rates, delays in land acquisition, increased land acquisition costs, and claims for additional work involving boulders. Furthermore, the Earned Value Method (EVM) was utilized to assess the performance of an ongoing dam construction project, offering insights into cost and schedule efficiency. The findings of this study are intended to assist policymakers, planners, and project managers in implementing effective control mechanisms to mitigate cost overruns in future irrigation infrastructure developments.

Keywords: Dam Projects, land acquisition, Cost overruns, Garrett's ranking, Earned Value.

INTRODUCTION

Irrigation projects are typically long-term and require significant financial investment. Callegari, Szklo, and Schaeffer (2018) investigated the cost overruns and delays in energy megaprojects. According to their study, power generation megaprojects, particularly hydroelectric dams, frequently experience significant cost overruns and delays. On average, construction costs for these projects have been 97.53% above initial estimates. (Ansar et al., 2014) assessed the largest dataset of hydropower megaprojects to show that cost estimates are often underestimated by 96%, indicating a systemic planning flaw. The use of reference class forecasting found that larger projects and those with longer time horizons are more likely to experience cost overruns, supporting psychological theories of over optimism and strategic deception. Research on the frequency, scope, and reasons behind cost increases in public and commercial infrastructure projects has been conducted within the past ten years. Early research highlighted the necessity of organized frameworks to explain cost overruns (Brunes et al., 2014). The majority of overruns start during the planning and starting phases, mostly as a result of design modifications and quantity increases, according to their analysis of Swedish infrastructure projects. Cost underestimation has not decreased over the past 70 years. According to (Sovacool et al., 2014) hydroelectric dams have the greatest amount and frequency of cost overruns. In their study, (Flyvbjerg et al., 2002) discovered that, cost underestimation exists across 20 nations and 5 continents, it appears to be a global phenomenon. No learning that would improve cost estimate accuracy seems to take place. While cost uncertainties are an unavoidable risk in hydropower planning, determining the generation expansion plan requires least-cost estimates for the dam construction that are reliable and that have accounted for substantial uncertainty (Awojobi and Jenkins, 2016b).

Pai et al. (2018) supplemented this by analyzing PPP-based road and highway projects and outlining important risk categories, including financial, technical, and legal. According to their research, the main reasons for cost overruns include inadequate planning, environmental delays, and financial incompetence. When (Al-Hazim et al., 2017) looked at infrastructure projects in Jordan, they discovered that weather and terrain were the main reasons for delays and cost increases. According to their research also identified recurrent difficulties such as inadequate planning, late payments, and financial problems pertaining to contractors. (Plummer Braeckman et al., 2019) examined data from more than 180 large dam projects in the hydropower industry Cost overruns in large hydropower dams, averaging 43% across all data, are higher than those for roads (20%), mining (14%), thermal generation (6%), and wind (8%), but lower than rail (45%) and significantly lower than nuclear plants (117-207%). The study confirms that project size (both dam height and plant capacity) has a statistically significant impact on both cost and schedule overruns. While time overruns shown statistically significant improvements, cost overruns did not, according to their research, underscoring ongoing shortcomings in project planning and execution. In their assessment of 98 dam projects from Australia, (Petheram et al., 2019) discovered that median cost overruns reached 49%, with lengthy construction times and intricate underlying geology being major contributing reasons. To keep costs under control, they emphasized the significance of thorough pre-feasibility studies and third-party reviews. All of these studies highlight how

widespread cost overruns in infrastructure building are and how important it is to have strong planning, improved risk distribution, and accountability systems. Early-stage estimation errors, environmental uncertainties, and governance flaws show themselves as recurring issues across contexts. Project viability and policy efficacy are still threatened by the economic impact of unresolved cost overruns, even with advancements in time management, particularly since 2000. A substantial amount of research has investigated the ongoing problem of cost overruns in construction and public infrastructure projects in various countries and contexts. (Catalão et al., 2020) performed an empirical analysis of 4,305 public projects in Portugal from 1980 to 2014 to investigate the influence of political, institutional, and economic factors on cost deviations. The findings demonstrate that electoral cycles, government type (majority versus minority), and broader economic conditions, including inflation and GDP growth, significantly affect the probability and extent of cost overruns. (Subramani et al., 2021) applied a mixed-method approach that included surveys and desk research to examine cost overruns in construction projects in India. The research results showed that the primary root causes of budget overruns were delayed decision-making, inadequate contract and schedule management, soaring material costs, and imprecise calculation techniques. The study addressed the need for improved planning, stakeholder coordination, and risk management as well as the pervasiveness of the issue in India's rapidly expanding construction industry. Out of 57 dams their study, (Baurzhan et al., 2021b) discovered that about 70% of the dams incurred construction costs greater than their initial estimates. In Port Harcourt, Nigeria, (Olupitan et al., 2021) worked on construction projects for the government sector. They identified significant factors such as variation orders, scope modifications, contractor financial issues, and poor planning by using generic surveys that were analyzed using mean item score. Extended project timeframes, higher overall costs, stakeholder disagreements, and in extreme situations, project abandonment and insolvency, were the most commonly mentioned consequences.

While cost overruns in infrastructure have been widely discussed in global literature, water resources projects present additional vulnerabilities linked to climatic variability, hydrological uncertainty, and irrigation performance dynamics (Oga et al., 2016; Doumounia et al., 2020; Assemanian et al., 2021; Chadee et al., 2023). Recent studies published emphasize that climate change projections in semi-arid regions indicate increased precipitation variability and hydrological stress on reservoirs and irrigation systems (Chibane and Ali-Rahmani, 2015; Choukrani et al., 2018; Zeggane et al., 2021). Such variability compounds planning uncertainty and underscores the necessity for robust technical and financial preparedness in long-term irrigation infrastructure projects (Aroua, 2018; Nassa et al., 2021; Pang and Tan, 2023; Mah et al., 2024).

In addition to financial and administrative weaknesses, international case studies highlight that irrigation modernization and performance-based water distribution management are critical in ensuring that infrastructure investments translate into measurable agricultural gains (Douh et al., 2013; Thabet, 2018; Berrezel and al., 2023; Kezzar and Souar, 2024; Derdour et al., 2022). For instance, Fecih et al. (2018) demonstrated that the expansion of economizing irrigation systems significantly improved water-use efficiency. Similarly, performance-indicator-based regulation

frameworks have been recommended to improve operational transparency and accountability in water service delivery systems (Boutebba et al., 2014; Fecih et al., 2018). These findings suggest that improving governance and monitoring water supply systems is equally important as controlling initial construction costs (Argaz, 2018; Rouissat and Smail, 2022; Patel and Mehta, 2022; Pandey et al., 2022; Remini, 2024).

Performance monitoring mechanisms such as Earned Value Management align with the broader performance-assessment philosophy advocated in water infrastructure literature. Several contributions have emphasized the use of quantitative performance indicators to regulate and optimize water resource systems (Fecih et al., 2018; Panchal and Suryanarayana, 2025; Remini, 2025). Applying such structured evaluation tools during execution phases can prevent escalation trends from becoming irreversible, thereby strengthening financial and schedule discipline.

Beyond administrative and contractual deficiencies, climate-related uncertainties further complicate and threaten dam and irrigation project execution and maintenance (Remini and Bensafia, 2016; Remini et al., 2019; Bougamouza et al., 2020; Mezenner et al., 2022; Shaikh et al., 2024). Studies focusing on small-scale irrigated agriculture under changing climatic regimes have demonstrated increasing vulnerability to temperature rise and precipitation fluctuation (Thabet, 2018). Moreover, long-term water-resource planning frameworks highlight the necessity of integrating economic needs with ecological and hydrological constraints (Aroua, 2018). Therefore, cost control in water infrastructure should be embedded within broader adaptive water governance strategies to ensure sustainability.

COST OVERRUN IN INFRASTRUCTURE PROJECTS

Cost overruns in infrastructure projects occur when the final cost of a project exceeds the originally estimated or budgeted cost. This is a common problem that has piqued the interest of project managers and other stakeholders. In essence, a cost overrun in infrastructure projects is a deviation from the original financial plan that frequently has a detrimental impact on the project's success and the stakeholders involved. It is essential to take into account that cost overruns in infrastructure projects, which involve spending more than anticipated to get the same desired result, are typically seen as a failure in planning and a waste of public resources. To mitigate the probability of cost overruns, efficient control systems are crucial from the initial phase of the design process. This study focuses on the following objectives:

- To study various ongoing irrigation projects in view of cost overruns and determine the percentage of overrun in medium and major projects in a particular basin.
- Examine and conduct a questionnaire survey among contractors and department officials to rank the factors leading to cost escalation in water sector projects, using Garrett ranking.
- Performing the earned value analysis for better understanding of project performance.
- Corrective recommendations for performance improvement for future projects.

NEED FOR STRATEGIC FOCUS ON COST OVERRUNS IN WATER INFRASTRUCTURE PROJECTS

Extensive research has been conducted on cost overruns in sectors like transportation, power, and petroleum, there is a significant literature gap concerning cost escalation in water infrastructure projects such as dams and canals. In the context of Maharashtra, cost escalation in irrigation projects is a pressing issue. These long-term, capital-intensive projects often suffer from lack of strategic planning and prioritization, resulting in delays due to land acquisition issues, rehabilitation challenges, and bureaucratic clearances. Furthermore, poor cost estimation often neglecting inflation and future scope changes combined with execution inefficiencies such as frequent design changes and geological difficulties, exacerbates cost overruns. Consequently, despite heavy investments, the actual irrigation potential realized remains significantly below expectations, leading to underutilization of command areas and reduced agricultural productivity. Addressing these issues is essential for enhancing project outcomes and optimizing public resource utilization.

Table 1 and Fig. 1. show the percentage of irrigated area across Indian states. The ratio of gross irrigated area to gross cropped area in Maharashtra for the year 2024 is approximately 17%. This means that about 17% of the total area of crops grown in Maharashtra is irrigated. More specifically, the irrigated area is about 2.94 million hectares out of a total cultivated area of 17.43 million hectares. Irrigation potential created up to June, 2023 by major, medium and minor irrigation (State sector) projects was 56.33 lakh ha. During 2023-24, actual irrigated area (Provisional) was 39.27 lakh ha. (Economic Survey of Maharashtra 2024-25). Maharashtra's irrigation landscape presents a paradox: despite a vast number of irrigation projects, the actual area irrigated remains relatively low. While Maharashtra has invested heavily in irrigation infrastructure, the gap between potential and actual irrigation highlights challenges in project completion, maintenance, and water distribution. Addressing these issues is crucial for enhancing agricultural productivity and ensuring water security across the state.

Table 1: Details of gross irrigated area state wise

Rank	State	Irrigated Area (%)	Rank	State	Irrigated Area (%)
1	Punjab	98.1	9	Uttarakhand	42.9
2	Harayana	87.6	10	Odisha	33.6
3	Andhra Pradesh	63.9	11	Karnataka	28.5
4	Bihar	63.4	12	Chattisgarh	27.6
5	Tamil Nadu	63.1	13	Rajasthan	26.4
6	West Bengal	48.2	14	Maharashtra	16.8
7	Gujarat	44.7	15	Jharkand	5.4
8	Madhya Pradesh	44.5	16	Assam	4.9

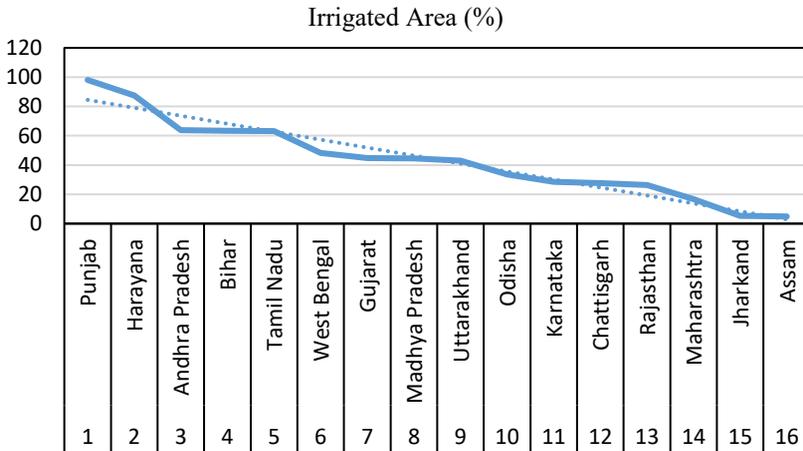


Figure 1: Percentage of irrigated area state wise

Fig. 2. illustrates the extent of cost overruns observed in various infrastructure sectors in India, showing that water resources projects face the highest cost overruns. Based on monthly flash report on central sector projects as of March 2024. Cost overrun is the difference between original and currently anticipated cost. Source: Ministry of Statistics and Programme Implementation (MOSPI). (Cost Overrun in Rs trillion)

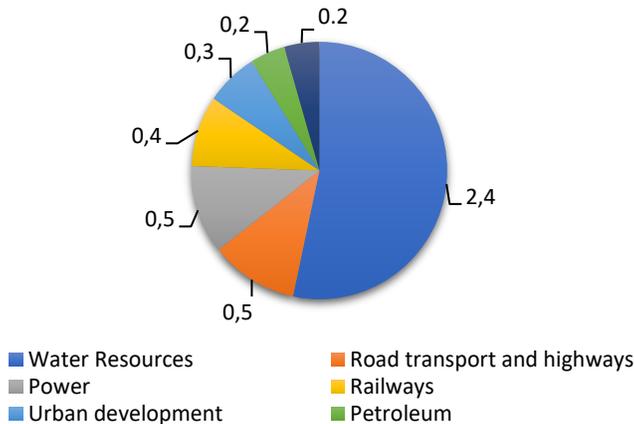


Figure 2: Pie Chart depicting cost overrun in various sectors

Table 2 provides a summary of major and medium irrigation projects in Maharashtra's Konkan region, including their original and revised costs, as well as the year of work awarded. The data show an alarming inclination of cost escalation across all listed projects, with some projects (such as Aruna and Deharji) soaring by more than 900%, particularly in Sindhudurg, Thane, and Ratnagiri districts. Several projects are also categorized as "Not yet started," despite the fact that they have been administratively approved for several years, showing significant delays which lead to cost overruns.

Table 2: Ongoing Dam projects in west flowing basin, as per data obtained from Konknan Irrigation Development Corporation.

Type	Project	District	Original cost Rs (cr)	Revised Cost Rs (cr)	Year
Major	Cultivable Command Area (CCA) >10,000 hectare				
1	Tilari Interstate	Sindhudurg	1612.15	2790.67	1997
2	Bhatsa	Thane	463.10	1290	2007
3	Talamba	Sindhudurg	816.65	1478.12	2009
4	Surya	Thane	550.00	1370.00	2004
Medium	Cultivable Command Area (CCA) >2,000 hectare				
5	Deharji	Palghar	158.25	2120.34	2011
6	Hetawane	Raigad	600.23	1679.11	1996
7	Sambarkund	Raigad	323.68	789	Not yet started
8	Arjuna	Ratnagiri	497.10	1054	2004
9	Jamada	Ratnagiri	50.44	473	2011
10	Gadnadi	Ratnagiri	743	1260	2003
11	Aruna	Ratnagiri	50.60	1667	2005
12	Deoghar	Sindhudurg	119	566	1998
13	Nardave	Sindhudurg	325	826.90	2010
14	Korle Satandi	Sindhudurg	158	981.20	Not yet started
15	Sarabala	Sindhudurg	69	428	Not yet started

RESEARCH METHODOLOGY

Fig. 3. depicts the methodology flow chart. It starts with a thorough analysis of the literature and the development of a problem statement, followed by data collecting from ongoing dam projects in the Konknan region. Expert advice and official documentation are used to identify key cost overruns. The project stakeholders are then given a standardized questionnaire to complete. The Garrett Ranking Method is used to prioritize the identified factors, while Earned Value Management (EVM) is utilized to understand real-time project performance. The outcomes shape the formation of remedial initiatives aimed at mitigating future cost overruns.

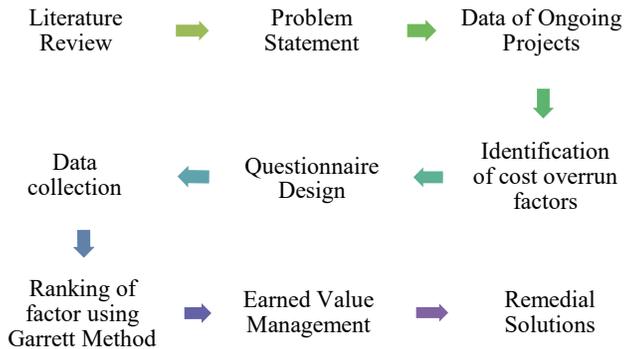


Figure 3: Methodology flowchart

Data Collection

The study was carried out in Konkan Region, western part of Maharashtra. Primary data were collected from Irrigation Development Corporation particularly engaged in construction of dams and canals in the region. The study incorporated questionnaires as a tool to engage with the government officials, contracting agencies and PAP's. The questionnaire was designed based on factors identified in the report of Irrigation Development Corporation and report of Comptroller and Auditor General of India. A total of 22 cost overrun causing factors have been identified and listed for this research study. Since most of the literature related to cost overrun has been from various countries around the world, only those factors which are consistent with the circumstances and conditions in the western basins has been considered in this study and also with interviews with the professionals in the construction industry in the state of Maharashtra.

Garrett Ranking Technique

Application of Garret's ranking method: To find out the most significant factor which influences the respondent, Garrett's ranking technique was used. Respondents were requested to assign the rank to all the statements; these ranks were then converted into score values using the following formula:

$$\text{Percent Position} = 100 \frac{R_{ij} - 0.5}{N_j} \quad (1)$$

where R_{ij} = Rank given for the i th statement by j th respondents, and N_j = Number of statements ranked by j th respondents.

RESULTS AND DISCUSSION

Table 3 consists of 22 cost overrun factors identified from project records of the Irrigation Development Corporation and insights obtained from the CAG Audit Report (2009). These factors include technical, financial, administrative, and other aspects, and were used for ranking via the Garrett Ranking Method.

Table 4 ranks the 22 identified cost overrun factors from stakeholder responses such as engineers, contractors, and departmental officials. The mean ratings reflect each factor's assessed severity or impact on project cost escalation. A higher Garrett mean score indicates higher relevance as assessed by the respondents.

Table 5 shows the count of each rank awarded to the 22 cost overrun factors by all respondents. This data serves as the base for applying the Garrett Ranking Technique, which translates each rank into a specific score using Garrett's conversion table. The frequencies are used to compute the total and mean score for each factor, which determines the final ranking.

Table 6 shows how the Percent Position and Garrett Score were calculated for each rank.

Table 7 shows the results of the Garrett Ranking analysis. Garrett scores were assigned to each response using the previously calculated percentage positions. The total and average scores for each method were then calculated. Based on these mean ratings, the factors have been scored in order of their perceived relevance by the respondents.

Table 8 shows the final ranking of the 22 cost overrun factors based on their Garrett mean scores.

Table 3: Identified cost overrun factors as per data obtained from Irrigation Development Corporation and CAG audit report 2022

Factor No	Factor	Factor No	Factor
1	Excess due to change in D.S. R	12	Claims for extra lead
2	Excess due to higher tender rates	13	Claims for extra work of boulders during excavation
3	Excess due to structural modification	14	Idle charges claim
4	Price escalation	15	Expenditure on Arbitration Awards
5	Increase in cost of land acquisition rates	16	Payment for compensation on rehabilitated villagers
6	Increase in cost of land acquisition due to increase in command area	17	Conversion of open canals to PDN
7	Increase in royalty rates	18	Increase in dam height/length
8	Implementation of clause 38	19	Rework due to faulty design
9	Paucity of funds	20	Increase in scope of work
10	Delay in land acquisition	21	Stoppage of work due to pandemic
11	Delay in approval of revised estimate	22	New tender process for balance work (incomplete/abandoned work by previous contractor)

Table 4: Ranking of factors based on response of respondents

Sr.No	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22
1	1	3	8	12	3	4	9	7	5	1	13	10	4	10	16	18	14	4	20	4	22	19
2	1	2	9	14	7	6	10	6	9	4	15	12	7	12	18	19	17	6	18	4	21	22
3	1	2	10	11	4	6	10	6	7	2	14	14	6	9	17	17	19	9	21	5	22	20
4	2	3	12	14	5	3	11	9	4	3	16	12	4	11	14	19	19	7	19	7	22	21
5	4	3	7	13	5	7	8	8	6	5	16	14	5	8	18	20	18	5	22	7	21	19
6	4	3	11	11	3	3	8	10	1	1	12	13	8	13	15	17	15	8	19	7	21	21
7	2	4	12	12	3	5	9	10	5	4	15	12	8	10	19	19	18	9	21	8	21	22
8	3	6	10	12	6	5	9	11	3	2	15	10	5	10	15	18	16	6	20	8	21	18
9	2	5	10	14	5	4	11	7	7	1	16	12	4	12	18	20	17	4	18	6	21	20
10	2	5	7	12	5	6	10	9	1	1	14	10	6	11	17	19	14	5	22	6	21	22
11	5	8	12	14	4	6	11	6	4	2	11	14	7	11	14	18	18	8	18	9	22	22
12	7	9	11	13	7	7	10	9	5	3	13	12	4	9	16	17	19	7	21	7	20	21
13	2	4	9	11	3	4	10	8	2	4	13	14	7	10	15	20	16	10	20	7	21	22
14	2	4	10	11	3	5	12	6	2	1	12	13	6	9	16	17	16	8	22	7	19	22
15	4	3	8	13	5	8	11	6	1	2	15	13	4	9	17	19	17	11	19	4	22	19
16	1	6	8	14	6	7	9	7	5	1	15	14	5	13	18	20	17	7	19	4	21	19
17	1	6	10	14	6	4	11	6	2	4	16	11	8	8	14	18	18	4	22	8	21	18
18	5	3	11	12	7	7	12	9	6	3	13	14	5	10	15	20	17	9	20	6	19	19
19	3	2	12	12	7	7	9	8	8	1	14	12	8	12	19	17	16	6	21	5	22	22
20	2	2	12	12	3	5	8	10	4	2	12	14	8	9	15	19	15	8	18	4	21	21
21	2	3	11	13	3	5	9	11	3	4	15	14	6	11	19	18	13	5	21	6	20	21
22	7	4	8	13	5	6	12	10	1	1	16	11	4	10	18	19	16	10	19	7	19	22
23	4	5	8	12	4	6	10	6	1	2	13	13	7	8	14	20	17	11	18	8	19	20
24	6	5	12	11	6	3	10	9	3	2	13	13	7	13	17	17	17	11	21	8	20	18
25	6	6	7	13	6	7	9	7	6	3	15	10	4	10	15	18	18	9	20	7	20	21
26	2	2	7	11	7	3	11	6	7	1	14	12	6	12	16	18	19	4	18	9	22	22
27	2	2	11	14	3	4	11	8	7	4	15	13	5	12	16	19	16	7	22	9	21	22
28	1	3	10	15	6	4	10	9	2	1	16	12	4	10	14	20	16	6	21	10	22	20
29	1	4	9	14	7	6	12	11	3	2	13	11	8	9	17	19	14	6	22	4	22	22
30	3	4	9	12	6	5	9	10	6	3	11	14	6	11	16	19	14	10	20	4	20	21

Table 5: Count of number of ranks assigned to each factor

Factors	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th	21st	22nd
F1	7	10	3	4	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F2	0	6	8	6	4	4	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
F3	0	0	0	0	0	0	4	5	4	6	5	6	0	0	0	0	0	0	0	0	0	0
F4	0	0	0	0	0	0	0	0	0	0	6	9	6	8	1	0	0	0	0	0	0	0
F5	0	0	8	3	6	7	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F6	0	0	4	6	6	7	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	0	3	8	8	7	4	0	0	0	0	0	0	0	0	0	0
F8	0	0	0	0	0	8	4	4	6	5	3	0	0	0	0	0	0	0	0	0	0	0
F9	5	4	4	3	4	4	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
F10	10	8	5	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F11	0	0	0	0	0	0	0	0	0	0	2	3	7	4	8	6	0	0	0	0	0	0
F12	0	0	0	0	0	0	0	0	0	4	3	8	6	9	0	0	0	0	0	0	0	0
F13	0	0	0	8	5	6	5	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F14	0	0	0	0	0	0	0	3	6	8	5	5	3	0	0	0	0	0	0	0	0	0
F15	0	0	0	0	0	0	0	0	0	0	0	0	0	5	6	6	5	5	3	0	0	0
F16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	7	10	7	0	0
F17	0	0	0	0	0	0	0	0	0	0	0	0	1	4	2	7	7	5	4	0	0	0
F18	0	0	0	4	3	5	4	4	4	3	3	0	0	0	0	0	0	0	0	0	0	0
F19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	5	6	7	6
F20	0	0	0	7	2	4	8	5	3	1	0	0	0	0	0	0	0	0	0	0	0	0
F21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	5	12	9
F22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	4	7	11

Table 6: Calculation of Percent Position and Garrett score

Rank	100(Rij-0.5)/Nj	Percent Position	Garrett Value
1 st	100(1-0.5)/22	2.272727273	88
2 nd	100(2-0.5)/22	6.818181818	79
3 rd	100(3-0.5)/22	11.36363636	73
4 th	100(4-0.5)/22	15.90909091	69
5 th	100(5-0.5)/22	20.45454545	66
6 th	100(6-0.5)/22	25	63
7 th	100(7-0.5)/22	29.54545455	60
8 th	100(7-0.5)/22	34.09090909	58
9 th	100(9-0.5)/22	38.63636364	56
10 th	100(10-0.5)/22	43.18181818	53
11 th	100(11-0.5)/22	47.72727273	51
12 th	100(12-0.5)/22	52.27272727	49
13 th	100(13-0.5)/22	56.81818182	47
14 th	100(14-0.5)/22	61.36363636	44
15 th	100(15-0.5)/22	65.90909091	42
16 th	100(16-0.5)/22	70.45454545	39
17 th	100(17-0.5)/22	75	36
18 th	100(18-0.5)/22	79.54545455	34
19 th	100(19-0.5)/22	84.09090909	30
20 th	100(20-0.5)/22	88.63636364	26
21 st	100(21-0.5)/22	93.18181818	21
22 nd	100(22-0.5)/22	97.72727273	12

Table 7: Conversion of percent position to scores based on Garrett table and ranking of strategies based on Mean Score values

Sr.No	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22
1	88	73	58	49	73	69	56	60	66	88	47	53	69	53	39	34	44	69	26	69	12	30
2	88	79	56	44	60	63	53	63	56	69	42	49	60	49	34	30	36	63	34	69	21	12
3	88	79	53	51	69	63	53	63	60	79	44	44	63	56	36	36	30	56	21	66	12	26
4	79	73	49	44	66	73	51	56	69	73	39	49	69	51	44	30	30	60	30	60	12	21
5	69	73	60	47	66	60	58	58	63	66	39	44	66	58	34	20	34	66	12	60	21	30
6	69	73	51	51	73	73	58	53	88	88	49	47	58	47	42	36	42	58	30	60	21	21
7	79	69	49	49	73	66	56	53	66	69	42	49	58	53	30	30	34	56	21	58	21	12
8	73	63	53	49	63	66	56	51	73	79	42	53	66	53	42	34	39	63	20	58	21	34
9	79	66	53	44	66	69	51	60	60	88	39	49	69	49	34	20	36	69	34	63	21	26
10	79	66	60	49	66	63	53	56	88	88	44	53	63	51	36	30	44	66	12	63	21	12
11	66	58	49	44	69	63	51	63	69	79	51	44	60	51	44	34	34	58	34	56	12	12
12	60	56	51	47	60	60	53	56	66	73	47	49	69	56	39	36	30	60	21	60	26	21
13	79	69	56	51	73	69	53	58	79	69	47	44	60	53	42	20	39	53	26	60	21	12
14	79	69	53	51	73	66	49	63	79	88	49	47	63	56	39	36	39	58	12	60	30	12
15	69	73	58	47	66	58	51	63	88	79	42	47	69	56	36	30	36	51	30	69	12	30
16	88	63	58	44	63	60	56	60	66	88	42	44	66	47	34	20	36	60	30	69	21	30
17	88	63	53	44	63	69	51	63	79	69	39	51	58	58	44	34	34	69	12	58	21	34
18	66	73	51	49	60	60	49	56	63	73	47	44	66	53	42	20	36	56	26	63	30	30
19	73	79	49	49	60	60	56	58	58	88	44	49	58	49	30	36	39	63	21	66	12	12
20	79	79	49	49	73	66	58	53	69	79	49	44	58	56	42	30	42	58	34	69	21	21
21	79	73	51	47	73	66	56	51	73	69	42	44	63	51	30	34	47	66	21	63	26	21
22	60	69	58	47	66	63	49	53	88	88	39	51	69	53	34	30	39	53	30	60	30	12
23	69	66	58	49	69	63	53	63	88	79	47	47	60	58	44	20	36	51	34	58	30	26
24	63	66	49	51	63	73	53	56	73	79	47	47	60	47	36	36	36	51	21	58	20	34
25	63	63	60	47	63	60	56	60	63	73	42	53	69	53	42	34	34	56	26	60	20	21
26	79	79	60	51	60	73	51	63	60	88	44	49	63	49	39	34	30	69	34	56	12	12
27	79	79	51	44	73	69	51	58	60	69	42	47	66	49	39	30	39	60	12	56	21	12
28	88	73	53	42	63	69	53	56	79	88	39	49	69	53	44	20	39	63	21	53	12	26
29	88	69	56	44	60	63	49	51	73	79	47	51	58	56	36	30	44	63	12	69	12	12
30	73	69	56	49	63	66	56	53	63	73	51	44	63	51	39	30	44	53	26	69	26	21
Mean	2279	2102	1621	1423	1988	1961	1599	1730	2125	2357	1324	1435	1908	1575	1146	894	1122	1797	723	1858	598	635
Rank	2	4	11	15	5	6	12	10	3	1	16	14	7	13	17	19	18	9	20	8	22	21

Table 8: Ranking of factors

No	Factor	Rank	No	Factor	Rank
1	Excess due to change in D.S. R	2	12	Claims for extra lead	14
2	Excess due to higher tender rates	4	13	Claims for extra work of boulders during excavation	7
3	Excess due to structural modification	11	14	Idle charges claim	13
4	Price escalation	15	15	Expenditure on Arbitration Awards	17
5	Increase in cost of land acquisition rates	5	16	Payment for compensation on rehabilitated villagers	19
6	Increase in cost of land acquisition due to increase in command area	6	17	Conversion of open canals to PDN	18
7	Increase in royalty rates	12	18	Increase in dam height/length	9
8	Implementation of clause 38	10	19	Rework due to faulty design	20
9	Paucity of funds	3	20	Increase in scope of work	8
10	Delay in land acquisition	1	21	Stoppage of work due to pandemic	22
11	Delay in approval of revised estimate	16	22	New tender process for balance work (incomplete/abandoned work by previous contractor)	21

The results of the Garret ranking showed that delay in land acquisition is in the strongest position to become a prioritized factor for cost overruns in such projects. Followed by four other factors; excess due to change in district schedule rates, Paucity of funds, higher tender rates, and increase in cost of land acquisition rates.

EARNED VALUE MANAGEMENT

Effective control over a project can be exercised only by performing periodic and systematic performance analysis. Earned Value Management (EVM) provides an analytical framework for project control by estimating factors like cost variance, time variance, schedule variance, cost performance index, schedule performance index, estimated cost performance index etc. In table 9, the key performance indices are defined based on Earned Value Management concepts.

Table 9: Basic terms of Earned Value

Term	Description	Interpretation
BCWS	Budgeted Cost of Work Scheduled	It is the planned value of the work planned to be accomplished in a period of time.
BCWP	Budgeted Cost of Work Performed	It is the budgeted amount for the work actually accomplished on the schedule activity or work breakdown structure (WBS) component during a given time
ACWP	Actual Cost of Work Performed	It is resolved from accounting records that keeps record of actual expenditure money, that means it is secret and actual money spent by the contractor
SV	Schedule Variance (BCWP – BCWS)	Negative means behind schedule, Positive means ahead of schedule
CV	Cost Variance (BCWP – ACWP)	Negative means over budget, Positive means under budget
EAC	Estimate at Completion	The expected total cost of the project when the defined scope of work is completed.
BAC	Baseline Cost at Completion	The total approved budget when the scope of the project is completed.
VAC	Variance at Completion	It is used to assess the variance between the planned budget and the estimated budget at the completion of a project.
CPI	Cost Performance Index (BCWP/ACWP)	More than 1 means Profit and less than 1 means loss
SPI	Schedule Performance Index (BCWP/BCWS)	More than 1 means ahead of schedule and less than 1 means behind the schedule.

Case Study

To conduct our case study, we opted for an ongoing minor irrigation Earthen Dam construction project that was overseen by Konkan Irrigation Development Corporation. The basic details and current progress of a Minor Irrigation Scheme selected for the case study are shown in Table 10 and Table 11, respectively. The said project on completion will irrigate 279 ha of land. Table 10 and table 11 depict the project details. For the EVM analysis on this project, we required four specific pieces of information initially. They are Budget at Completion (BAC), Planned Value (PV), Earned Value (EV), and Actual Cost (AC). We collected all the required data regarding the four inputs of the dam project for Earned Value Analysis.

Table 10: Hasol minor irrigation scheme; project basic information as per data obtained from Konkan Irrigation Development Corporation

Serial Number	Title	Description
1	Name of Work	Hasol Minor Irrigation Scheme, Ratnagiri. Construction of Earthen Dam and Appurtenant Works
2	Employer	Konkan Irrigation Development Corporation (WRD) Maharashtra
3	Commencement year	2005
4	Contract Value	1545 Lakhs
5	Duration	48 calendar months
6	Current Status	Ongoing
7	Revised Cost	5367 Lakhs
8	Amount of Work Executed	2345 Lakhs

Table 11: Current Status of Project

Serial number	Title	Description
1	Earthen Dam (Main Body)	60% complete
2	Concrete ogee spillway	Work not yet started
3	Head Regulator conduit	60% complete
4	Canal and distribution (pipeline distribution network)	Survey work in progress

Increase in project estimate

The said project envisages creating storage of 4.66 Mm³ and irrigating 279 ha through left bank canal of 5.97 km. The dam height was increased by 5.50 meter as a result height of the Ogee spillway and head regulator conduit was also required to be increased proportionally, thereby increasing the gross storage to 8.22 Mm³ and creating irrigation potential of 498 ha through left bank canal of 8.25km. Provision baffle blocks in stilling basin to dissipate energy. Similarly, implementation of pipe line distribution network was opted, replacing open canals. Table 12 and Fig. 4. highlight the key variables and indices used in EVM to assess both current performance of the project.

Table 12: Earned Value Management (EVM) Analysis of Cost and Schedule Performance

Metric	Value	Formula/case
Budget at Completion (BAC)	₹15,45,00,000	—
Percentage Completed (%)	60%	—
Actual Cost (AC)	₹23,45,67,000	—
Planned Completion (%)	100%	—
Planned Value (PV)	₹15,45,00,000	—
Earned Value (EV)	₹9,27,00,000	—
Cost Variance (CV)	₹- 14,18,67,000	EV – AC

Schedule Variance (SV)	₹-6,18,00,000	$EV - PV$
Cost Performance Index (CPI)	0.40	$EV \div AC$
Schedule Performance Index (SPI)	0.60	$EV \div PV$
To-Complete Performance Index (TCPI)	2.53	$(BAC - EV) \div (BAC - AC)$
Estimate at Completion (EAC)	₹39,09,45,000	Case I: $BAC \div CPI$
	₹29,63,67,000	Case II: $AC + (BAC - EV)$
	₹49,51,97,000	Case III:
Estimate to Complete (ETC)	₹15,63,78,000	$AC + [(BAC - EV) \div (CPI \times SPI)]$
Variance at Completion (VAC)	₹-23,64,45,000	$EAC - AC$
		$BAC - EAC$

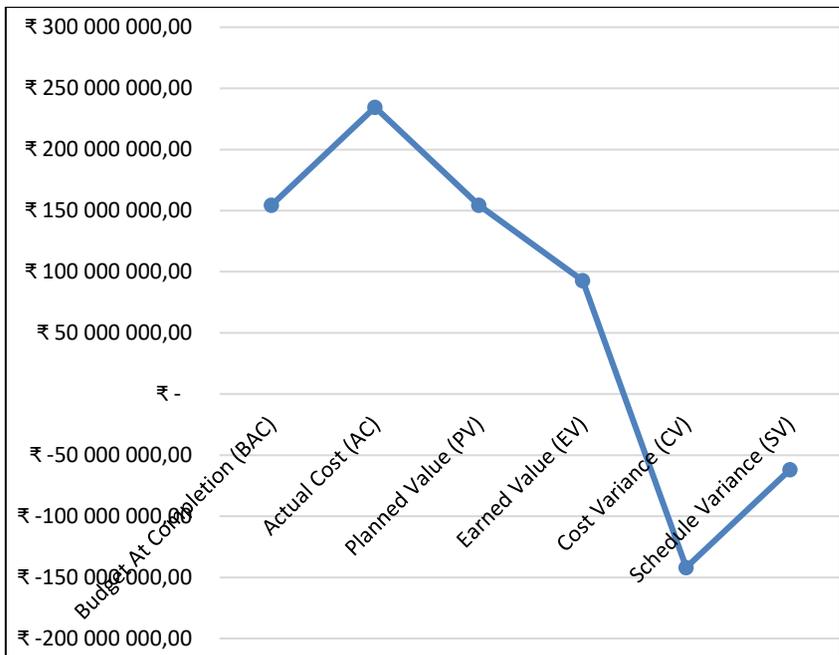


Figure 4: Graphical Representation of Earned Value Management Metrics

SUGGESTED REMEDIAL MEASURES

Restriction on sanctioning new projects

It is necessary to limit the number of newly sanctioned projects by having a precise policy for newly sanctioned works. Only projects with high demand for completion or water scarcity should be presented. Following technical verification, a detailed project report

(DPR) must be created, and only then may works be presented in accordance with the project's needs, priority, availability of funds, availability of land, and the forest department's no-objection certificate. To avert cost overruns, it is vital to prohibit splitting projects into smaller portions, submitting misleadingly low-cost estimates, and executing duplicate work.

Land Pooling Method

Instead of harsh land acquisition, land pooling offers affected landowners contributing or consolidating their land in exchange for a share of developed property or long-term benefits once the project concludes. Landowners agree to pool land for submergence and dam infrastructure. In exchange, they receive land in resettlement zones or irrigation command areas, as well as privileges such as the following:

- Priority in irrigation water access
- Shares in power generation profits (if hydroelectric)

Compulsory acquisition of minimum 90% land

Projects entering into tendering phase need to have acquired at least 90% of land. Similarly, any project going for tendering should have obtained the environmental clearances and forest clearances

Procurement and contract management

A rating mechanism should be used instead of selecting contractors just on an L1 basis. Each bidder should be evaluated based on a variety of factors such as financial condition, prior performance, technical know-how, risk carrying ability, and effective handling of local difficulties. To lower the chance of higher project costs, contracts can include provisions for capping idle claims and arbitration values. Profit sharing with contractors (during the early commissioned time of the project) should be addressed within the primary contract. Such incentives encourage contractors to complete their tasks on schedule.

Implement social cost benefit analysis for projects

All projects over a specific threshold value that require considerable land acquisition or rehabilitation may be required to conduct a social cost benefit analysis (SCBA). The SCBA results may be made public to ensure that enough awareness is generated about the project's benefits, which can generate goodwill and positivity around the project, enabling land purchase.

CONCLUSION

The present study aimed to identify the preference and ranking of factors adopted by stakeholders involved to address the factors leading to cost overruns. The Garret Ranking Technique in this case of project cost overruns and problems associated to it deems fit. This is significantly because of the ranking method that puts up the highest mean value indicating it as an important factor in studying the problem. The respondents had given their preferential ordering of the unranked problems at the initial stage. The problems were outlined during the interviews with stakeholders involved. The Earned Value Management (EVM) analysis of the ongoing dam construction project reveals critical performance issues in both cost and schedule dimensions. As of the current reporting period, only 60% of the total work has been completed, yet the actual cost incurred is ₹23,45,67,000, significantly higher than what would be expected for this level of progress. The project's Cost Performance Index (CPI) of 0.40 indicates that the project is operating at just 40% efficiency in cost terms, with a cost variance (CV) of - ₹14,18,67,000, clearly signalling substantial cost overruns. Similarly, the Schedule Performance Index (SPI) of 0.60 reflects that the project is lagging well behind schedule, confirmed by the schedule variance (SV) of -₹6,18,00,000.

REFERENCES

- AL-HAZIM N., SALEM Z.A., AHMAD H. (2017). Delay and Cost Overrun in Infrastructure Projects in Jordan, *Procedia Engineering*, Vol. 182, pp. 18-24.
- ALEESWARI A., MERLINE W. L., MARTIN N. (2019A). Study on Industrial Problems using Garrett Ranking Technique, Bhavan's Usha & Lakshmi Mittal Institute of Management (BULMIM) *Journal of Management and Research*, Vol. 4, pp. 7-19.
- AL O., UO A., OP N. (2021). The critical causes and effects of cost overruns in public sector construction projects in Port Harcourt, Nigeria, *International Journal of Scientific and Research Publications*, Vol. 11, Issue 10, pp. 304-317.
- ANSAR A., FLYVBJERG B., BUDZIER A., LUNN D. (2014). Should we build more large dams? The actual costs of hydropower megaproject development, *Energy Policy*, Vol. 69, pp. 43-56
- ARGAZ A. (2018). 1D model application for integrated water resources planning and evaluation: case study of Souss river basin, Morocco, *Larhyss Journal*, No 36, pp. 217-229.
- AROUA N. (2018). Water resources in SNAT 2030. between economic needs and ecological requirements, *Larhyss Journal*, No 35, pp. 153-168. (In French)
- ASSEMIAN A.E., DJE BI DOUTIN S., SAMAKÉ Y. (2021). Consequences of the effects of climate change on water resources in a humid tropical zone of central eastern Côte d'Ivoire, *Larhyss Journal*, No 45, pp. 95-105.

- AWOJOBI O., JENKINS G.P. (2016). Managing the cost overrun risks of hydroelectric dams: An application of reference class forecasting techniques, *Journal of Renewable and Sustainable Energy Reviews*, Vol. 63, pp. 19-32.
- BASU P.K., JOSHI S. (2000). Study for the Efficient Planning, control and Management of Water Resources development Projects in India, *International Journal of Water Resources Development*, Vol. 16(4), pp. 563-570.
- BAURZHAN S., JENKINS G.P., OLASEHINDE-WILLIAMS G.O. (2021b). The Economic Performance of hydropower dams supported by the World Bank Group, 1975-2015, *Energies*, Vol. 14, Issue 9, Paper ID 2673
- BERREZEL Y.A. ABDELBAKI C., ROUISSAT B., BOUMAAZA T., KHALDOON A.M. (2023). Decision support system for the management of water distribution networks a case study of Tourville, Algeria, *Larhyss Journal*, No 54, pp. 7-24.
- BOUGAMOUSA A., REMINI B., SAKHRAOUI F. (2020). Analytical study of sediment evolution in the lake of the Fom El Gherza dam (Biskra, Algeria), *Larhyss Journal*, No 43, pp. 169-179.
- BOUTEBBA K., BOUZIANE M.T., BOUAMRANE A. (2014). Decision-making aid for optimizing the management of drinking water supply networks, *Larhyss Journal*, No 20, pp. 279-296. (In French)
- BRAECKMAN J.P., DISSELHOFF T., KIRCHHERR J. (2019b). Cost and schedule overruns in large hydropower dams: an assessment of projects completed since 2000, *International Journal of Water Resources Development*, Vol. 36, Issue 5, pp. 839-854.
- CALLEGARI C., SZKLO A., SCHAEFFER R. (2017). Cost overruns and delays in energy megaprojects: How big is big enough? *Energy Policy*, Vol. 114, pp. 211-220.
- CHADEE A., NARRA M., MEHTA D., ANDREW J., AZAMATHULLA H. (2023). Impact of climate change on water resource engineering in Trinidad and Tobago, *Larhyss Journal*, No 55, pp. 215-229.
- CHIBANE B., ALI-RAHMANI S.E. (2015). Hydrological based model to estimate groundwater recharge, real-evapotranspiration and runoff in semi-arid area, *Larhyss Journal*, No 23, pp. 231-242.
- CHOUKRANI G., HAMIMSA A., SAIDI M.E., BABQIQI A. (2018). Diagnosis and future projection of climate change in arid zone: Case of Marrakech–Safi region (Morocco), *Larhyss Journal*, No 36, pp. 49-63.
- DERDOUR A., BELAM N., CHEBAB W. (2022). Traditional irrigation system and methods of water harvesting in the oasis of Sfisifa Ksour mountains – Algeria, *Larhyss Journal*, No 49, pp. 17-35.
- DOUH B., BOUJELBEN A., KHILA S., BEL HAJ MGUIDICHE A. (2013). Effect of subsurface drip irrigation system depth on soil water content distribution at different depths and different times after irrigation, *Larhyss Journal*, No 13, pp. 7-16.
- DOUMOUNIA A., ZEBA A., DAMIBA L., ZOUGMORE F, NIKIEMA M. (2020). Climate variability analysis in the Nouhao sub-basin in eastern center of Burkina Faso, *Larhyss Journal*, No 41, pp. 57-69. (In French)

- FECIH A., HABI M., MORSLI B. (2018). Development of the economisatrices irrigation in the northwest of Algeria: The case of the Tlemcen department, *Larhyss Journal*, No 35, pp. 59-71.
- FLYVBJERG B., HOLM M. S., BUHL S. (2002). Underestimating costs in public works projects: Error or Lie? *Journal of the American Planning Association*, Vol. 68, Issue 3, pp. 279-295.
- FLYVBJERG B., HOLM M. K. S., BUHL S. L. (2004). What causes cost overrun in transport infrastructure projects? *Transport Reviews*, Vol. 24, Issue 1, pp. 3-18.
- FLYVBJERG, B., HOLM, M. K. S., BUHL, S. L. (2003). How common and how large are cost overruns in transport infrastructure projects? *Transport Reviews*, Vol. 23, Issue 1, pp. 71-88.
- KEZZAR M., SOUAR A. (2024). The water management system in the village of Menades in Algeria between past and present, *Larhyss Journal*, No 57, pp. 55-79.
- LARSEN J. K., SHEN G. Q., LINDHARD S. M., BRUNOE T. D. (2015b). Factors affecting schedule delay, Cost overrun, and Quality Level in Public Construction Projects, *Journal of Management in Engineering*, Vol. 32, Issue 1, Paper ID 04015032.
- LIND H., BRUNES F. (2015b). Explaining cost overruns in infrastructure projects: a new framework with applications to Sweden, *Construction Management and Economics*, Vol. 33, Issue 7, pp. 554-568
- MAH D.Y.S., ALHADI H.F., BATENI N., TEO F.Y. (2024). Model simulation of dry stormwater detention pond with IPCC AR6 projected climate change scenarios, *Larhyss Journal*, No 60, pp. 151-169.
- MEZENNER N., BENKACI T., BERMAD A., DECHEMI N. (2022). Dam reservoir operation optimization using genetic algorithm and principal component analysis simulation model - case of dam Ghrib, *Larhyss Journal*, No 51, pp. 145-160.
- NASSA R.A.K., KOUASSI A.M., BOSSA S.J. (2021). Analysis of climate change impact on the statistical adjustment models of extreme rainfall case of Ivory Coast, *Larhyss Journal*, No 46, pp. 21-48.
- OGA Y.M.S., ADJA M., YAPI A.F., KPAN J.G., BAKA D. (2016). Projection of climate variability by 2050 in the coastal area in the southeast of ivory coast (Abidjan in Aboisso), *Larhyss Journal*, No 25, pp. 67-81. (In French)
- PAI S., PATNAIK B., MITTAL A. (2018). Identification of risks causing time and cost overrun in roads and highway projects in India, In *International Journal of Civil Engineering and Technology*, Vol. 9, Issue 3, pp. 683-697
- PANCHAL S.L., SURYANARAYANA T.M.V. (2025). Optimized operation of a multipurpose reservoir by evolutionary algorithm for Panam reservoir project in eastern Gujarat, India, *Larhyss Journal*, No 61, pp. 31-52.
- PANDEY P., MISHRA R., CHAUHAN R.K. (2022). Future prospects in the implementation of a real-time smart water supply management and water quality monitoring system, *Larhyss Journal*, No 51, pp. 237-252.

- PANG J.M., TAN K.W. (2023). Development of regional climate model (RCM) for Cameron highlands based on representative concentration pathways (RCP) 4.5 and 8.5, *Larhyss Journal*, No 54, pp. 55-70.
- PATEL K., MEHTA D. (2022). Design of the continuous water supply system using Watergems software: a case study of Surat city, *Larhyss Journal*, No 50, pp. 125-136.
- PETHERAM C., MCMAHON T. (2019). Dams, dam costs and damnable cost overruns, *Journal of Hydrology X*, Vol. 3, Paper ID 100026.
- REMINE B., BENSALFIA D. (2016). Siltation of dams in arid regions - Algerian examples, *Larhyss Journal*, No 27, pp. 63-90. (In French)
- REMINE B., BOUABIBSA R., MOUDJED K. (2019). Beni Haroun and Koudiat Acerdoune (Algeria): two large dams threatened by the phenomenon of siltation, *Larhyss Journal*, No 38, pp. 131-151. (In French)
- REMINE B. (2024). The Algerian Foggara, Part 1: Originality of a hydraulic system, *Larhyss Journal*, No 58, pp. 105-145.
- REMINE B. (2025). Algeria's groundwater: an untapped strategic resource for water security, *Larhyss Journal*, No 61, pp. 401-431.
- ROUISSAT B., SMAIL N. (2022). Contribution of water resource systems analysis for the dynamics of territorial rebalancing, case of Tafna system, Algeria, *Larhyss Journal*, No 50, pp. 69-94.
- SENOUCI A., ISMAIL A., EL DIN N. (2016). Time delay and cost overrun in Qatari public construction projects, *Procedia Engineering*, Vol. 164, Paper ID 368-375.
- SHAIKH A.F., BHIRUD Y.L., MORE S.B., PAWAR A.D., VAIDYA O.V. (2024). Comparative analysis of optimization algorithms for reservoir operations: a case study on Ukai dam, *Larhyss Journal*, No 58, pp. 179-196.
- SINDHU VAARDINI U., KARTHIYAYINI S., EZHILMATHI P. (2016). Study on cost overruns in construction projects - a review, *International Journal of Applied Engineering Research*, Vol. 11, Issue 3, pp. 356-357.
- THABET M. (2018). Small scale irrigated agriculture face to climate change: Case of Tunisian south arid zone, *Larhyss Journal*, No 34, pp. 183-197.
- VENKATESWARAN C.B., MURUGASAN R. (2017). Time Delay and Cost Overrun of Road over Bridge (ROB) Construction Projects in India, *Journal of Construction in Developing Countries*, Vol. 22, pp. 79-96.
- ZEGGANE H., GHERNAOUT R., BOUTOUTAOU D., ABDULLAH S.S., REMINE B. (2021). Multidimensional analysis of precipitation in central-northern region of Algeria, *Larhyss Journal*, No 47, pp. 209-231.